Bioengineering 241: Metabolism and Magnetic Resonance Spectroscopy

Winter Quarter (UCSF)/Spring Semester (UCB) 2024: In-person Lectures on Monday from 12:30 – 2:00 pm and Thursday from 12 noon - 1:30 pm

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Faculty Offices:
Dr. Sriram has an office in QB3/Byers Hall, room 203E

BioE241 CLE Website –
https://courses.ucsf.edu/course/view.php?id=11089#section-0

BioE241 Zoom Link - Meeting ID: 979 8816 4446, Passcode: 687967
https://ucsf.zoom.us/j/97988164446?pwd=V0tob0QwMFFxbElDcFRBMUdpazhqdz09

Course Description:
This course assumes a basic understanding of magnetic resonance physics and will cover in detail the topic of nuclear magnetic resonance spectroscopy including both *in vitro* and *in vivo* applications. The course will cover basic theory, underlying biochemistry and physiology, basic and advanced techniques for acquiring and processing MR spectroscopic data, and biomedical

* See table at the end of syllabus for classroom schedule

applications for this emerging medical imaging modality.that can be used to study metabolism. The course also involves hands-on/demonstration of experiments a to give exposure to the magnetic resonance infrastructure and the various applications that are being performed routinely in the core laboratory. While not a pre-requisite, taking either Bioengineering 240, Biomedical Imaging 201, or a similar course that covers the basics of magnetic resonance imaging or NMR is advised.

Course grading convention:

______Letter only ________P/NP only ___S/U only

_X__Letter, P/NP or S/U

Course objectives

• Understanding of the basic physical concepts behind magnetic resonance spectroscopy.
• To achieve familiarity with the hardware instrumentation and acquisition techniques used for Magnetic Resonance spectroscopy and methods to improve performance for specific applications.
• To comprehend the methods used in data analysis of NMR spectra; both for routine data processing and for specific advanced applications.
• To understand the types of chemical compounds observable by MRS and the underlying biochemistry probed by this modality.
• To understand what biochemical and physiologic processes can be monitored by MRS.
• To gain a working knowledge of how to acquire and analyze in vitro and in vivo NMR spectra.
• To appreciate the areas of current interest for research applications

Course requirements: (Check all that apply)

__X__Attendance __X__Practical Data Analyses _X__Homework __X__Final exam

Evaluation of student performance: (Check all that apply)

__10%__Attendance __25%__Practical Data analyses _25%__Homework __40%__Final exam

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Winter Quarter(UCSF)/Spring Semester (UCB) 2024: 1/11/2024 – 3/14/2024

Date	Faculty In Charge	Topic
1/11	RS	Physical Concepts Behind Magnetic Resonance Spectroscopy, Introduction to Spectral Acquisition and Processing
1/18	XJ	Instrumentation, RF Coils
1/22	XJ/TN	Practical experience with Magnetic resonance instrumentation

1/25	JK	Information Content of an NMR spectrum Lecture 1: Organic Chemistry Concepts, Chemical Shift and J-coupling
1/29	JK	Information Content of an NMR spectrum lecture 2: T_1 and T_2 relaxation
2/1	JK	Identification of Compounds/Metabolites in ^{1}H NMR spectra using chemical shift J-coupling and T_1 and T_2 relaxation information
2/5	PEZL	Localized Spectroscopy – Gradients/ selective RF Pulses, and advanced pulse sequences
2/8	XJ	Practical experience with 1-D/localized ^{1}H NMR spectral acquisition and data analyses
2/12	RS	X- nuclei: ^{31}P NMR spectroscopy – Sensitivity, Chemical shift and J-coupling, T_1 and T_2 relaxation, identification of metabolites in *ex vivo* and *in vivo* ^{13}C and ^{31}P NMR spectra
2/15	RS	X- nuclei: ^{2}H NMR spectroscopy / ^{13}C NMR spectroscopy – stable isotopomer resolved spectroscopy
2/22	XJ/TN	Practical Experience with X-nuclei spectroscopy
2/26	RS	Hyperpolarized ^{13}C Magnetic Resonance Spectrscopy/Spectroscopic Imaging
2/29	RS	Cancer Metabolism: Metabolic pathways that can be probed by spectroscopic studies, Cell and tissue culture bioreactors, animal models
3/4	RS/XJ	Practical experience with Hyperpolarized 13C Magnetic resonance spectroscopy.
3/7	RS	Metabolic Dynamics – Kinetics and Transport Measured by 1 and 2D NMR Spectroscopy
3/11	RS	Non-cancer metabolism applications – Muscle bioenergetics, diabetes, neurodegenerative diseases
3/14	RS/JK	Wrap-up lecture – cover topics missed in prior lectures and areas students would like to explore further – Hand out Final Take Home Exam
3/18	JK/RS	Start of Finals Week
3/20	JK/RS	Final due

