

## **BCH 6741C** **Magnetic Resonance Imaging and Spectroscopy in Living Systems**

**Class Time:** Lectures will be 4<sup>th</sup> 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:** **Online in Canvas with Zoom** (or Room R3-265, Academic Research Building)

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

**Prerequisites:** Students should have completed courses in chemistry and physics, or the equivalent. The course uses calculus 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 4<sup>th</sup> 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: Measurement of physiological parameters; pH and reaction rates (class notes)
- Week 14: Chemical-shift-selective and spectroscopic imaging (Chap. 10 & class notes)
- Week 15: Localized MR spectroscopy and adiabatic excitation (class notes)

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

1. RF magnetic resonance antenna coils and construction
  - a. Coil circuit elements and radio-frequency response
  - b. Coil construction
  - c. Effect of the number of turns on apparent inductance
  - d. Inductive coupling between coils
2. MR imaging *In vivo*
  - a. Lab Safety
    - i. Effects of static magnetic fields
    - ii. Biological effects of the magnetic resonance process
  - b. NMR Instrumentation
    - i. Overview of hardware and software systems
    - ii. Sample loading and RF coil tuning
    - iii. Shimming and RF pulse-power calibration
    - iv.  $^1\text{H}$  NMR imaging (quantification of T1 and T2 relaxation times)
  - c. 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
  - a. Fourier transformation, scaling and image display
  - b. T1 and T2 relaxation time calculation
  - c. Analyzing dynamic contrast enhanced images
4. Diffusion-weighted image and functional image processing
  - a. Diffusion tensor image calculation
  - b. Analysis of rate of diffusion and diffusion anisotropy
  - c. Streamline fiber track mapping
  - d. Function image processing
  - e. Resting-state image processing
5. P-31 NMR spectroscopy and the measurement of physiological processes
  - a. NMR spectroscopy processing (e.g. Fourier transformation & phase correction)
  - b. Measurement of pH and reaction rates

**Note:** All necessary lab supplies will be provided.

## Course Outline

Week 1: Behavior of Magnetic Moments and Bloch 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 Bloch Equations

Homework 2 Bloch Equations & T<sub>2</sub>

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 during the 8<sup>th</sup> week 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 Measurement of physiological parameters; pH and reaction rates

Week 14 Chemical-shift-selective and spectroscopic imaging

Week 15 Localized MR spectroscopy and adiabatic excitation

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 4: Diffusion weighted imaging

Lab 5: P-31 NMR spectroscopy and physiological processes

### **Final exam during final-exam period 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). The assigned grade are based on a comparison to the performance of other current and previous students.

### **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 who experience learning barriers and would like to request academic accommodations should connect with the Disability Resource Center by visiting <https://disability.ufl.edu/students/get-started/>. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

**Online Course Evaluation:** Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via **GatorEvals**. Guidance on how to give feedback in a professional and respectful manner is available at <https://gatorevals.aa.ufl.edu/students/>. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from **GatorEvals**, in their Canvas course menu under **GatorEvals**, or via <https://ufl.bluera.com/ufl/>. Summaries of course evaluation results are available to students at <https://gatorevals.aa.ufl.edu/public-results/>.

## Campus Resources:

### Academic Resources

**E-learning**, <http://elearning.ufl.edu/>

Support, 352-392-4357 (select option 2) or e-mail [learningsupport@ufl.edu](mailto: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://distance.ufl.edu/student-complaint-process>

### 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](mailto: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](mailto:umatter@ufl.edu) or Call 352-294-2273 so that a team member can reach out to the student.

**Counseling and Wellness Center**: <https://counseling.ufl.edu>

Phone 352-392-1575; and

The University Police Department: 352-392-1111 or 9-1-1 for emergencies.

**Sexual Harassment**

<https://hr.ufl.edu/forms-policies/policies-managers/sexual-harassment>

**Sexual Assault**

Student Health Care Center, 352-392-1161

<https://umatter.ufl.edu/concern/sexual-assault>

**University Police Department**, 352-392-1111 (or 9-1-1 for emergencies).

<http://www.police.ufl.edu/>