Introduction

M219 - Principles and Applications of MRI

Kyung Sung, Ph.D.

1/6/2025

UCLA

Department of Radiological Sciences
David Geffen School of Medicine at UCLA

Introduction

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

- Your department
- Research lab (if you have)
- Years at UCLA
- Hometown
- Your favorite restaurant in LA

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

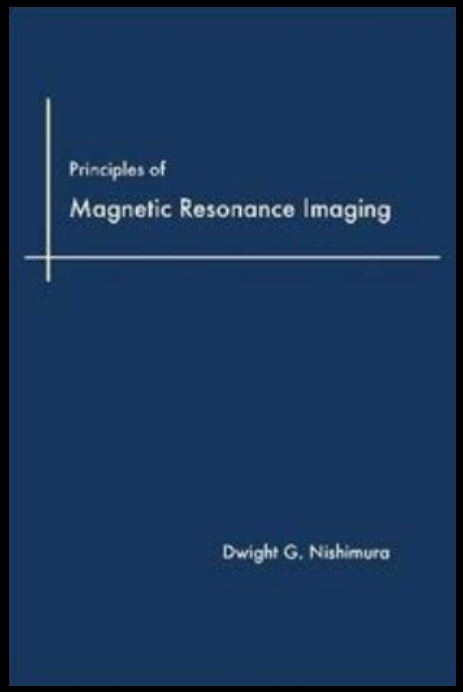
Learning Objectives

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

Prerequisites

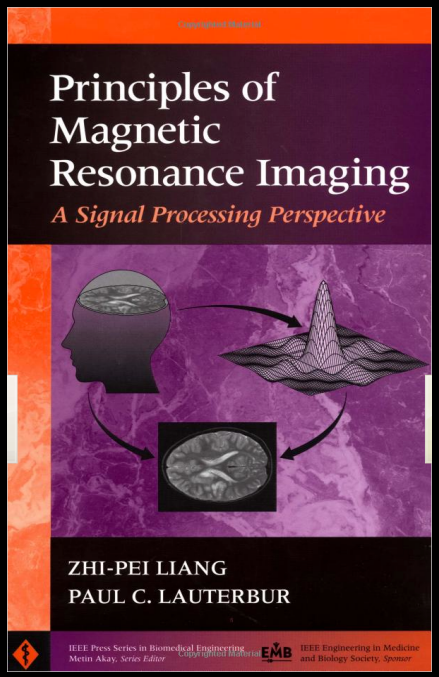
- Vectors and Vector Operations
  - dot product
  - cross product
- Basic Matrix Algebra
  - Determinant
  - Inverse
  - Transpose
  - Matrix Multiplication
  - Eigenvectors