<u>Book:</u>

Handbook of Magnetic Resonance Spectroscopy In Vivo: MRS Theory, Practice and Applications (ISBN: 9781118997666), edited by Paul A. Bottomley & John R. Griffiths, published on 30th November 2016

<u>Online Courses:</u>

http://www.cis.rit.edu/htbooks/mri/

http://www.cis.rit.edu/htbooks/nmr/

<u>^{1}H, ^{13}C, ^{15}N, and ^{31}P Coupling Constants, Chemical Shifts</u>

http://www.chem.wisc.edu/areas/reich/Handouts/nmr-c13/cdata.htm

^{1}H, ^{13}C Spectra, Coupling Constants, Chemical Shifts

http://www.ymdb.ca/

http://sdbs.db.aist.go.jp/sdbs/cgi-bin/cre_index.cgi

http://www.hmdb.ca/metabolites

<u>Data Analysis Software Website:</u>

https://www.chenomx.com

<u>Books:</u>

1. Braun, S., Kalinowski, H.O., and Berger, S. *150 and More Basic NMR Experiments.* Germany: Wiley-VCH, 1998.
2. Malcolm H. Levitt. Spin dynamics: basics of nuclear magnetic resonance. John Wiley & Sons, Chichester, UK, 2001
3. P. J. Hore. Nuclear Magnetic Resonance. Oxford Chemistry Primers No. 32. Oxford Science Publications, Oxford University Press, Oxford, 1995
4. James, Thomas and Margulis, Alexander. *Biomedical Magnetic Resonance.* California: Radiology Research and Education Foundation, 1984.
5. Salibi, Nouha and Brown, Mark. *Clinical MR Spectroscopy.* New York: Wiley-Liss, Inc., 1998.
6. Homans, S.W. *A Dictionary of Concepts in NMR.* New York: Oxford University Press, 1995.
7. Bernstein, Matt, King, Kevin, and Zhou, Xiaohong Joe. *Handbook of MRI Pulse Sequences.* California: Elsevier, Inc., 2004.
8. Diehl, P., Fluck, E., Gunther, H., Kosfeld, R., and Seelig, J. *In-Vivo Magnetic Resonance Spectroscopy I: Probeheads and Radiofrequency Pulses, Spectrum Analysis.* Germany: Springer-Verlag, 1992.

9. Beall, Paula, Amtey, Sharad, and Kasturi, Sitapati. *NMR: Data Handbook for Biomedical Applications.* New York: Pergamon Press Inc, 1984.

10. Roberts, G.C.K. *NMR of Macromolecules.* New York: Oxford University Pres, 1993.

11. Martin, Delpuech, and Martin. *Practical NMR Spectroscopy.* Pennsylvania: Heyden and Son Ltd, 1980.

12. Nishimura, Dwight. *Principles of Magnetic Resonance Imaging.* California: Dwight G. Nishimura, 1996.

13. Silverstein, Bassler, and Morrill. *Spectrometric Identification of Organic Compounds.* Fourth Edition. New York: Wiley and Sons, Inc., 1981.

12. Tosi, R. and Tugonli V. *Nuclear Magnetic Resonance Spectroscopy in the Study of Neoplastic Tissue.* Nova Science Publishers, New York, New York, 2005.

Review Articles: Recent review articles associated with topics covered in the labs and lectures will be handed out and discussed in the weekly discussion sessions.

Handouts: Handouts describing the use of the 500 and 600 MHz spectrometers, DNP polarizers and procedures for data processing and analysis will be handed out on a weekly basis and discussed in the weekly discussion sessions.

Practical Experience Sessions – These session will take the place of the Course's hands-on labs during the COVID-19 pandemic. These sessions will have video presentations of actual spectroscopy experiments performed in the lab and the subsequent analyses and interpretation of the actual data acquired.

Problem Sets: Problem sets will be handed out weekly and will be due 1 week later.

Final Exam: The final exam will be a take-home exam that will test your ability to apply the concepts taught during the course to practical problems that are often encountered during *in vivo* spectroscopic research. Students should work individually on the exam and provide complete, detailed answers to the problem solving type questions. In some cases there may not be only one correct answer nor may the answer be known, so the thought process used to obtain the answer is critical and needs to be provided.