Introduction

M219 - Principles and Applications of MRI

Kyung Sung, Ph.D.

1/8/2024

Department of Radiological Sciences
David Geffen School of Medicine at UCLA

Introduction

- Your instructor
  - Kyung Sung
- Guest lecturers
  - Dr. Holden Wu
  - Dr. Albert Thomas
  - Dr. Xiaodong Zhong
  - Dr. Anthony Christodoulou
- You

- Your department
- Research lab (if you have)
- Years at UCLA
- Hometown
- Your favorite movie in recent 5 years

Course Overview

- https://mrrl.ucla.edu/pages/m219
- Assignments
  - 3 homework assignments (20 points each)
  - 1 final exam (30 points)
  - Class participation (10 points)
- Bring questions to class!
  - Slides will be available prior to lecture
- MATLAB
  - Required for homework

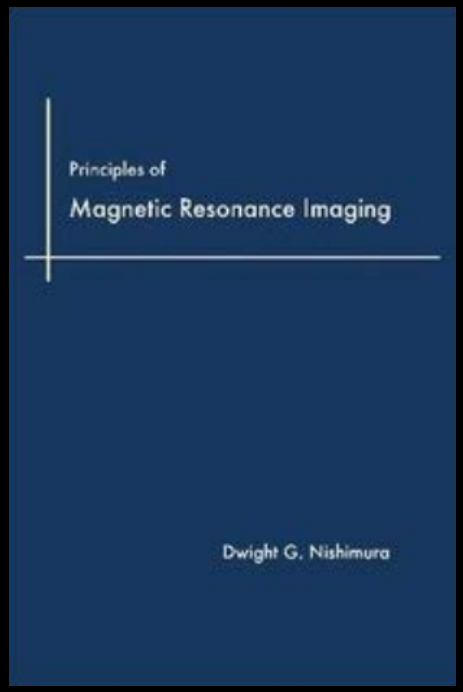
Learning Objectives

- To introduce the students to the fundamental principles of magnetic resonance imaging
- To demonstrate basic applications of MRI

Prerequisites

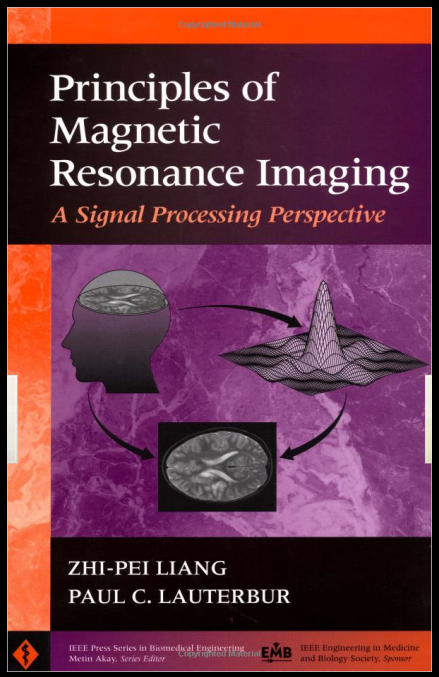
- Vectors and Vector Operations
  - dot product
  - cross product
- Basic Matrix Algebra
  - Determinant
  - Inverse
  - Transpose
  - Matrix Multiplication
  - Eigenvectors