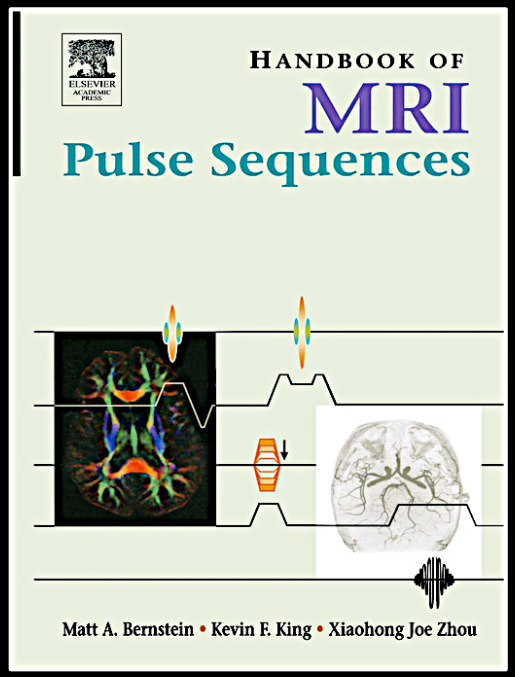
Primary Books



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

Supplementary Books

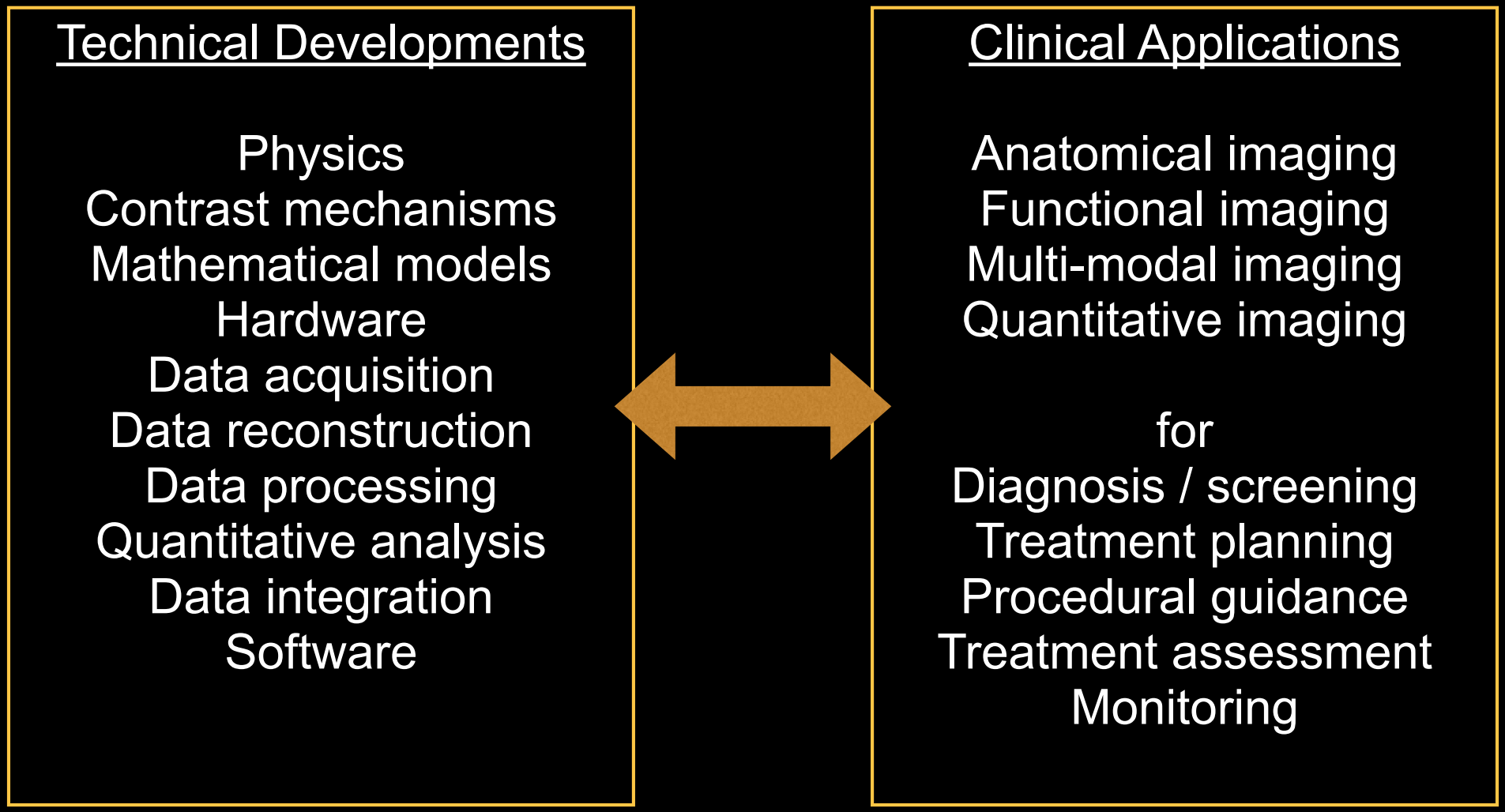




Course Schedule:

