BMED4823/MSE 4803:
Introduction to Biomaterials

Class Timing and Location:
Tuesdays and Thursdays, 4:35 to 5:55pm, MSE (Love Bldg.) Room # 183

Instructors:
Roger Narayan (RN; roger.narayan@mse.gatech.edu),
MSE – Lead Professor and Course Coordinator,

Ravi V. Bellamkonda (RVB: ravi@bme.gatech.edu), BME

Guest Professor: Yadong Wang (yadong.wang@bme.gatech.edu)

TAs:
Nitesh Kumbhat (**gtg321p@mail.gatech.edu**);
Abhishek Sivapurapu (**gtg129p@mail.gatech.edu**);
R. Gilstrap (gte549x@prism.gatech.edu)

Synopsis:
The course will emphasize the interaction between the human body environment and synthetic materials. Materials for both medical implants and dental restoration and appliances will be covered. Biomaterials directly impact many disciplines within the field of biomedical engineering. Tissue engineering, biosensing, imaging, and drug delivery interact directly with biomaterials. Development of new technologies in these varies disciplines may largely depend upon overcoming present material limits and improving material/biological environment interactions. Course will include weekly quizzes and homework assignments.

Text Books:
- Buddy Ratner. Biomaterials science. Second edition. Orlando, Academic Press, 2000
- Jonathan Black. Biological performance of material: fundamentals of biocompatibility / Jonathan Black. New York : Marcel Dekker, c1999.

Outline:

I. Introduction to Biomaterials (1 week – RVB, RN)
Week 1 (Jan 6th and 8th):
How do Biomaterials impact us? Discussion of state of the art, ethics of biomaterials use.

II. Biomaterials Science and Engineering (5 weeks – RN)

II a. Introduction to 'Hard' biomaterials (4 weeks – RN)

This section of the course introduces students to the common classes of materials used in medical devices. In addition, students learn about the analytical tools used to evaluate the structure and properties of materials.

Week 2 (Jan 13th and 15th):
How does atomic structure impact bulk properties of materials? Ceramics and glasses: alumina, zirconia, diamondlike carbon, hydroxyapatite, Bioglass, refractory nitrides (TiN), and refractory carbides (TiC).

Week 3 (Jan 20th and 22nd):
Metals: steel, cobalt-chromium, titanium, new titanium alloys, shape memory alloys, niobium alloys, tantalum alloys, and beyond.

Week 4 (Jan 27th and 29th):
Surface modification techniques: ion implantation, ion plating, plasma spraying, magnetron sputtering, PVD, CVD, atomized liquid spray, dip, spin-on, sol-gel, electrochemical techniques; pros and cons of porous coating.

Week 5 (Feb 3rd and 5th):
Orthopedic applications; joint prostheses, fracture fixation devices; interaction of bone with implanted materials and resulting complications.

EXAM I (20 points): February 10th

IIb. Characterization of Hard Tissue Related Biomaterials (1 Week - RN)
Week 6 (Feb 12th and 17th):

- What information is essential for optimum medical device surface characterization
- Biocompatibility Testing, Mechanical Characterization, Wear Resistance Materials, Raman Spectroscopy, Corrosion Testing
- Requirements for Biomaterials: Nontoxic, Noncorrosive, Adequate Fatigue Life, Proper Weight and Density
- Metal Corrosion, Pitting Corrosion, Fretting Corrosion, Crevice Corrosion, Intergranular Corrosion, Stress Corrosion Cracking, Galvanic Corrosion, Fatigue and Wear Corrosion -Microbiological Corrosion
- Wear Mechanism: abrasive wear, adhesive wear, fatigue wear, corrosive wear
- The future of Hard Tissue Biomaterials

III. Introduction to 'Soft' biomaterials (5 weeks: RVB (4), Yadong Wang (1))

IIIa. Introduction to Polymeric Biomaterials. (4 weeks – RVB)
This section will cover the use of Polymeric Biomaterials. It will introduce the attractive features of polymeric biomaterials that enable their use as biomaterials, discuss how one might pick or modify materials based on a particular biological need. By the end of this section, students should be able to recognize the structures of many popular polymeric biomaterials and understand how their structure gives rise to their properties which in turn affect their biological application.

Weeks 7-8 (Feb 19th to Mar 2nd):
Introduction to polymers as biomaterials: What are they, how do we name them, how does their structure affect their properties? How do we characterize Polymers?

Week 9 (Mar 4th and 16th): Some prominent biomaterials and how they are used.

Spring Break (March 8th to 12th)

Week 10 (Mar 18th and 23rd): Biomaterials and Drug Delivery in the Brain.

EXAM II (20 points): March 25th

IIIb. Characterization of Polymeric Biomaterials (1 week - Yadong Wang)
Week 11 (Mar 30th and April 1st)

IV. The 'Biological' constraints on biomaterials (2 Weeks - RVB)

Biocompatibility of Biomaterials: Biological Constraints on performance

In this section, students learn how components of the biological environment, particularly proteins and cells, interact with biomaterials. The goal is to understand what causes some materials to be well tolerated by the body while others cause intense negative reactions. How can materials be designed that will give better biocompatibility within the requirements of a given application? Methods for evaluation are also discussed, as well as the impact of biological interactions with materials on the performance of various devices and systems. The topics covered include:

Week 12 (Apr 6th and 8th):
Cells; interactions with proteins and materials; characterization of cell-material interactions. Protein structure, interaction of proteins with synthetic materials; methods for evaluating protein adsorption; inflammatory responses; acute inflammation, chronic inflammation, foreign body response, assessment of material performance.

Week 13 (Apr 13th and 15th):
Immunological responses to biomaterials; can antibodies be generated against synthetic materials? Role of the complement system; evaluation of immune responses.
Blood compatibility; platelet adhesion and aggregation; coagulation; effects of the mechanical environment; in vitro and in vivo assessment of blood compatibility.

EXAM III (20 points): April 20th

V. Applications of Biomaterials and Product Development (RN)

Week 14 (Apr 22th):
Several examples of medical devices whose performance is largely determined by biomaterials are covered in detail, particularly the considerations important in selecting or designing a material for the application and the evaluation necessary to determine the suitability of the selected material. In addition, students are exposed to issues important in the translation of biomaterials into products that impact health care.

Topics covered include:
Cardiovascular applications; grafts, catheters, stents, valves, embolic agents; sterility and infection; interactions of bacteria with biomaterials; methods of sterilization; assessment of sterility; device failure; analysis of retrieved implants; ethical considerations with animal testing; alternatives to animal testing; considerations in the

design of in vivo models to evaluate biomaterials; intellectual property issues, regulatory affairs; ethical issues associated with clinical trials; development of voluntary consensus standards for biocompatibility; medical device regulation by the FDA.

FINAL EXAM (COMPREHENSIVE) (30 points): May 6th
Homework and Quiz (10 points)