BIOEN 3202
Physiology for Engineers
Fall 2015

LECTURE INSTRUCTORS:
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1480 MEB (on independent study lab weeks), or by appt.

TEACHING ASSISTANTS:
David Page (DP)
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Office hours: Tu 9-10 AM
1480 MEB (on independent study lab weeks), or by appt.

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Office hours: We 2-3 PM
1480 MEB (on independent study lab weeks), or by appt.

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Office hours: Th 2-3 PM
1480 MEB (on independent study lab weeks), or by appt.

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Lab Sessions: Tu AM, We PM
Office hours: Tu 2-3 PM
1480 MEB (on independent study lab weeks), or by appt.

DESIGNATION:
Required course for BIOEN majors.

CATALOG DESCRIPTION (modified):
This course teaches students to apply knowledge of mathematics, science, and engineering to cellular and systems physiology, including function, dysfunction, and the mechanisms that underlie treatment. The course
also addresses professional and ethical responsibility associated with the development, testing, and implementation (or withholding) of biomedical devices or treatments. Associated laboratory modules teach students to design, conduct, and analyze experiments, and to use the techniques, skills and tools necessary for engineering practice. Topics this semester include the nervous system, striated and smooth muscle, and respiratory, renal, and cardiovascular systems. 4 credit hours.

**TEXTS (REQUIRED):**
- Selected readings and web materials.

**LEARNING OBJECTIVES:**
To produce students and future engineers who:
- Have fundamental knowledge of physiological system function and dysfunction
- Can analyze physiological systems from an engineering perspective
- Have the ability to formulate practical engineering solutions to ameliorate biological disorders
- Understand how solutions manifested in biological systems may potentially be applied to the solution of traditional engineering problems—a “bio-based” approach
- Appreciate the ability of bioengineering to improve the quality of life
- Recognize the ethical issues associated with testing and implementation of biomedical devices and treatments
- Understand the need for life-long learning to maintain and enhance their technical skills, and to stay abreast of advances in understanding
- Have a strong work ethic and can work effectively in teams
- Have good written and oral communication skills
- Are independent, critical, and creative thinkers who seek out new points of view and who can effectively evaluate assumptions, evidence, and conclusions and can distinguish among them

**TOPICS COVERED:**

**Lecture Topics**
- Cellular neuroscience (7 lectures)
- Systems neuroscience (8 lectures)
- Applied neuroscience/neuroengineering (2 lectures)
- Striated and smooth muscle (3 lectures)
- Respiratory systems (3 lectures)
- Renal systems (3 lectures)
- Cardiovascular system (14 lectures)

**Laboratory Topics**
- Bioinstrumentation and R-C modeling of neurons
- Stimulating and recording from nerve
- Neuromuscular systems
- Respiratory systems
- Cardiovascular structure and function
- Cardiovascular monitoring and signal analysis

**CLASS SCHEDULE:**

- **Lecture:** M, W, F: 9:40-10:30 AM, WEB L103
- **Laboratory:** MEB 1480, 3-1/2 h laboratory on selected weeks (see later in syllabus).
ASSESSMENT TOOLS:
- Homework assignments
- Two in-class exams, plus possible quizzes (especially in Cardiovascular Module)
- One final exam
- Written lab reports, quizzes; observation and questioning of students during experiments
- In-class presentations
- Student evaluation of teaching
- Student evaluation of course

Lecture: ~75% of overall course grade split between exams and possible quizzes (~60-65%) and homework assignments (~10%). Formal didactic lectures may be complemented by discussion/problem-solving sessions that may have special assignments. Students will be expected to have completed the assignments and be prepared to participate in the topic discussion or problem solving.

Laboratory: ~25% of overall course grade. Laboratory participation, laboratory reports and presentations, and laboratory quizzes or exams.

Standards: Curves may be applied to improve letter grades if appropriate, but will not be applied to decrease grades. Hence, it can be both beneficial and more enjoyable for you to help each other learn the material, and we encourage you to do so. Note, however, comments below on plagiarism regarding written assignments.

