22485 Medical imaging systems

Magnetic Resonance Imaging V

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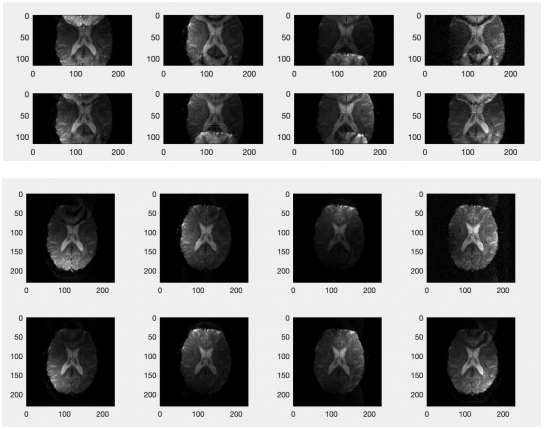
Module E2, Monday kl. 13.00 - 14.30 **in building 349, room 205**
and Thursday kl. 9.00 - 11.00, in building 349, room 205

The movie shows cornflakes in a bowl of water.

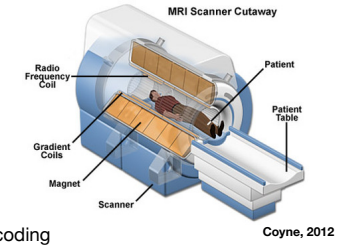
Cornflakes contain supplemental iron and move in the strong magnetic field.

Exercise recap



Overall MRI topics

- The basic hardware components of an MRI system
- Nuclear spins and precession
- RF-pulses (B1-field), magnetic resonance and relaxation
- Signal preparation, sequences and contrast mechanisms
- Magnetic field gradients, slice selection, and phase and frequency encoding
- The k-space and image reconstruction
- Image reconstruction (exercise)
- Advanced and emerging MRI methods and applications
- MRI safety

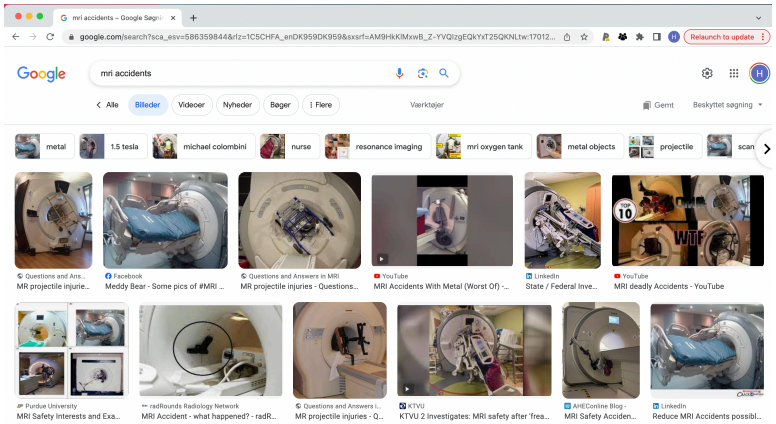


Coyne, 2012

Today’s Intended Learning Objectives

- Identify main hardware components of an MRI scanner and their role (B0-field, RF Transmit(B1)/Recieve coils, Gradient coils).
- Describe the basic properties of nuclear spins in a magnetic field (B0-field).
- Describe the interaction between radio waves (RF, B1-field) and an ensemble of nuclear spins.
- Distinguish between longitudinal (T1) and transverse (T2,T2’,T2*) relaxation processes and how it relates to the MR-signal.
- Explain strategies for providing signals that are T1- or T2-weighted.
- Understand the role of the gradient system and how it relates to slice selection, frequency and phase encoding.
- Explain dephasing mechanisms resulting in the T2* relaxation and how the T2 relaxation is isolated with the spin echo effect.
- Explain strategies for collecting k-space data and how to reconstruct the image from it.
- Relate to safety issues for people in and around MRI scanners.

MRI Safety



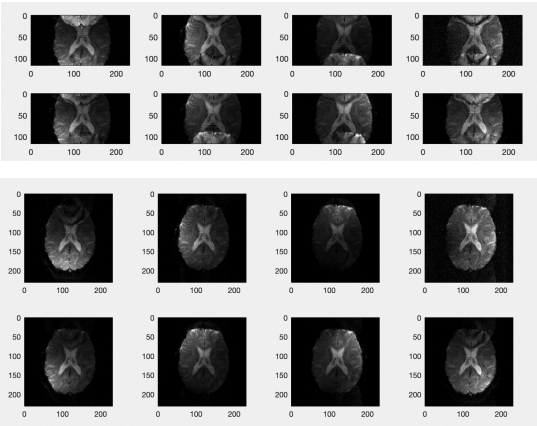
MRI Safety

- Static B0-field - Strong forces
- RF transmit B1-field - Tissue heating (SAR)
- Gradient system - Peripheral nerve stimulation

Advanced methods, applications and trends

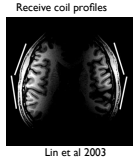
Parallell imaging approaches

- Speed up acquisitions by partial sampling
- Classical SENSE using prior knowledge to deconvolve folded image to a full image
- Newer methods may use more elaborate undersampling and reconstruction methods.

