BCH 6741C
Magnetic Resonance Imaging and Spectroscopy in Living Systems

Class Time: Lectures will be 4th period (10:40 - 11:30 am) on Tuesdays and Thursdays. Labs meeting times will be arranged to suit the schedule of registered students.

Class Location: Room R3-265, Academic Research Building (ARB)

Instructor: Thomas H. Mareci, Ph.D.
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Office hours: Tuesdays and Thursday, 4:30 to 5:30 pm by appointment

Course Objective and Goals: The objective of this course is to provide students with the knowledge necessary to apply modern methods of MR imaging and spectroscopy *in vivo* to solve research problems. Lectures provide a detailed treatment of the principles of nuclear magnetic resonance imaging and spectroscopy necessary to understand current methods for visualizing the structure of living systems; cells, tissues, whole animals, and humans. Also current methods will be discussed which allow monitoring of biochemical processes in cells suspensions, whole animals, and humans using *in vivo* MR spectroscopy. The lab will provide practical experience in sample preparation, instrument operation, data analysis and construction of simple MR coils.

Prerequisites: Students should have completed a course in chemistry and physics, or the equivalent. Calculus is used throughout so students should have completed a course in calculus or the equivalent. No experience with electronics is required.

Registration: The lectures and labs combine for a three-credit hour course. Advanced undergraduates may register for the course with the permission of the instructor.

Lectures (One-hour class twice a week on Tuesday and Thursday during 4th period):

Week 1: Behavior of magnetic moments in an applied magnetic field (Chap. 2)
Week 2: RF coils, magnetic field gradients and the rotating reference frame (Chap. 3)
Week 3: Relaxation and magnetic-field-strength dependence (Chap. 4)
Week 4: Signal detection and Fourier transformation (Chaps. 7, 8)
Week 5: Multiple RF pulses, echoes, and one-dimensional imaging (Chaps. 9, 10)
Week 6: Imaging in multiple dimensions (Fourier imaging) and slice selection (Chaps. 10)
Week 7: Rapid imaging methods: FLASH, Echo Planar, Spiral, and RARE (Chaps. 19)
Week 8: Image contrast: SNR, relaxation, and flow (Chap. 8, Sect 3 & Chaps.15, 22-24)
Week 9: Diffusion weighted imaging (Chap. 21)
Week 10: Functional magnetic resonance imaging (Chap. 25)
Week 11: Basic quantum description of NMR (Chaps. 5-6 and class notes)
Week 12: Chemical shift and scalar coupling (class notes)
Week 13: Chemical-shift-selective and spectroscopic imaging (Chap. 10 & class notes)
Week 14: Localized MR spectroscopy and adiabatic excitation (class notes)
Week 15: Measurement of physiological parameters; pH and reaction rates (class notes)

Laboratory (3-hour class; once a week for 5 weeks at appropriate times during the term):

1. RF magnetic field coils and construction
   - Coil circuit elements and radio-frequency response
   - Coil construction
   - Effect of the number of turns on apparent inductance
2. MR imaging *In vivo*
   - Lab Safety

     Effects of static magnetic fields
     Biological effects of the magnetic resonance process
   - NMR Instrumentation

     Overview of hardware and software systems
     Sample loading and RF coil tuning
     Shimming and RF pulse-power calibration
     ^{1}H NMR imaging (quantification of T1 and T2 relaxation times)
   - Samples for labs; Vegetable or fruit (e.g. apple, kiwi, or orange) or grocery store hen's egg, each no more than 4 cm wide.
3. Basic image processing
   - Fourier transformation, scaling and image display
   - T1 and T2 relaxation time calculation
   - Analyzing dynamic contrast enhanced images
4. Diffusion weighted image processing
   - Diffusion tensor image calculation
   - Analysis of rate of diffusion and diffusion anisotropy
   - Fiber track mapping
5. P-31 NMR spectroscopy and the measurement of physiological processes
   - NMR spectroscopy processing (e.g. Fourier transformation, phase correction)
   - Measurement of pH and reaction rates

Note: All necessary lab supplies will be provided.