Assignments: Reading and other assignments are listed on the class schedule. Additional assignments not listed on the syllabus may be given throughout the semester.

Exams: There will be two exams during the semester and one final exam at semester's end. The exams will not be comprehensive and will cover only material presented since the previous exam. Exams cannot be rescheduled except in cases of documented emergencies.

Quizzes: Occasional announced or unannounced quizzes may be given throughout the semester in order to provide more frequent feedback and additional incentive for students to keep pace with course materials. Quizzes may be given in addition to, or at times different from, those presently scheduled on syllabus. Quizzes on the lab manual are especially likely at the start of lab.

LATE POLICY:
Except in cases of legitimate, compelling extenuating circumstances, the late policy for assignments, including but not necessarily limited to homeworks, lab reports, any papers, etc., will be as follows:

- “On time”:
  Electronic submissions: Most or all lecture homework assignments, lab assignments and reports should be turned in via Canvas by the specified time.
  - Electronic homework assignments: typically will be due at the start of the lecture period indicated.
  - Electronic lab assignments: typically will be due on Sunday 11:59 PM, ~1-1/2 weeks after the data collection.

- “Late”: 10% grade penalty (one letter grade).
  - Lecture homework submissions. Start of next normally scheduled meeting for lecture.
  - Lab assignments: One additional calendar week.
  - Other electronic submissions. As specified.

- “Not accepted”: Assignments not turned in by the late period will not be accepted.

PLAGIARISM:
You can study together for upcoming exams and quizzes, or to learn material. This is often the best way to learn, and we encourage you to do so.
In contrast, you should work independently for any homework assignments and lab assignments that you turn in for credit, unless you are explicitly informed otherwise in writing. Feel free to contact instructors or a TA for assistance. Lab partners necessarily will work together and collect data together during laboratory sessions, but the subsequent analyses, interpretation, figure generation and reporting of your results should represent your own work. Selected exceptions to this expectation, if any, will be communicated in writing by the course instructors to the students. Plagiarism or undue reliance on another person’s work, or on your own work for which you have previously received credit in another course, may result in reduced grades and/or disciplinary action. For a more complete description of what does and does not constitute plagiarism, consult the University of Utah policies.

INSTRUCTOR AVAILABILITY:
Instructors and TAs will be available during their scheduled office hours (see above), after most lecture/laboratory sessions, and by appointment. We realize that many students’ schedules are highly constrained and may not allow students to meet during our “scheduled” office hours. We encourage you to arrange alternative times to meet with us to discuss any questions or issues associated with the course, or beyond.

WEB POSTINGS OF COURSE MATERIALS:
Most course materials will be posted on the web, at either the University’s Canvas site, or elsewhere as indicated.

GAC file-naming conventions for Canvas:
AaaBb_yymmdd_Cc_Dd_vymmdd-hhmm-author_Ee.*
Example: <Lec01_150824_LS_Intro_v150823-2318-gac_Misc.pdf> translates into:

“Meeting type, Number: Lecture01_Date: 2015-Aug-24_File type: Lecture Slides_Abbreviated Title: ‘Intro’_Version: 2015 Aug 23, 11:18 PM, Gregory A. Clark_MiscInfo: example"

COURSE GUIDELINES:
The course will be conducted according to the policies and procedures of the College of Engineering, which can be found on the College of Engineering website, http://www.coe.utah.edu/wp-content/uploads/pdf/faculty/semester_guidelines.pdf (or comparable COE site)

CHANGES TO SYLLABUS:
The enclosed information represents a plan, not a contract. Topics, dates, and assignments and other content are subject to change at instructors’ discretion.

ACCOMMODATIONS POLICY STATEMENT:
The University’s Office of General Counsel recommends use of a disclaimer if a faculty member has reason to believe an accommodation request might arise. Accordingly, please note the following:

"Some of the writings, lectures, films, readings, activities, presentations, or other content in this course may include material that conflicts with the core beliefs of some students. Please review the syllabus carefully to see if the course is one that you are committed to taking. If you have a concern, please discuss it with the relevant faculty instructor at your earliest convenience."

