Lec.1 Introduction to Biomaterials

Dr.AMIR NAJAH SAUD AL-HUMAIRI

AL-MUSTAQBAL UNIVERSITY COLLEGE/ DEPARTMENT OF BIOMEDICAL ENGINEERING

Email: Amir_najah@mustaqbal-college.edu.iq

Weekly Syllabus

1. Joon Park R.S. Lakes, Biomaterials: An introduction, Third Edition: 2007 Springer Science.

2. An Integrated Approach W.D. Callister, Jr. and D. G. Rethwisch, Fundamentals of Materials Science and Engineering: 8th Edition: John Wiley and Sons, Inc. (2010).

- Introduction to Biomaterial
- Atomics Bonding, Crystal lattice and Arrangement of Atoms
- Mechanical Properties (Stress & Strain) and Mechanical Properties (Mechanical failure)
- Mechanical Properties (Fracture)
- Mechanical Properties (Fatigue, Wear & Friction), Surface Properties & Adhesion
- Viscoelasticity (Theory and Applications)
- Phase Diagram (Building and Alloys)
- **Midterm Exam.**
- Classification Metal Alloys & Metallic Implantation
- Metallic Biomaterials: Miscellaneous Others
- Corrosion of Metals (Types, Pourbaix Diagrams, Case Studies, Toxicity)
- Polymer (Types, Classifications and Polymer Implants)
- Ceramic Material (Bioceramics, Bioactive and Bioresorbable Ceramics)
- Composites Material (Classification, Structure, Property, Natural and Synthetic Composites)
- Applications of Biomaterials in Hard and Soft Tissue Replacement
- Electrical, Thermal, Piezoelectricity, Optical & Porosity Properties
- **Final Exam.**

Introduction to Biomaterials

Materials Science is the investigation of the relationship between processing, structure, properties, and performance of material.
These elements: properties, structure and composition, synthesis and processing, and performance and the strong interrelationship among them-that define the field of materials science and engineering.

Biomaterials are those materials that come in contact with the human body closely or directly to support or substitute defective tissues. More specifically, any material with high biocompatibility whether it naturally occurs or man-made is considered biomaterial and can be used to substitute or support a part of the living tissue, organs, or other function of the body in a safe, reliably economical, 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.

Biomaterials

- Biomaterial is a material intended to interface with biological systems to evaluate, treat, replace any tissue, organ or function of the body. Also biomaterial is a nonviable material used in a (medical) device, intended to interact with biological systems (bio functionality).

- 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.

- 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 Engineering .

Requirements of Biomaterials

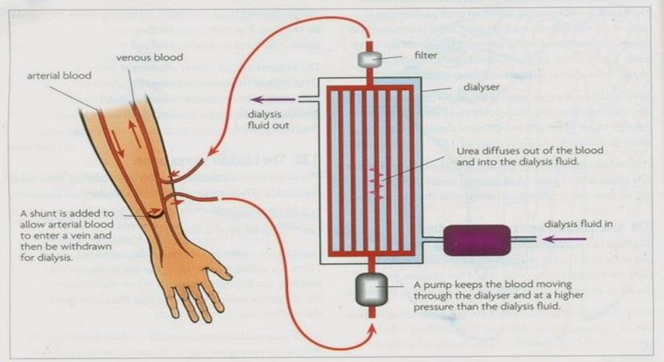
- Biomaterials must have special properties that can be tailored to meet the needs of a particular application - this is an important concept to bear in mind.
- For example, a biomaterial must be biocompatible, non-carcinogenic, corrosion- resistant, and has low toxicity and wear.
- However, depending on the application, differing requirements may arise. Sometimes these requirements can be completely opposite.
- In tissue engineering of the bone, for instance, the polymeric scaffold needs to be biodegradable so that as the cells generate their own extracellular matrices, the polymeric biomaterial will be completely replaced over time with the patient's own tissue.
- In the case of mechanical heart valves, on the other hand, we need materials that are biostable, wear-resistant, and which do not degrade with time.

