

## **BCH 6741: 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; Academic Research Building, Room R3-265**

### **Instructor**

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**Phone**, 352-273-5348 (office)  
**Office hour**: Tuesday, 4:30 to 5:30 pm (other times 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 and function, with a focus on *in vivo* studies of 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 (e.g., CHM 2045-6 series, PHY 2048-9 series or the equivalent). Calculus is used so students should have completed courses in calculus (e.g., MAA 4211-2 series 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.

### **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 and elaborated upon in class discussions.

- With an excused absence, course materials will be provided, and you will be given a reasonable amount of time to make up work. <https://catalog.ufl.edu/UGRD/academic-regulations/attendance-policies/>.

### **In-Class Recording**

Students may record video or audio of class lectures in accordance with UF policy: <https://aa.ufl.edu/policies/in-class-recording/>

## 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.

## Grades and Grading Policy

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 the course is designed 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.*

Recommended textbook; Handbook of MRI Pulse Sequences by M. A. Bernstein, K. F. King, and X. J. Zhou, Elsevier, Academic Press, 2004. *This is a very good reference, and you might be able to find a used copy.*

Journal articles: Early literature on the basics of MR and recent literature 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/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 (<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,

## Campus Resources

### Academic Resources

**Academic Resources:** 1317 Turlington Hall or  
<https://academicresources.clas.ufl.edu/>

**E-learning,** <http://elearning.ufl.edu/>  
Support, 352-392-4357 (select option 2) or e-mail [helpdesk@ufl.edu](mailto:helpdesk@ufl.edu)

**Library Support,** <https://uflib.ufl.edu/>, provides various ways to receive assistance with using the libraries or finding resources.

**Writing Studio:** 2215 Turlington Hall, 352-846-1138 or <https://umatter.ufl.edu/office/writing-studio/>. Help brainstorming, formatting, and writing papers.

**Career Connections Center:** Reitz Union Suite 1300, 352-392-1601 or <https://career.ufl.edu/>. Career assistance and counseling services.

**Student Honor Code:** <https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/>

**On-Line Students Complaints:** <https://flexible.dce.ufl.edu/student-complaints/>

## **Health and Wellness**

Your well-being is important to the University of Florida and the University 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. Please remember that asking for help is a sign of strength.

**In case of emergency, call 9-1-1.**

### **U Matter, We Care:**

If you or a friend is in distress, please contact <https://umatter.ufl.edu/> or Call 352-392-1575 so that a team member can reach out to the student.

**Counseling and Wellness Center:** <https://counseling.ufl.edu/>  
Phone 352-392-1575 for information on crisis services as well as non-crisis services.

**Sexual Harassment:** <https://titleix.ufl.edu/report/>

**Sexual Assault:** <https://police.ufl.edu/divisions/behavioral-services/office-of-victim-services/resources-for-victims/sexual-violence-assault/>

**Student Health Care Center:** Call 352-392-1161 for 24/7 information to help you find the care you need, or <https://shcc.ufl.edu/>.

**UF Health Shands Emergency Room / Trauma Center:** For immediate medical care call 352-733-0111 or go to the emergency room at 1515 SW Archer Road, Gainesville, FL 32608.

**University Police Department,** 352-392-1111 (or 9-1-1 for emergencies). Also <https://police.ufl.edu/>

## Course Outline

- Week 1: Behavior of Magnetic Moments and Bloch Equations
- Week 2: RF coils, magnetic field gradients and the rotating reference frame
- 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: 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 scalar coupling
- 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: Pulse Sequence Timing
- Homework 8: Image Interpretation
- Homework 9: Fourier Spectrum and Phase Modulation
- Homework 10: Gradient Echo Sequence

- Lab 3: Diffusion weighted imaging
- Lab 4: In Vivo MRI
- Lab 5: P-31 NMR spectroscopy and physiological processes

### **Final exam during final-exam period covering weeks 8-15**

## Laboratory

~ 3 hours once a week for 5 weeks throughout the term at appropriate times

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. Basic image processing
  - a. Fourier transformation, scaling and image display
  - b. T1 and T2 relaxation time calculation
  - c. Analyzing dynamic contrast enhanced images
3. 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
4. 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.
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.