According to the University, not all changes to course content trigger the use of the Accommodations Policy. Only student requests for accommodations based on conflict with sincerely-held core beliefs trigger the use of this policy. Thus, for example, instructors continue to be able to make modifications to course content for pedagogical reasons, such as adding or substituting a new reading.

The Bioengineering Department has adopted the following:
“None of the following, either singularly or in combination, is sufficient grounds for requesting a content accommodation:

a. personal disagreement with legitimate course content or its implications;
b. conflict between a student’s beliefs and legitimate course content or its implications;
c. any burden imposed on a student’s beliefs by legitimate course content or its implications.

Accommodations requested on such grounds, either singularly or in combination, will not be granted.”

ADA STATEMENT
The University of Utah seeks to provide equal access to its programs, services and activities for people with disabilities. If you will need accommodations in the class, reasonable prior notice needs to be given to the Center for Disability Services 162 Olpin Union Building, 801-581-5020 (V/TDD). CDS will work with you and the instructor to make arrangements for accommodations. All information in this course can be made available in alternative format with prior notification to the Center for Disability Services. (http://www.oeo.utah.edu/ada/guide/faculty/)

WELLNESS STATEMENT
Personal concerns such as stress, anxiety, relationship difficulties, depression, cross-cultural differences, etc., can interfere with a student’s ability to succeed and thrive at the University of Utah. For helpful resources, you should contact the Center for Student Wellness - www.wellness.utah.edu; 801-581-7776.
# LECTURE SYLLABUS

