Biosensor Principles and Applications
BE/MBBE 625, Spring 2008
Course Syllabus

Instructor: Daniel M. Jenkins
Office: Agricultural Science 415L — Telephone: 956-6069
Office Hours: Thursday 4-5 PM & by appointment — Email: danielje@hawaii.edu

Meeting Time and Location
Monday, Wednesday, Friday, 11:30 AM to 12:20 PM; St. John 13
(Meeting time and location subject to change pending unanimous approval)

Grading:

Written Summaries/Reports:	10%
Discussion/Participation:	20%
Exams (2):	20% each
Final Project/ Presentation:	30%

Textbook: Chemical Sensors and Biosensors, Eggins, B. R., John Wiley & Sons, 2002.

Additional Readings and Course Notes: Available on Laulima:
https://laulima.hawaii.edu/portal/
(Account was just requested- more information about the Laulima environment will be forthcoming)

Reference Texts (in order of value for this course):

Biochemistry (3rd ed), Mathews, C. K., K. E.van Holde, and K. G. Ahern, Addison Wesley Longman, Inc., 2000.

The Art of Electronics (2nd ed), Horowitz, P. and W. Hill, Cambridge University Press, 1989.

Chemical Sensors and Biosensors for Medical and Biological Applications, Spichiger-Keller, U. E., Wiley-VCH, 1998.

Prerequisites: (Instructor consent).

Catalog Description: 3 units. Elaboration of common biochemical interactions used to quantify biological molecules, and the electronic technologies used to detect them. Discussion of desirable properties of biosensors, miniaturization, and applications related to medicine, agriculture, bioproduction, and environment.

Course Content

A) Biosensor applications and issues

i) Overview of biosensor applications: medicine, agriculture, bioproduction, and environment **(~1 period)**.

ii) Desired characteristics of biosensors: reliability, simplicity, cost, and related parameters **(~1 period)**.

iii) Application notes: operating conditions, calibration, positive and negative controls, safety **(~1 period)**.

B) Biochemical recognition

i) Chemical reactions: history of gravimetric and colorimetric reactions. Problems of specificity **(~1 period)**.

ii) Enzymes: biological catalysts, specificity, activity, storage/shelf life. Enzyme kinetics in solution and on a surface. Chemical equilibria- forcing an unfavorable reaction **(~3 periods)**.

iii) Cells: Signal transduction through chemoreception, membrane potential, cell metabolism, cytotoxicity, and transformed ‘bioreporter’ organisms **(~3 periods)**.

iv) Antibodies: Immunochemistry, binding affinity and kinetics; hapten synthesis **(~3 periods)**.

v) Nucleic Acids (RNA and DNA): Basic biochemistry, hybridization; Amplification/self replication; Secondary Structure and folding **(~3 periods)**.

vi) Aptamer (oligonucleotide) based recognition and molecularly imprinted polymers **(~1 period)**.

C) Common assaying formats

i) Labels: Radioisotopes, fluorophores, dyes, enzymes/substrates, liposomes, electroactive compounds **(~2 periods)**.

ii) ELISAs and nucleotide capture assays **(~2 periods)**.

iii) Immobilization of biorecognition element; conjugation of labels **(~1 period)**.

D) Electrical signal transduction

i) Seismic (mass) and thermal sensors: Electromechanical resonance, electrochemical forces, Henry’s and ideal gas laws; Surface acoustic wave (SAW) devices; atomic force microscopy; manometric sensors; thermometric detection **(~4 periods)**.

ii) Electrochemical sensors: Redox potentials, membrane potential, Gauss’s Law, basic electrochemistry; conductimetric sensors; potentiometric sensors (ISE’s and ISFETs); amperometric sensors; Charge sensing with FET **(~8 periods)**.

iii) Optical sensors: fundamentals of optics- sources (LED’s, lasers, lamps), detectors (photodiodes, photomultiplier tubes, charge coupled devices), and optical circuits (filters, gratings, fiber optics); detection of absorbance, reflectance, and fluorescence; Surface plasmon resonance (SPR) based devices **(~8 periods)**.

Important Dates, Spring 2006 Semester:

January 14- First day of class

January 21- Dr. Martin Luther King Jr. Day (no class)

January 22- Last day to drop classes without ‘W’

January 23- (4 PM)- Last day to add classes

February 18- President’s Day (no class)

March 14- Last day to drop classes (with ‘W’)

March 21- Good Friday (no class)

March 24-28- Spring Break (no class- Prince Kūhiō Kalaniana‘ole Day on March 26)

April 1- Last day to change ‘Incomplete’ grades from Fall 2007 (Seriously!)