Lecture	Date	Topic
#1	Jan 6, 2025	Introduction
#2	Jan 8, 2025	MRI Systems I: B0 and Bulk Magnetization
#3	Jan 13, 2025	MRI Systems II: Nuclear Precession and B1
	Homework #1 out	
#4	Jan 15, 2025	Bloch Equations and Relaxation I
#5	Jan 20, 2025	MLK Holiday
#6	Jan 22, 2025	Bloch Equations and Relaxation II
#7	Jan 27, 2025	MRI Systems III: Gradients
#8	Jan 29, 2025	Imaging Principles
	Homework #1 due, Homework #2 out	
#9	Feb 3, 2025	Spatial Localization I
#10	Feb 5, 2025	Spatial Localization II
#11	Feb 10, 2025	MRI Signal Equation and Basic Image Reconstruction (by Dr. Wu)
#12	Feb 12, 2025	Fast Imaging and Advanced Image Reconstruction (by Dr. Wu)
	Homework #2 due, Homework #3 out	
#13	Feb 17, 2025	Presidents' Day Holiday
#14	Feb 19, 2025	Imaging Sequences I
#15	Feb 24, 2025	Imaging Sequences II
#16	Feb 26, 2025	Imaging Sequences III
#17	Mar 3, 2025	Volumetric Imaging (by Dr. Zhong)
#18	Mar 5, 2025	Fast Imaging (by Dr. Christodoulou)
	Homework #3 due	
#19	Mar 10, 2025	Basics of MR Spectroscopy (by Dr. Thomas)
#20	Mar 12, 2025	Fast MR Spectroscopic Imaging (by Dr. Thomas)
	Mar 17-21	**Final Exam**