<table>
<thead>
<tr>
<th>Session</th>
<th>Topic</th>
<th>Reading &amp; Assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit 1. Nervous &amp; Muscular Systems. Greg Clark.</strong></td>
<td></td>
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</tr>
<tr>
<td>1.1. Introduction: Neurons &amp; Neural Signaling</td>
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<tr>
<td>01. M 08/24</td>
<td>Overview of Physiology &amp; Neural Function</td>
<td>S9:285-296, 302-304, (305-308)†; review syllabus; &amp; TBA††</td>
</tr>
<tr>
<td>03. F 08/28</td>
<td>Neurons and Neuronal Signaling</td>
<td>S8:226-236.</td>
</tr>
<tr>
<td>04. M 08/31</td>
<td>Ion Channels and Resting Membrane Potentials</td>
<td>S5:125-137, 153-159, (161-164, as relevant); S8:236-240.</td>
</tr>
<tr>
<td>05. W 09/02</td>
<td>R-C Circuits and the Resting Membrane Potential</td>
<td>S8:240-242. Appendix B.</td>
</tr>
<tr>
<td>06. F 09/04</td>
<td>R-C Circuits and the Passive Propagation of Electrical Signals</td>
<td>HW1.1a, due before lecture. Additional readings.</td>
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<tr>
<td>--- M 09/07</td>
<td>Labor Day Holiday</td>
<td>N/a</td>
</tr>
<tr>
<td>07. W 09/09</td>
<td>Action Potentials and Active Conductances 1</td>
<td>HW1.1b, due before lecture. S8:242-253 (to be cont’d).</td>
</tr>
<tr>
<td>08. F 09/11</td>
<td>Action Potentials and Active Conductances 2</td>
<td>Continued</td>
</tr>
<tr>
<td>09. M 09/14</td>
<td>Synaptic Potentials and Intercellular Communication</td>
<td>HW1.1c, due before lecture. S6:166-180; S8:253-268 (269-273).</td>
</tr>
<tr>
<td>10. W 09/16</td>
<td>EXAM 1 (Unit 1.1)</td>
<td>HW1.1d, due before lecture.</td>
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<tr>
<td>1.2. Sensory Systems</td>
<td></td>
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<tr>
<td>11. F 09/18</td>
<td>Overview of CNS, PNS, and Sensory Systems; Somatosensory 1</td>
<td>S10:310-324.</td>
</tr>
<tr>
<td>1.3. Somatic Neuromuscular Systems</td>
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<tr>
<td>17. F 10/02</td>
<td>Neural Control of Movement 1: Overview, Spinal Reflexes</td>
<td>S13:417-426</td>
</tr>
<tr>
<td>18. M 10/5</td>
<td>Neural Control of Movement 2</td>
<td>Continued.</td>
</tr>
<tr>
<td>19. W 10/07</td>
<td>Neural Control of Movement 3</td>
<td>S13:426-431; (432-434)</td>
</tr>
<tr>
<td>1.4. Autonomic, Regulatory, and Modulatory Systems</td>
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<tr>
<td>10/12 - 10/18</td>
<td>Fall Break</td>
<td>None</td>
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<tr>
<td>Date</td>
<td>Activity</td>
<td>Reading Material</td>
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<tr>
<td>22. W 10/21</td>
<td>ANS 2: Control of Target Tissues: To Pee or Not to Pee.</td>
<td>S10:342-343; S15:490-491, 493-495; S19:612-613</td>
</tr>
<tr>
<td>23. F 10/23</td>
<td>EXAM 2 (Units 1.2, 1.3, &amp; 1.4)</td>
<td>HW 1.4, due before lecture.</td>
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<tr>
<td><strong>Unit 2.</strong></td>
<td><strong>Cardiovascular System. Frank Sachse.</strong></td>
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<tr>
<td>24. M 10/26</td>
<td>CV01: Overview of CV System and Heart Anatomy</td>
<td>S14: 436-439; 443-449</td>
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<tr>
<td>25. W 10/28</td>
<td>CV02: Electrophysiology of Cardiac Cells</td>
<td>S14: 451-454</td>
</tr>
<tr>
<td>26. F 10/30</td>
<td>CV03: Electrical Propagation in Cardiac Tissues</td>
<td>S14: 454-455</td>
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<tr>
<td>27. M 11/02</td>
<td>CV04: Whole Heart Electrophysiology</td>
<td>S14: 454-457</td>
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<tr>
<td>28. W 11/04</td>
<td>CV05: Regulation of Heart Rate</td>
<td>S14: 466-468</td>
</tr>
<tr>
<td>29. F 11/06</td>
<td>CV06: Cardiac Excitation-Contraction Coupling</td>
<td>S14: 449-451</td>
</tr>
<tr>
<td>30. M 11/09</td>
<td>CV07: Cardiac Cycle and the Pumping Heart</td>
<td>S14: 460-466</td>
</tr>
<tr>
<td>31. W 11/11</td>
<td>CV08: Regulation of Cardiac Function</td>
<td>S14: 466-472</td>
</tr>
<tr>
<td>32. F 11/13</td>
<td>CV09: The Electrocardiogram I (ECG)</td>
<td>S14: 457-460</td>
</tr>
<tr>
<td>33. M 11/16</td>
<td>CV10: The Electrocardiogram II (ECG)</td>
<td>S14: 460</td>
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<tr>
<td><strong>2.2. CV Mechanics and Flow</strong></td>
<td></td>
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<tr>
<td>--- F 11/27</td>
<td>Thanksgiving Break</td>
<td>None</td>
</tr>
<tr>
<td><strong>Unit 3.</strong></td>
<td><strong>Respiratory System. Greg Clark.</strong></td>
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<tr>
<td><strong>Unit 4. Renal (Kidney) System. Greg Clark.</strong></td>
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<tr>
<td>41. M 12/07</td>
<td>Kidneys 1: Overview; Filtration</td>
<td>HW 3.1, due before lecture. S19:590-602</td>
</tr>
<tr>
<td><strong>FRI 12/18/2015</strong></td>
<td><strong>8:00-10:00. FINAL EXAM (Exam 3). Units 2-4.</strong></td>
<td>Review</td>
</tr>
</tbody>
</table>

1 Reading assignments: S = Silverthorn Chapter pages. For example, S9:285-296 ≡ Silverthorn, Chapter 9 pg. 285-296. The associated review pages at the end of the chapter are also assigned in conjunction with all Silverthorn readings. These are typically demarcated in parentheses; for example, Chap. 9 Running Problem Conclusions, plus Chapter Summary, Questions, and Answers. In cases where only portions of the chapter are assigned, only the review material associated with the assigned readings is required, irrespective of the review pages indicated herein. “Explorations” exercises are not required unless explicitly assigned. HINT: Occasionally, questions or variations thereof may be taken from these review pages for exams or quizzes.

