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

Academic Research Building, Room R3-265

Instructor

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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 (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.

Weekly Schedule of Lectures

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; 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. 1H 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.

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 & T2
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 8th 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 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

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.

Face-to-Face Instruction

We will have face-to-face instructional sessions to accomplish the student learning objectives of this course. In response to COVID-19, the following recommended procedures should be followed to maintain your learning environment and to enhance the safety of our interactions (these procedures are subject to change if the situation requires modification).

- You are welcome to wear approved face coverings during class, labs, and within buildings.
- This course has been assigned a physical classroom with enough capacity to maintain physical distancing (6 feet between individuals) requirements. Please maintain appropriate spacing between students. Please do not move desks or stations.
- Practice physical distancing, to the extent possible, when entering and exiting the classroom and lab.
- If you are experiencing COVID-19 symptoms (Click here for guidance from the CDC on symptoms of coronavirus).
- Course materials will be provided to you with an excused absence, and you will be given a reasonable amount of time to make up work. Find more information in the university attendance policies.

In-Class Recording

Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

- A "class lecture" is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or lecturer during a class session.
- Publication without permission of the instructor is prohibited. To "publish" means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or discipline under UF Regulation 4.040 Student Honor Code and Student Conduct Code.

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 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*.

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/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. Click here for guidance on how to give feedback in a professional and respectful manner. 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 ufl.bluera.com/ufl/. Summaries of course evaluation results are available to students here.

Campus Resources

Academic Resources

E-learning technical support: Contact the UF Computing Help Desk at 352-392-4357 or via e-mail at helpdesk@ufl.edu.

Career Connections Center: Reitz Union Suite 1300, 352-392-1601. Career assistance and counseling services.

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

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

Teaching Center: Broward Hall, 352-392-2010 or to make an appointment 352-392-6420. General study skills and tutoring.

Writing Studio*:* 2215 Turlington Hall*,* 352-846-1138. Help brainstorming, formatting, and writing papers.

Student Complaints On-Campus: Visit the Student Honor Code and Student Conduct Code webpage for more information.

On-Line Students Complaints: View the Distance Learning Student Complaint Process.

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: 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: https://counseling.ufl.edu
Phone 352-392-1575 for information on crisis services as well as non-crisis services.

Sexual Harassment:
https://hr.ufl.edu/forms-policies/policies-managers/sexual-harassment

Sexual Assault: https://police.ufl.edu/services/victim-services/sexual-violence-assault/

Student Health Care Center: Call 352-392-1161 for 24/7 information to help you find the care you need, or visit the Student Health Care Center website.

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; Visit the UF Health Emergency Room and Trauma Center website.

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