MRI Research

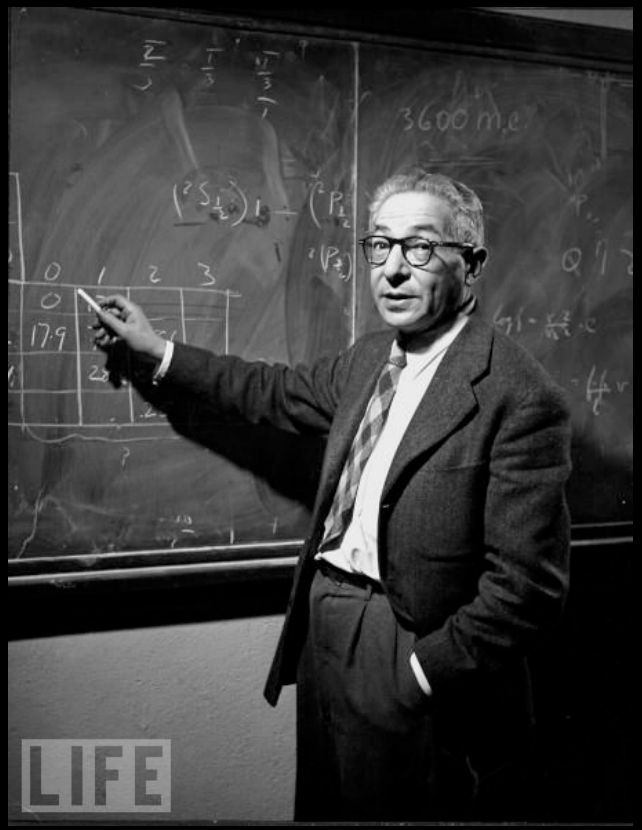


A Brief History of MRI

Detection of the Signal

1944 Nobel Prize in Physics

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

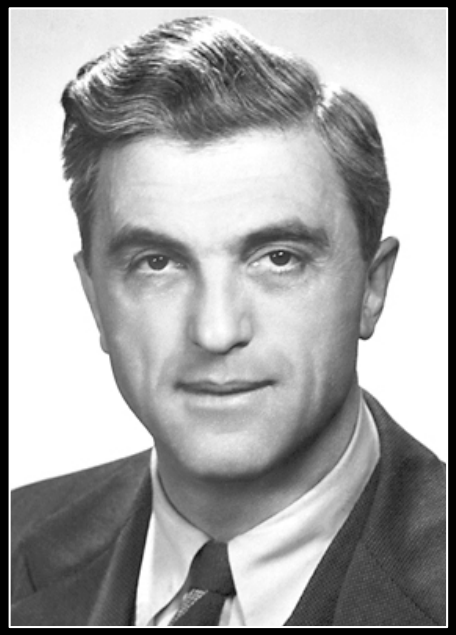


Discovery of NMR

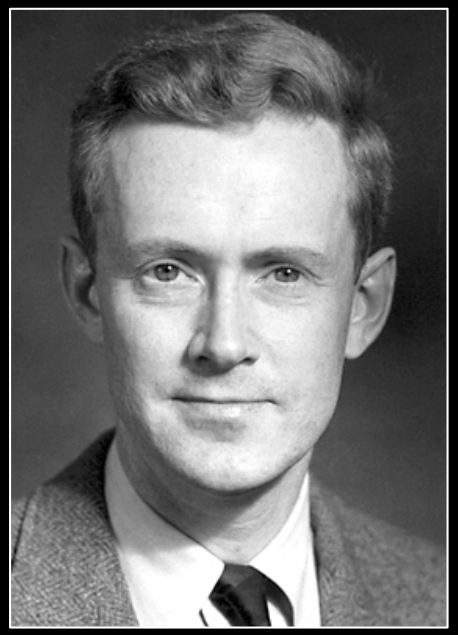
Isidor Isaac Rabi
b. 22 Jul 1898
d. 11 Jan 1988

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

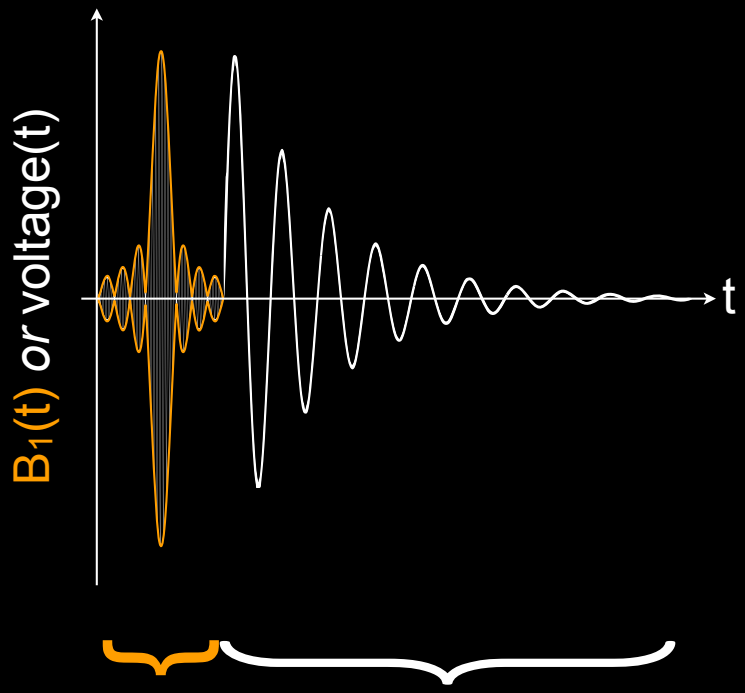
Peter Mansfield
b. 1933.10.09
d. 2017.02.08

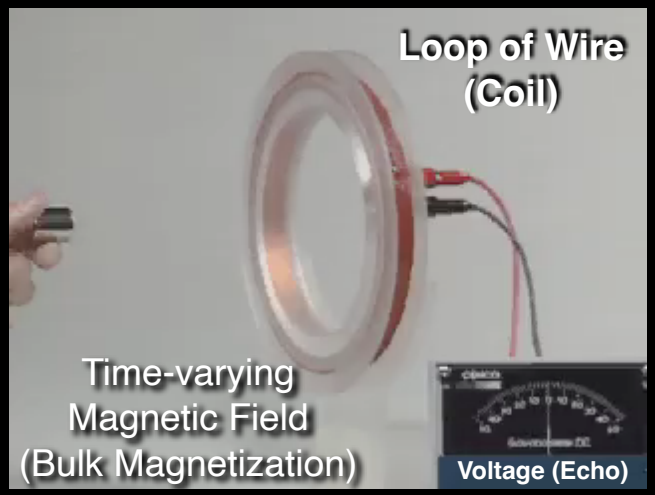
What is MRI?