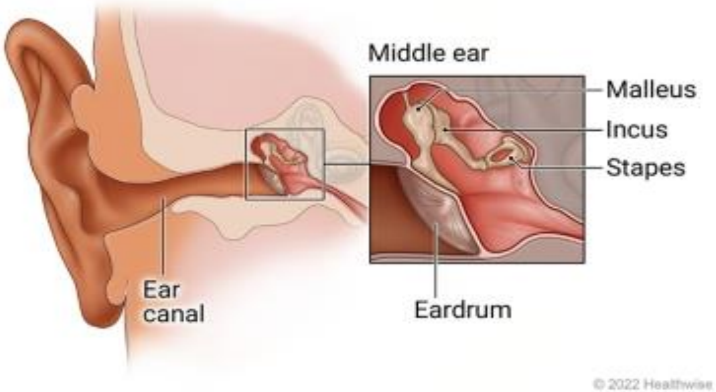
Uses of Biomaterials

Uses of Biomaterials	Example
Replacement of diseased and damaged part	Artificial hip joint, kidney dialysis machine
Assist in healing	Sutures, bone plates and screws
Improve function	Cardiac pacemaker, intra-ocular lens
Correct functional abnormalities	Cardiac pacemaker
Correct cosmetic problem	chin augmentation
Aid to diagnosis	Probes and catheters
Aid to treatment	Catheters, drains

Biomaterials in Organs

Organ	Example
Heart	Cardiac pacemaker, artificial heart valve, Totally artificial heart
Lung	Oxy-generator machine
Eye	Contact lens, intraocular lens
Ear	Artificial stapes, cochlea implant
Bone	Bone plate, intra-medullary rod
Kidney	Kidney dialysis machine
Bladder	Catheter and stent





Artificial stapes are prosthetic devices used to replace a damaged or diseased stapes bone in the middle ear, typically due to conditions like otosclerosis, which can lead to hearing loss

Selection of Biomedical Materials

The process of material selection should ideally be for a logical sequence involving:

- 1- Analysis of the problem;
- 2- Consideration of requirement;
- 3- Consideration of available material and their properties leading to:
- 4- Choice of material.

The choice of a specific biomedical material is now determined by consideration of the following:

- 1- A proper specification of the desired function for the material;
- 2- An accurate characterization of the environment in which it must function, and the effects that environment will have on the properties of the material;
- 3- A delineation of the length of time the material must function;
- 4- A clear understanding of what is meant by safe for human use.

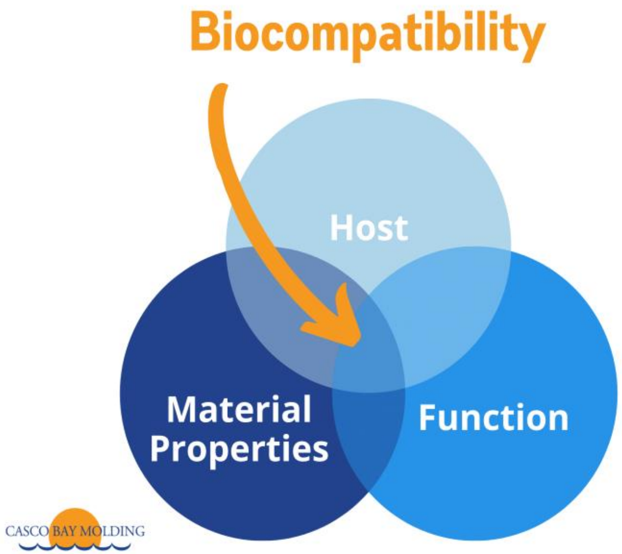
What Subjects are Important to Biomaterials Science?

1. **Toxicology**

- A biomaterial should not be toxic, unless it is specifically engineered for such requirements (for example a "smart" bomb" drug delivery system that targets cancer cells and destroy them). Toxicology for biomaterials deals with the substances that migrate out of the biomaterials. It is reasonable to say that a biomaterial should not give off anything from its mass unless it is specifically designed to do so.

What Subjects are Important to Biomaterials Science?