11 Additional readings or homeworks beyond those indicated in the syllabus may be assigned throughout the course, particularly for the CV section.

* If the class falls behind the projected syllabus timeline, then homework due dates may be shifted accordingly.
### LABORATORY SYLLABUS

<table>
<thead>
<tr>
<th>Session (Week)</th>
<th>Topic</th>
<th>Reading/Assignment</th>
</tr>
</thead>
</table>
| **1.** Tu 8/25  
  W 8/26  
  Th 8/27 | ● Independent study, plus office hours<sup>1</sup> | Independent Study |
| **2.** Tu 9/1  
  W 9/2  
  Th 9/3 | ● Module 1. R-C Modeling of Neurons | Canvas<sup>2</sup> |
| **3.** Tu 9/8  
  W 9/9  
  Th 9/10 | ● Module 2. Stimulating and Recording from Frog Sciatic Nerve  
  ● Turn in Module 1 (R-C Modeling) assignment as instructed | Canvas |
| **4.** Tu 9/15  
  W 9/16  
  Th 9/17 | ● Independent study and data analysis, plus office hours  
  ● Turn in Module 2 (Sciatic N.) Lab Report as instructed | Data Analysis |
| **5.** Tu 9/22  
  W 9/23  
  Th 9/24 | ● Independent study, plus office hours | Independent Study |
| **6.** Tu 9/29  
  W 9/30  
  Th 10/1 | ● Module 3. Human Muscle. EMG Measurements: Relation to Force, Co-contraction, Agonist/Antagonist Action, and Fatigue | Canvas |
| **7.** Tu 10/6  
  W 10/7  
  Th 10/8 | ● Independent study and data analysis, plus office hours  
  ● Turn in Module 3 (EMG) assignment as instructed | Data Analysis |
| **--** Tu 10/13  
  W 10/14  
  Th 10/15 | *Fall Break* | n/a |
| **8.** Tu 10/20  
  W 10/21  
  Th 10/22 | ● Independent study, plus office hours | Independent Study |
| **9.** Tu 10/27  
  W 10/28  
  Th 10/29 | ● Independent study, plus office hours | Independent Study |
| **10.** Tu 11/3  
  W 11/4  
  Th 11/5 | ● Module 4. Frog Heart Lab: Structure, Function & Regulation | Canvas |
| **11.** Tu 11/10  
  W 11/11  
  Th 11/12 | ● Independent study & data analysis, plus office hours  
  ● Turn in Module 4 (Frog Heart) Lab Report as instructed | Data Analysis |
| **12.** Tu 11/17  
  W 11/18  
  Th 11/19 | ● Module 5. ECG and Exercise | Canvas |
| **13.** Tu 11/24  
  W 11/25  
  Th 11/26 | ● Independent study and data analysis, plus office hours  
  ● Turn in Module 5 assignment (ECG and Exercise) as instructed  
  ● (Note: Thanksgiving week.) | Data Analysis |
| **14.** Tu 12/01  
  W 12/02  
  Th 12/03 | ● Module 6. Respiration | Canvas |
| **15.** Tu 12/08  
  W 12/09  
  Th 12/10 | ● Independent study and data analysis, plus office hours  
  ● Turn in Module 6 (Respiration) assignment as instructed | Data Analysis |

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<sup>1</sup> Office hours held during off-weeks are subject to change; times as indicated earlier in syllabus.

<sup>2</sup> Students are required to read the lab manual before coming to lab. This will greatly facilitate their ability to understand and complete the exercises. Announced or unannounced quizzes on the lab manual are possible.
ACCREDITING BOARD OF ENGINEERING AND TECHNOLOGY (ABET): RELATIONSHIP OF THE COURSE TO THE PROGRAM OUTCOMES

What students actually learn is more important than what teachers try to teach. Long-term educational objectives can be evaluated in terms of specific, measureable outcomes. ABET is a professional organization that provides accreditation of the Bioengineering Department undergraduate educational program as well as engineering programs throughout the world, based on what students actually achieve. Employers often consider graduation from accredited programs as part of their hiring decisions.