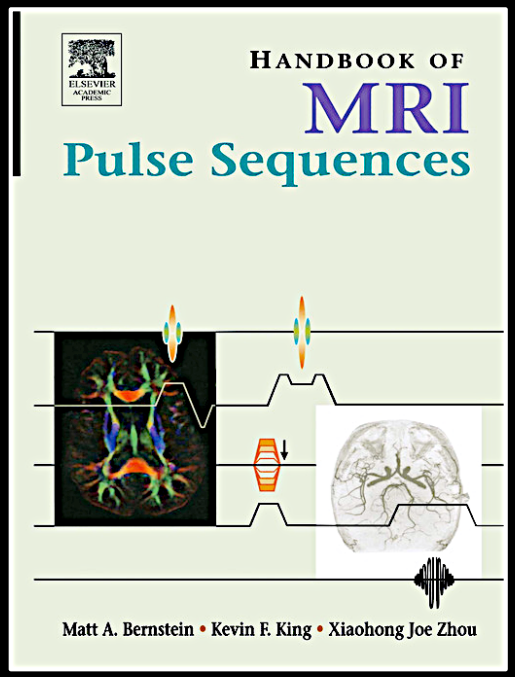
Primary Books



https://ee.stanford.edu/~dwight/
lulu.com - hardcover | paperback

Supplementary Books

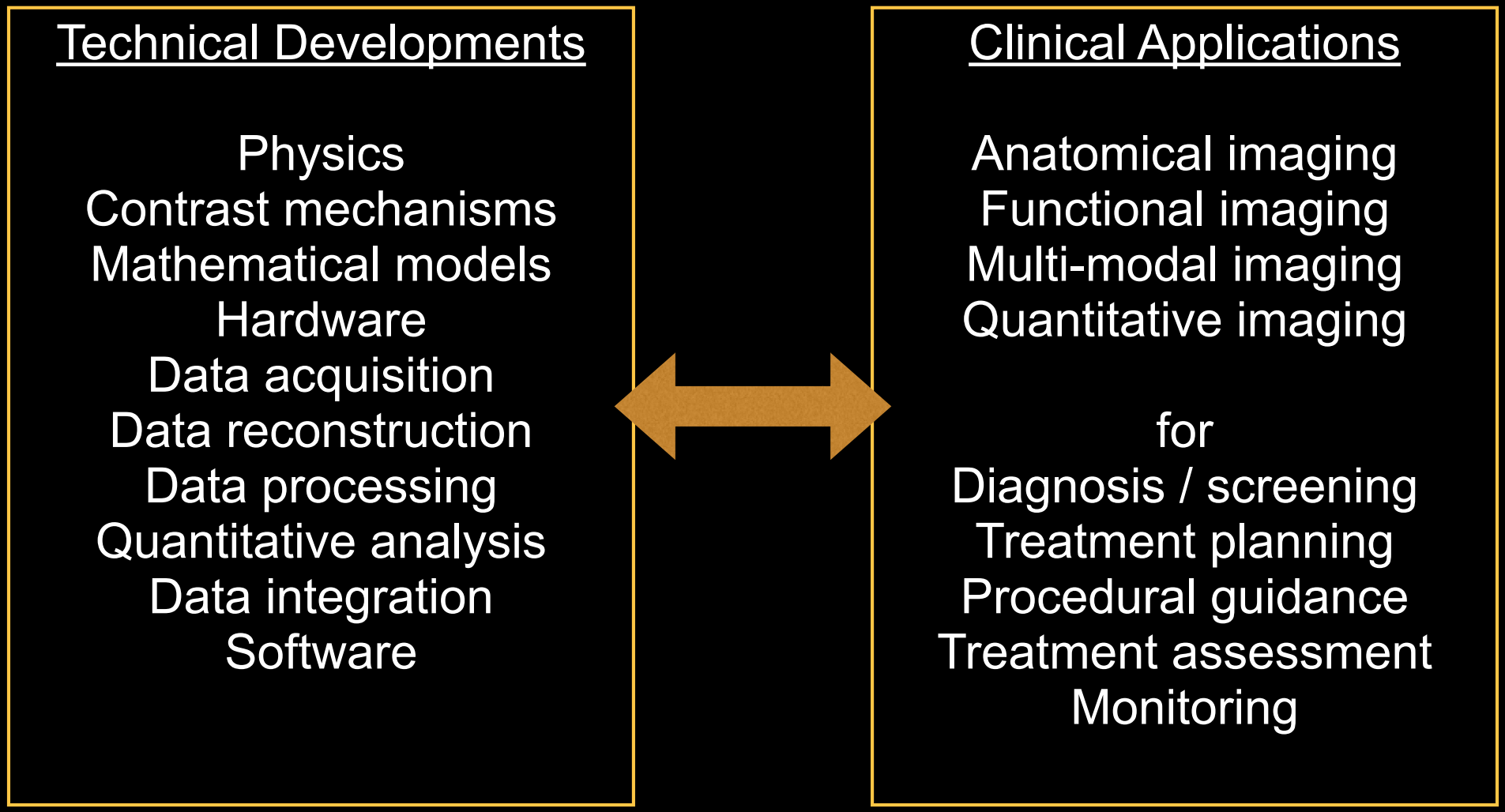




Course Schedule:

Lecture	Date	Topic
#1	Jan 9, 2023	Introduction
#2	Jan 11, 2023	MRI Systems I: B0 and Bulk Magnetization
#3	Jan 16, 2023	MLK Holiday
	Homework #1 out	
#4	Jan 18, 2023	MRI Systems II: Nuclear Precession and B1
#5	Jan 23, 2023	Bloch Equations and Relaxation
#6	Jan 25, 2023	MRI Systems III: Gradients
#7	Jan 30, 2023	Imaging Principles I
	Homework #1 due, Homework #2 out	
#8	Feb 1, 2023	Imaging Principles II
#9	Feb 6, 2023	Spatial Localization I
#10	Feb 8, 2023	Spatial Localization II
#11	Feb 13, 2023	MRI Signal Equation and Basic Image Reconstruction **(**by **Holden Wu)**
#12	Feb 15, 2023	Fast Imaging and Advanced Image Reconstruction **(**by **Holden Wu)**
	Homework #2 due, Homework #3 out	
#13	Feb 20, 2023	Presidents' Day Holiday
#14	Feb 22, 2023	Basic Pulse Sequences I: Saturation Recovery and Inversion Recovery
#15	Feb 27, 2023	Basic Pulse Sequences II: Gradient Echoes
#16	Mar 1, 2023	Basic Pulse Sequences III: Spin Echoes
#17	Mar 6, 2023	Basics of MR Spectroscopy **(**by **Dr. Albert Thomas)**
#18	Mar 8, 2023	Fast MR Spectroscopic Imaging **(**by **Dr. Albert Thomas)**
	Homework #3 due	
#19	Mar 13, 2023	TBD (by **Dr. Jason Chiang**)
#20	Mar 15, 2023	Vascular MRI (by **Dr. Zhaoyang Fan** from USC)
	Mar 20-24	**Final Exam**

MRI Research

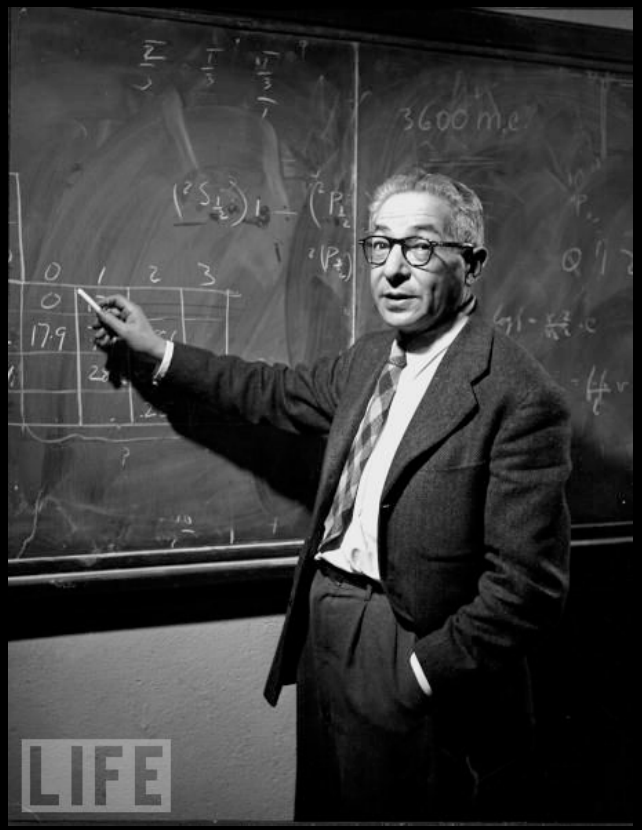


A Brief History of MRI

Detection of the Signal

1944 Nobel Prize in Physics

"for his resonance method for recording the magnetic properties of atomic nuclei"