May 7- Last day of class

May 12- Final Exam, 12:00 – 2:00 PM (tentative)

Course Policies:

1. Attendance will not formally be taken; we are all adults and capable of determining our own priorities. However, if attendance (and excused absences) of registered students drops below 80% for any given class period, course notes will not be posted for that period and the instructor will draw heavily from that material for exam questions.
2. To broaden the perspective beyond that of the instructor,
   a. Guest speakers from UH and elsewhere will occasionally be engaged to deliver guest lectures in their areas of expertise.
   b. Students will be expected to attend and deliver short written summaries/reports (~1 long paragraph) of at least two seminars given outside of class which are related to biosensing. A list of approved seminar times and locations will be posted each week for the students to choose from. Alternatively, students may petition the instructor in advance to attend relevant seminars or other discussions which had escaped the instructor's attention.
3. Due to the interdisciplinary nature of the course, discussion between class participants with a wide range of experience and interests is expected. Open dialog among the participants will allow course topics to be better focused to expressed interests and will expose participants to a wider range of experience and issues than is available from the instructor alone.
4. Reading in the textbook and emerging literature will be assigned. Reading assignments and discussion topics will typically be given a week in advance to allow participants to prepare.
5. Some simple homeworks *may* be assigned on occasion to demonstrate some important points. Typically these will not be collected, but will be designed to give important perspective about topics which may occur on exams or be expected in a final project.
6. Because the instructor is an engineer, a lot of presented material will involve quantitative analysis of various relevant processes and phenomena, and discussion of the implications of these for biosensing. Due to the multi-disciplinary nature of the course and the participants, the exams will primarily be composed of short answer and discussion of various concepts presented in class, with a small amount of quantitative analysis.
7. A final project will be assigned where students research potential applications/needs for biosensors, and propose a conceptual design of a suitable sensor to address this need.
8. Grades will be curved and scaled to give an average of at least 75%. Students above 90% will receive an A, those above 80% will receive at least a B, those above 70% will receive at least a C, and those above 60% will receive at least a D.
9. Participants are expected to be engaged in class, to learn from the execution of the coursework, and to share their own unique insights into the course material. To encourage this, a discretionary amount of extra credit will be awarded to students who identify errors in lectures, handouts, and other class materials, or who offer simpler or more elegant proofs, derivations, or explanations of phenomena described class. Up to 3% may be added to the students final grade per incidence, depending on the severity of the error and/or the astuteness of the student's observation. All extra credit will be added after adjustment of the final averages so that other students' grades are not affected.

Course Mapping to Program Outcomes

BE 625 is fulfills a technical elective credit for the Biological Engineering program, and contributes to preparing students to meet the following BE program outcomes:

a. *The graduate has the ability to solve problems involving differential equations*.
   In the class some simple differential equations will be used to describe such things as reaction and binding kinetics, fluorescence emission, etc.
b. *The graduate has the ability to solve physics problems involving mechanics, electromagnetic, and optics; chemistry problems involving inorganic and organic chemistry; problems involving general- and micro- biology.*
   Students will need to understand the basic physics of seismic and force transducers, behavior and detection of light, reaction kinetics, interactions of different classes of molecules, basic cell biology, and the structure and biology of different microorganisms.
c. *The graduate has the ability to solve engineering problems related to statics, dynamics, fluid mechanics, and thermodynamics.*
   Students will need to understand thermodynamics as it relates to chemical equilibria and electrochemistry.
d. *The graduate has the ability to design a system, component, or process in which biology plays a significant role.*
   Students will be designing a solution to a biosensor problem by incorporating biological elements onto a physical transducer.
e. *The graduate has the ability to design and conduct experiments to gather information for engineering designs.*
   Students will be required to exercise engineering judgement and preliminary modeling and experimentation to complete effective designs.
f. *The graduate has the ability to use modern engineering techniques, skills, and tools to define, formulate, and solve engineering problems.*
   Students will use tools ranging from computational modeling to basic instrumentation to complete their designs.
g. *The graduate has the ability to function effectively in multi-disciplinary teams.*
   Students designs will be completed in multi-disciplinary teams, and basic understanding of the basic biological and physical elements of the both the problem and solution.
h. *The graduate has the ability to identify professional and ethical responsibilities when practicing engineering.*
   The course will include superficial discussion of the ethical and safety responsibilities of engineering design related to biosensors.
i. *The graduate has the ability to communicate effectively in large and small groups.*
   The team design project is a fundamental part of the course, and will require effective communication between team members as well as to the entire class. In addition, classroom discussion will require clear and concise communication.
j. *The graduate has the background to understand the impact of engineering solutions on the surrounding context.*
   Students should be able to recognize the relevance of a variety of social issues, such as environmental protection and public health, as they relate to biosensors.

k. *The graduate recognizes the need to engage in life-long learning through participation in professional conferences, workshops, and courses, and by reading and writing in the relevant literature.*

   A fundamental part of this course will include reading and discussion of emerging literature in the field, and the recognition for the evolving nature of knowledge and the need for constant lifelong learning.

l. *The graduate has the ability to intelligently discuss contemporary issues.*

   This outcome is not specifically addressed, though students are expected to be able to discuss contemporary issues as they relate to outcome j.