The following information provides target levels of competence for student outcomes and capabilities (according to Bloom's Taxonomy of Educational Objectives) for BIOEN 3202. In short, these represent measurable goals of the course for student achievement.

**ABET Outcomes A-L**

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Description</th>
<th>Target Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Ability to apply knowledge of mathematics</td>
<td>4</td>
</tr>
<tr>
<td>A2</td>
<td>Ability to apply knowledge of science</td>
<td>4</td>
</tr>
<tr>
<td>A3</td>
<td>Ability to apply knowledge of engineering</td>
<td>4</td>
</tr>
<tr>
<td>B1</td>
<td>Ability to design experiments</td>
<td>3</td>
</tr>
<tr>
<td>B2</td>
<td>Ability to conduct experiments</td>
<td>3</td>
</tr>
<tr>
<td>B3</td>
<td>Ability to analyze and interpret data</td>
<td>3</td>
</tr>
<tr>
<td>C</td>
<td>Ability to design a system, component, or process to meet desired needs and within realistic constraints</td>
<td>3</td>
</tr>
<tr>
<td>D</td>
<td>Ability to function on multi-disciplinary teams</td>
<td>2</td>
</tr>
<tr>
<td>E</td>
<td>Ability to identify, formulate, and solve engineering problems</td>
<td>2</td>
</tr>
<tr>
<td>F</td>
<td>Understanding of professional and ethical responsibility</td>
<td>1</td>
</tr>
<tr>
<td>G1</td>
<td>Ability to communicate effectively in an oral format</td>
<td>2</td>
</tr>
<tr>
<td>G2</td>
<td>Ability to communicate effectively in a written format</td>
<td>3</td>
</tr>
<tr>
<td>H</td>
<td>Understanding of the impact of engineering solutions in a global and societal context</td>
<td>2</td>
</tr>
<tr>
<td>I1</td>
<td>Recognition of the need for life-long learning</td>
<td>1</td>
</tr>
<tr>
<td>I2</td>
<td>Ability to engage in life-long learning</td>
<td>1</td>
</tr>
<tr>
<td>J</td>
<td>Understanding of contemporary issues</td>
<td>2</td>
</tr>
<tr>
<td>K1</td>
<td>Ability to use the techniques and skills necessary for engineering practice</td>
<td>3</td>
</tr>
<tr>
<td>K2</td>
<td>Ability to use modern engineering tools necessary for engineering practice</td>
<td>3</td>
</tr>
<tr>
<td>L</td>
<td>Other Areas</td>
<td>2</td>
</tr>
</tbody>
</table>

**A1 - Ability to apply knowledge of mathematics**
A major focus of the course is analyzing physiological systems from mathematical, scientific, and
engineering principles in an integrated manner. For example, many physiological systems are examined from the perspective of feedback control.

A2 - Ability to apply knowledge of science
As indicated in A1, knowledge is integrated across these three domains.

A3 - Ability to apply knowledge of engineering
As indicated in A1, knowledge is integrated across these three domains.

B1 - Ability to design experiments
Lectures pose and design thought-experiments to distinguish among interpretations of observations or mechanisms. In laboratory exercise, students conduct experiments, and analyze and interpret data, with a modest experimental design component.

B2 - Ability to conduct experiments
As in B1.

B3 - Ability to analyze and interpret data
As in B1.

C - Ability to design a system, component, or process to meet desired needs and within realistic constraints
Much of the systems-level physiology is taught from a bio-based design perspective. Given physiological constraints, how would the student design a system to serve, repair or replace the function of the system or tissue being studied? What is the system "designed" to do, and how?

D - Ability to function on multi-disciplinary teams
Students occasionally break into small problem-solving groups in lecture, and work in teams of two in the lab for data collection and analysis.

E - Ability to identify, formulate, and solve engineering problems
Some forms of physiological dysfunctions are more readily addressed by certain types of engineering approaches than others. How does one determine what types of problems are tractable to which types of engineering approaches?