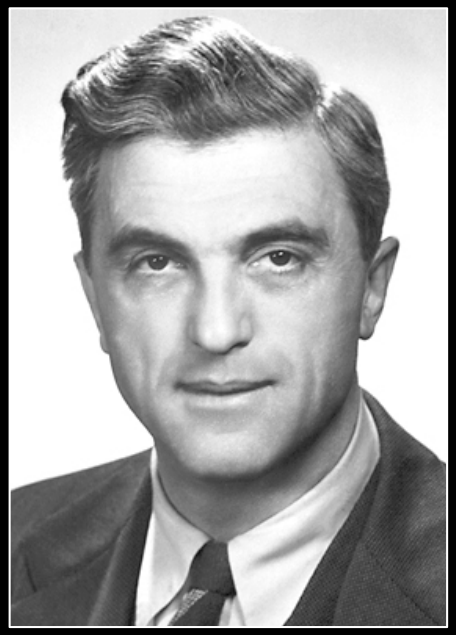


Discovery of NMR

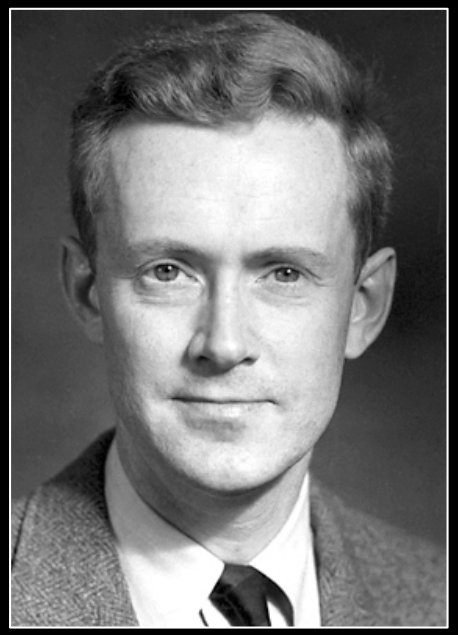
Isidor Isaac Rabi
b. 22 Jul 1898
d. 11 Jan 1988

1952 Nobel Prize in Physics

"for their development of new methods for nuclear magnetic precision measurements and discoveries in connection therewith"



Felix Bloch
b. 23 Oct 1905
d. 10 Sep 1983



Edward Purcell
b. 30 Sep 1912
d. 07 Mar 1997

Improved NMR Detection

1991 Nobel Prize in Chemistry

"for his contributions to the development of the methodology of high resolution nuclear magnetic resonance (NMR) spectroscopy"

Richard Ernst
b. 14 Aug 1933
d. 4 June 2021

Magnetic Resonance Imaging

2003 Nobel Prize in Medicine

"for their discoveries concerning magnetic resonance imaging"

Paul C. Lauterbur
b. 1929.05.06
d. 2007.03.27

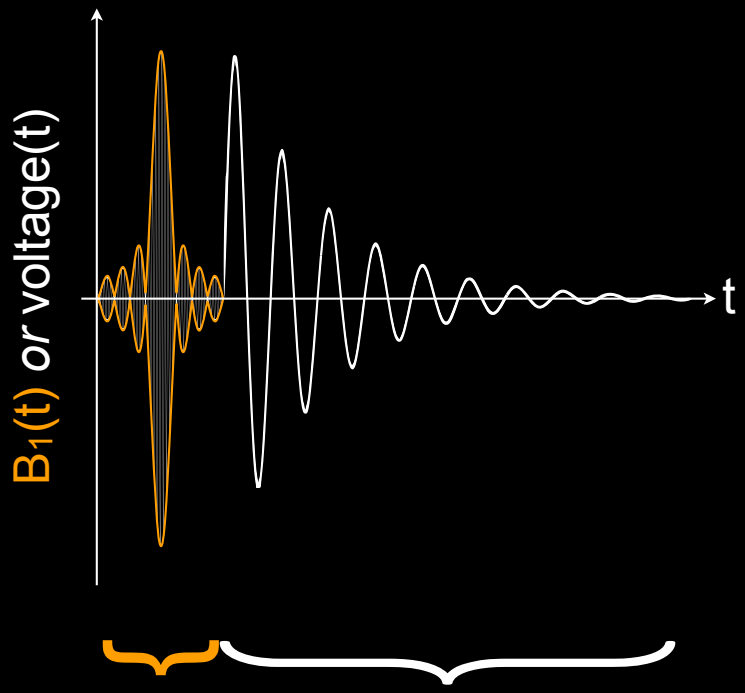
Peter Mansfield
b. 1933.10.09
d. 2017.02.08

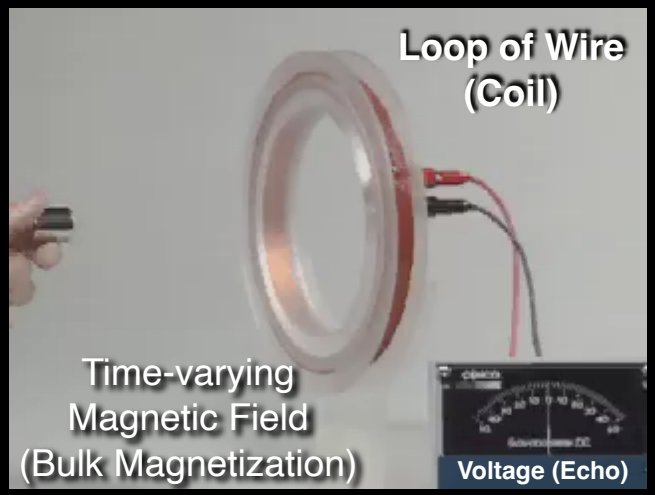
What is MRI?

- Magnetic
  - We need a big magnet
- Resonance
  - Excitation energy has to be on-resonance
- Imaging
  - We can make pretty pictures

What is MRI?

MRI follows a classic excitation-reception paradigm.