Course Outline

Week 1: Behavior of Magnetic Moments and Block Equations

Week 2: Precession, Phase, and MR Excitation

Week 3: Relaxation and magnetic-field-strength dependence

Week 4: Signal detection and Fourier transformation

Week 5: Multiple RF pulses, echoes, and one dimensional imaging,

Week 6: Imaging in multiple dimensions (Fourier imaging) and slice selection

Week 7: Rapid imaging methods: FLASH, Echo Planar, Spiral and RARE

Homework 1 Block Equations
Homework 2 Block Equations & T2
Homework 3 Faradays Law
Homework 4 Rotations & precession in matrix notation
Homework 5 k-space calculations

Lab 1: RF coils
Lab 2: In Vivo MRI
Lab 3: Basic imaging processing

Mid-term exam covering Weeks 1-7

Week 8 Image contrast: Resolution, SNR, relaxation weighting, and flow

Week 9 Diffusion weighted imaging

Week 10 Magnetic susceptibility and functional MR imaging

Week 11 Basic quantum description of NMR

Week 12 Chemical shifts and coupling constants

Week 13 Chemical-shift-selective and spectroscopic imaging

Week 14 Localized MR spectroscopy and adiabatic excitation

Week 15 Measurement of physiological parameters; pH and reaction rates

Homework 6 Quantitative Relaxation and Diffusion
Homework 7 Fourier Spectrum and Phase Modulation
Homework 8 Pulse Sequence Timing
Homework 9 Image Interpretation
Homework 10 Gradient Echo Sequence

Lab 3: Diffusion weighted imaging
Lab 5: P-31 NMR spectroscopy and physiological processes

Final exam covering Weeks 8-15

Class attendance: Class attendance is not required, but without regular attendance the student will miss a great deal of important discussion and interaction. In addition, some of the material covered will only be available in class notes.

Missed assignments and make-up exams: Assignments cannot be turned in late unless prior arrangements have been made with the instructor. Making up the mid-term or final exams is possible with prior approval of the instructor. Special arrangements can be made in case of a documented emergency.

Grading: The course grade will be based on results from graded homework (1/3), exams (1/3), and lab reports (1/3).

Textbook and Journal Articles:

Recommended textbook; Magnetic Resonance Imaging: Physical Principles and Sequence Design, by E. M. Haacke, R. W. Brown, M. R. Thompson, and R. Venkatesan, John Wiley & Sons, Inc, 1999. *The book is expensive so I have designed the course to use this book as complementary reading. You can get by without purchasing this book, but reading the book is very helpful. It is a good reference and you might be able to find a used copy.*

Journal articles: Early literature on the basics of MR and recent literature (1990-2015) published in the journals, such as Journal of Magnetic Resonance, Magnetic Resonance in Medicine, and Magnetic Resonance Imaging.

Accommodations for Students with Disabilities: Students with disabilities requesting accommodations should first register with the Disability Resource Center (www.dso.ufl.edu/drc/, phone 352-392-8565, fax 352-392-8570, or e-mail accessUF@dso.ufl.edu) by providing appropriate documentation. Once registered, students will receive an accommodation letter which must be presented to the instructor when requesting accommodation. Students with disabilities should follow this procedure as early as possible in the semester.

Online Course Evaluation: Students are expected to provide feedback on the quality of instruction in this course by completing online evaluations at https://evaluations.ufl.edu. Evaluations are typically open during the last two or three weeks of the semester, but students will be given specific times when they are open. Summary results of these assessments are available to students at https://evaluations.ufl.edu/results.

Campus Resources:

Academic Resources

E-learning, http://elearning.ufl.edu/
Support, 352-392-4357 (select option 2) or e-mail learningsupport@ufl.edu.

Library Support, http://cms.uflib.ufl.edu/ask. Various ways to receive assistance with respect to using the libraries or finding resources.

Student Complaints: https://www.dso.ufl.edu/documents/UF_Complaints_policy.pdf

Health and Wellness

Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact umatter@ufl.edu so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

U Matter, We Care: http://www.umatter.ufl.edu/
If you or a friend is in distress, please contact umatter@ufl.edu or
Call 352-392-1575 so that a team member can reach out to the student.

Counseling and Wellness Center: http://www.counseling.ufl.edu/cwc/Default.aspx
Phone 352-392-1575; and
The University Police Department: 352-392-1111 or 9-1-1 for emergencies.

Sexual Assault Recovery Services (SARS)
Student Health Care Center, 352-392-1161
http://www.umatter.ufl.edu/sexual_violence

University Police Department, 352-392-1111 (or 9-1-1 for emergencies).
http://www.police.ufl.edu/