F - Understanding of professional and ethical responsibility
Potential engineering solutions for medical problems must also address professional or ethical issues. For example, decisions regarding implants of a cochlear prosthesis for the congenitally deaf must be made when people are too young to decide for themselves.

G1 - Ability to communicate effectively in an oral format
Lecture meetings may have occasional prepared presentations and oral reports from small, directed problem-solving groups.

G2 - Ability to communicate effectively in a written format
Formal lab reports vary in length and depth but include some complete reports (with Abstract, Introduction, Methods, Results, Discussion). Exams and homeworks include essay questions.

H - Understanding of the impact of engineering solutions in a global and societal context
Bioengineering and physiology in particular address medical and quality-of-life in practical as well as conceptual terms.
I1 - Recognition of the need for life-long learning
The course emphasizes fundamental underlying physiological and engineering principles that subsequently may be applied to the analysis of a variety of organ systems using similar thought processes and approaches learned here.

I2 - Ability to engage in life-long learning
As in I1.

J - Understanding of contemporary issues
Rapid advances in medical and engineering technologies applied to biomedical problems allow consideration of contemporary technological and societal issues.

K1 - Ability to use the techniques and skills necessary for engineering practice
This ability is manifested in variety of laboratory modules, both for using the instrumentation and for data collection and analysis.

K2 - Ability to use modern engineering tools necessary for engineering practice
As in K1.

ABET Capabilities 1-8

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<th>Capability</th>
<th>Description</th>
<th>Target Level</th>
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<td>1</td>
<td>Understanding of Biology</td>
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<td>2</td>
<td>Understanding of Physiology</td>
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<td>3</td>
<td>Make measurements and interpret data from living systems</td>
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<td>4</td>
<td>Can address problems associated with the interaction between living and nonliving materials and systems</td>
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<td>5</td>
<td>Capability to solve the problems at the interface of engineering and biology by applying ADVANCED MATH including differential equations</td>
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<td>6</td>
<td>Capability to solve the problems at the interface of engineering and biology by applying STATISTICS</td>
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<td>Capability to solve the problems at the interface of engineering and biology by applying SCIENCE (hypothesis driven research)</td>
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<td>Capability to solve the problems at the interface of engineering and biology by applying ENGINEERING (design and analysis)</td>
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1 - Understanding of Biology
Understanding biological principles and mechanisms is essential for understanding physiology

2 - Understanding of Physiology
Understanding physiology with an emphasis on integrating ways of thinking from physiological and engineering perspectives, rather than rote memorization.

3 - Make measurements and interpret data from living systems
Several laboratory exercises measure and interpret animal and human physiological data, including
compound action potentials from nerve, muscle length-force and force-velocity curves, and cardiovascular responses in frogs, and EMG and pulmonary responses in humans.

4 - Can address problems associated with the interaction between living and nonliving materials and systems
The course considers the use of artificial organs and interfaces for restoration of function, and hence also addresses biocompatibility and device-tissue interactions

5 - Capability to solve the problems at the interface of engineering and biology by applying ADVANCED MATH including differential equations
Simple and some advanced mathematics is used for understanding biological (e.g., Hodgkin-Huxley) and electric-circuit equivalent models of neuronal and cardiovascular function.

6 - Capability to solve the problems at the interface of engineering and biology by applying STATISTICS
Students use extensive descriptive statistics (e.g., means, standard deviations) as well as modest inferential statistics for analysis of data in the laboratory exercises.

7 - Capability to solve the problems at the interface of engineering and biology by applying SCIENCE (hypothesis driven research)
In lecture, students are challenged to design thought-experiments whose potential outcomes might discriminate among various possible interpretations or mechanisms. In laboratory, students pose and subsequently test hypotheses in the real-world environment.

8 - Capability to solve the problems at the interface of engineering and biology by applying ENGINEERING (design and analysis)
Examples include brainstorming sessions for designing stimulus protocols for effective stimulation of bladder voiding, an artificial kidney, stimulating electrodes and stimulus paradigms to allow selective recruitment of small-diameter nerve fibers.