Faraday's Law of Induction

MRI encodes spatial information and image contrast in the echo.

Requirements for MRI

- NMR Active Nuclei
  - e.g. ^{1}H in H_20
- Magnetic Field (B_0): Polarizer
- RF System (B_1): Exciter
- Coil: Receiver
- Gradients (G_X, G_Y, G_Z): Spatial Encoding

MRI Hardware

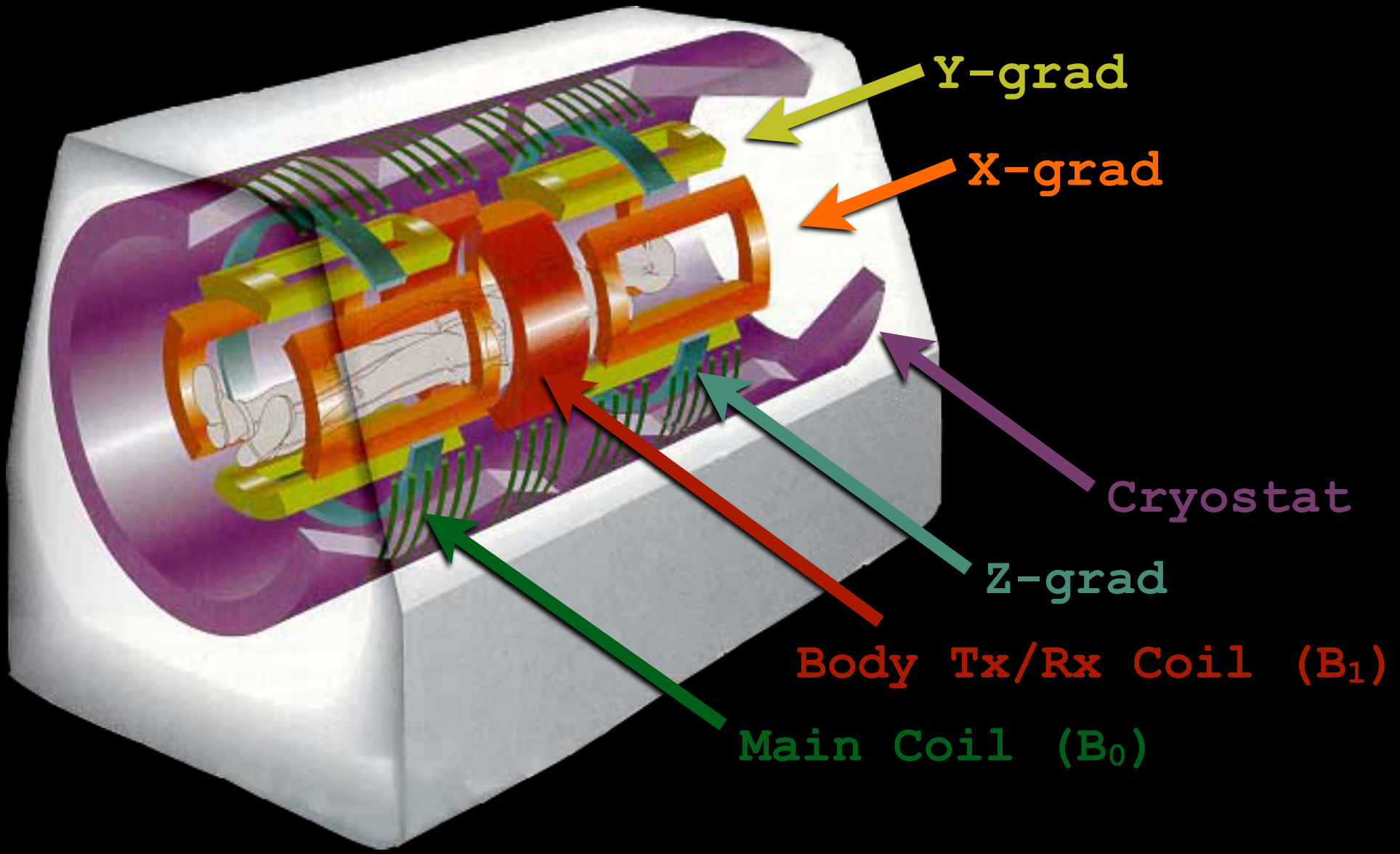


Image Adapted From: http://www.ee.duke.edu/~jshorey

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Questions?

- Related courses of interest
  - M229 Advanced Topics in MRI (https://mrrl.ucla.edu/pages/m229)
  - PBM 222 MR Spectroscopy
  - PBM 225 MR Contrast Mechanisms

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