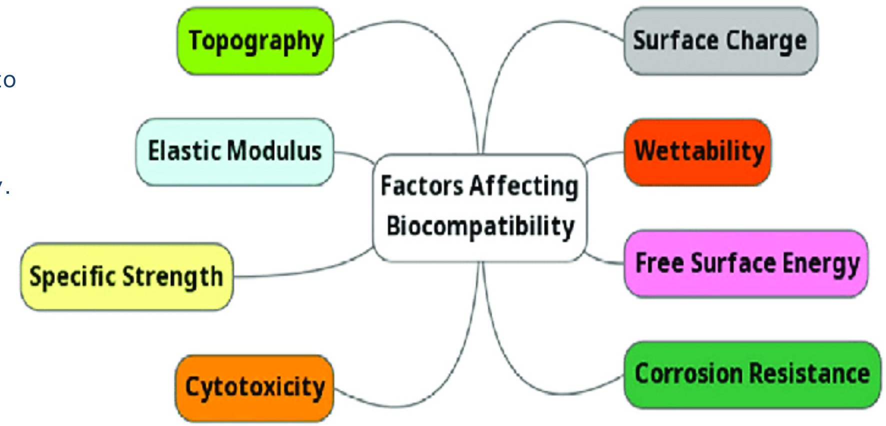
- Generally, the requirements of biomaterials can be grouped into four broad categories:
- Biocompatibility: Acceptance of an artificial implant by the surrounding tissues and by the body as a whole.
- Biocompatibility: is the most important property of any biomaterial that will be implanted in the body,
- The material must not disturb or induce unwelcoming response from the host, but rather promote harmony and good tissue-implant integration. An initial burst of inflammatory response is expected and is sometimes considered essential in the healing process.
- However, prolonged inflammation is not desirable as it may indicate tissue necrosis or incompatibility.



Biocompatibility

Biocompatibility affected by the mentioned features below in Figure.

- Topography - This refers to the surface features and roughness of a material.
- Elastic Modulus - This is a measure of a material's stiffness or resistance to deformation.
- Specific Strength - This is the strength of a material relative to its density.
- Cytotoxicity - This refers to the potential toxicity of a material to cells.
- Surface Charge - This relates to the electrical charge on the surface of a material.
- Wettability - This describes how easily a liquid can spread on or be absorbed by a surface.
- Free Surface Energy - This is the amount of energy required to create a new surface area.
- Corrosion Resistance - This is the ability of a material to withstand chemical degradation.



Requirements of Biomaterials

- Sterilizability: The material must be able to undergo sterilization. Sterilization techniques include gamma, gas (ethylene oxide (ETO)) and steam autoclaving. Some polymers such as polyacetal (artificial heart valves and artificial hip joints) will depolymerize and give off the toxic gas formaldehyde when subjected under high energy radiation by gamma.

- Functionability: The functionability of a medical device depends on the ability of the material to be shaped to suit a particular function. The material must therefore be able to be shaped economically using engineering fabrication processes.

Requirements of Biomaterials

- For example, The material must satisfy its design requirements in service:
- - Load transmission and stress distribution (e.g. bone replacement).
- - Articulation to allow movement (e.g. artificial knee joint).
- Control of blood and fluid flow (e.g. artificial heart).
- Space filling (e.g. cosmetic surgery).
- - Electrical stimuli (e.g. pacemaker).
- - Light transmission (e.g. implanted lenses).
- - Sound transmission (e.g. cochlear implant).

Mechanical, Physical and Performance Requirements

i. Mechanical Performance

Device Properties

- A hip prosthesis Must be strong and rigid
- A tendon material Must be strong and flexible
- An articular cartilage substitute Must be soft and elastomeric
- A dialysis membrane Must be strong and flexible.

ii. Mechanical durability

- A catheter may only have to perform for day.
- A bone plate may fulfill its function in 6 months or longer.
- A leaflet in a heart valve must flex 60 times per minute without tearing for the lifetime of the patient (for 10 years). A hip joint must not fail under heavy loads for more than 10 years.

Requirements of Biomaterials

- Physical Properties - The dialysis membrane has a specified permeability. - The articular cup of the hip joint has high lubricity. - The intraocular lens has clarity and refraction requirements.

- Manufacturability: It is often said that there are many candidate materials that are biocompatible. However, it is often the last step, the manufacturability of the material, that hinders the actual production of the medical device.