- 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

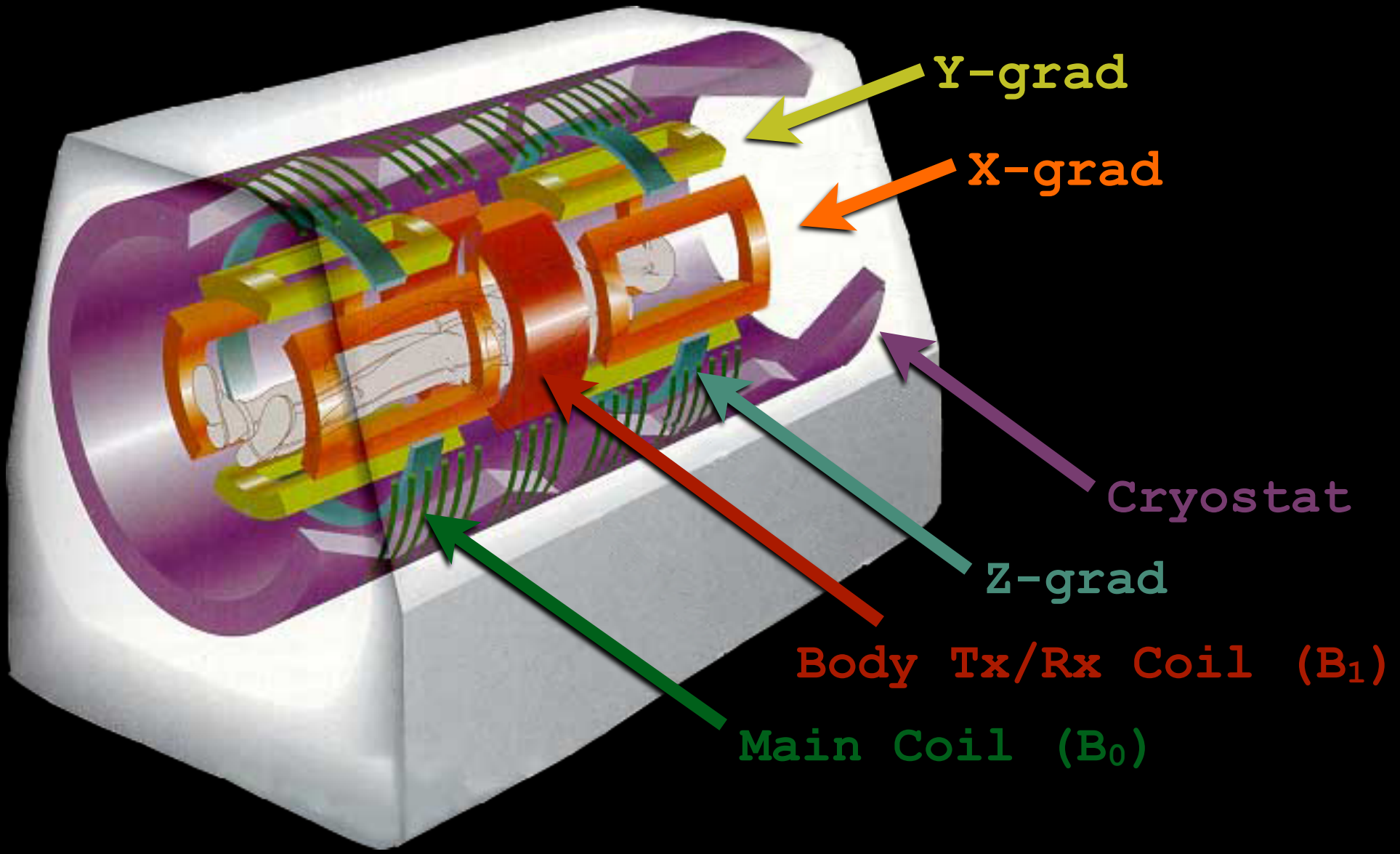


Image Adapted From: http://www.ee.duke.edu/~jshorey

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Questions?

- Related reading materials
  - Nishimura Chap 2

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