Materials Evaluation

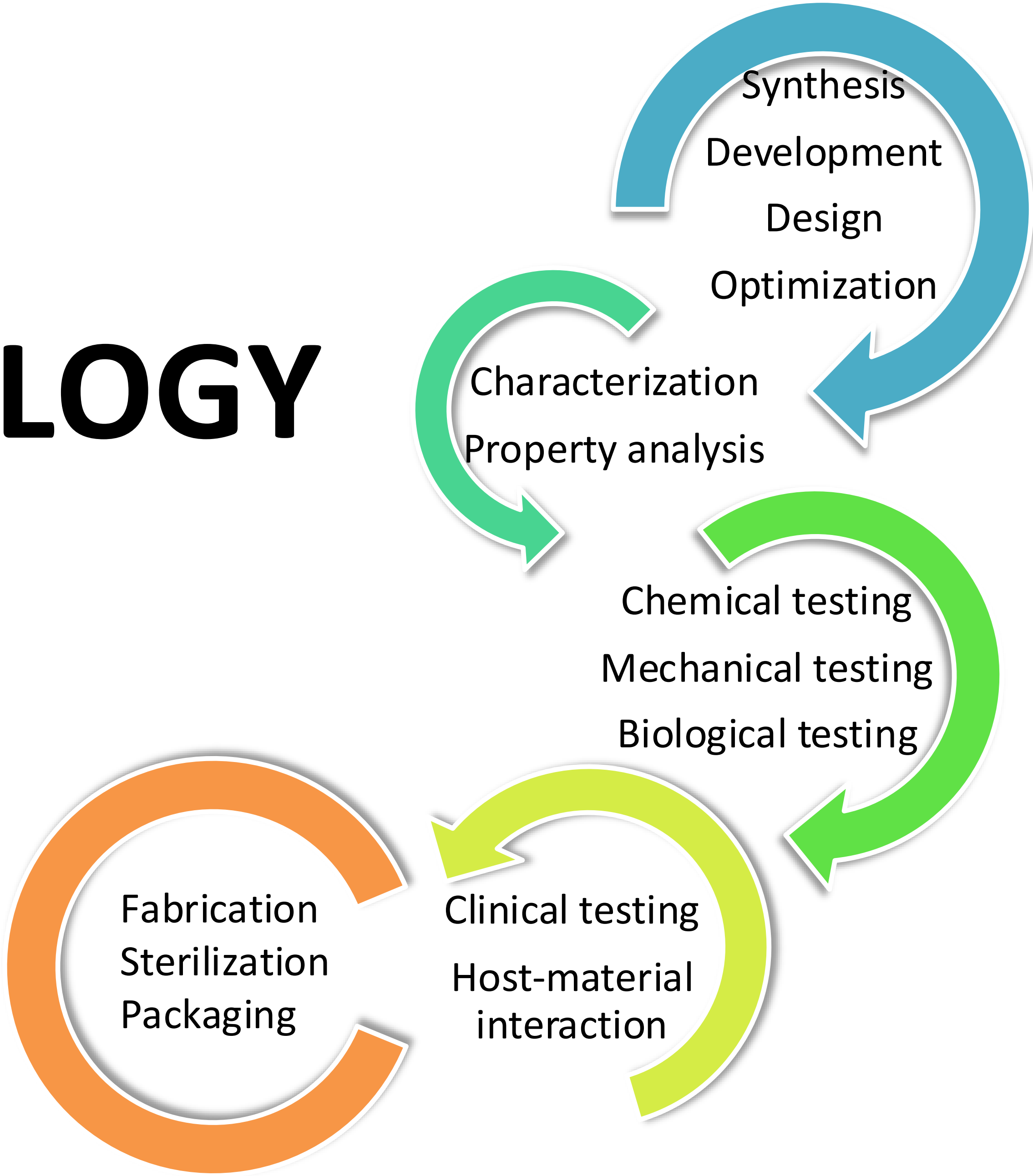
- As the number of available materials increases, it becomes more and more important to be protected from unsuitable products or materials, which haven't been thoroughly evaluated.
- Most manufacturers of materials operate an extensive quality assurance program and materials are thoroughly tested before being released to the general practitioner.
- 1- Standard Specifications: Many standard specification tests of both national and international standards organizations (ISO) are now available, which effectively maintain quality levels. Such specifications normally give details for:
- (a) the testing of certain products,
- (b) the method of calculating the results
- (c) the minimum permissible result, which is acceptable.
- 2- Laboratory Evaluation: Laboratory tests, some of which are used in standard specification, can be used to indicate the suitability of certain materials. It is important that methods used to evaluate materials in laboratory give results, which can be correlated with clinical experience.

Materials Evaluation

- 3- Clinical Trials: Although laboratory tests can provide many important and useful data on materials, the ultimate test is the controlled clinical trial and verdict of practitioners after a period of use in general practice. Many materials produce good results in the laboratory, only to be found lacking when subjected to clinical use.
- The majority of manufacturers carry out extensive clinical trials of new materials, normally in cooperation with a university or hospital department, prior to releasing a product for use by general practitioners.

LIFETIME CHRONOLOGY

HUMAN APPLICATIONS



Thank you for your Kind Attention