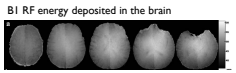


Quantitative imaging

- From weighting to measuring physical properties, such as relaxation times, diffusion, perfusion, flow speed
- Optimally comparable across different scanners
- Resolve biases from imperfect hardware
- Model the physics behind image contrasts

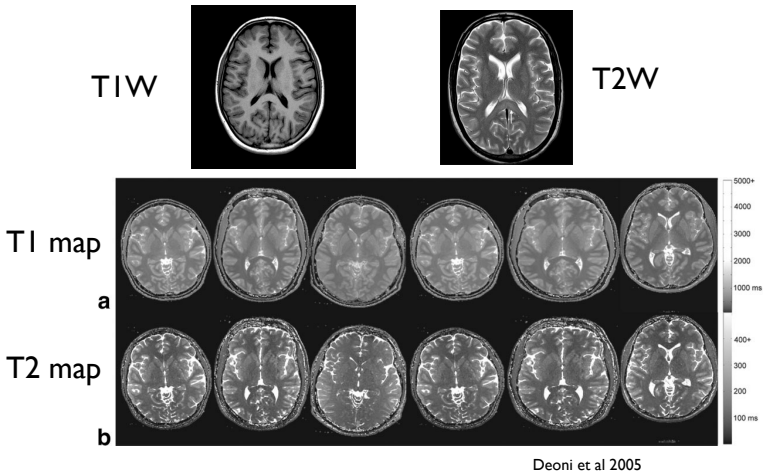


Lin et al 2003



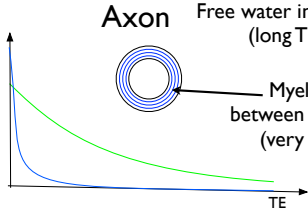
Wang et al 2006

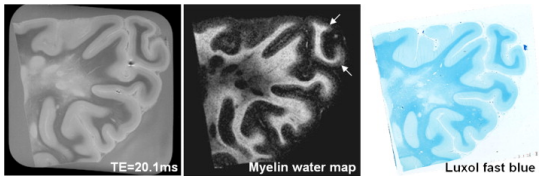
From image weighting to quantitative map



Deoni et al 2005

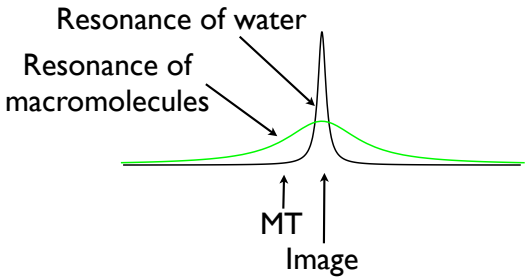
Multi compartment relaxation





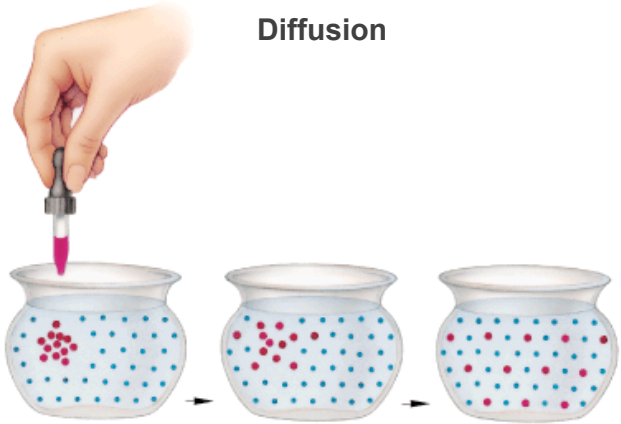
- Myelin water imaging - Laule et al

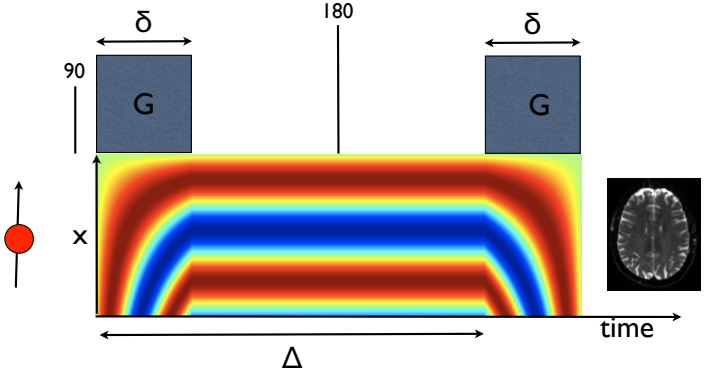
MT - Magnetization transfer



The MT-pulse is deposited in macromolecules and saturates the signal of proximal water

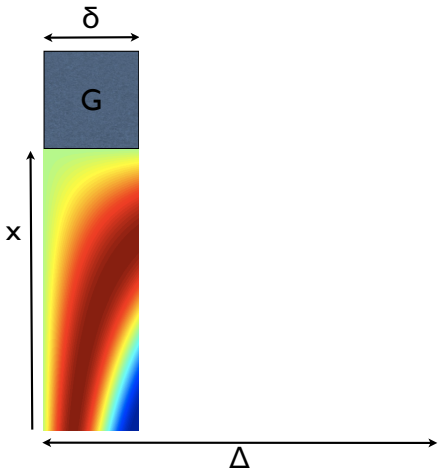
Diffusion



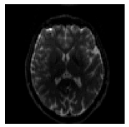


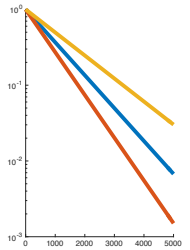
Stejskal and Tanner, J Chem Phys, 1964

Diffusion, spins with different phases (colours) will mix



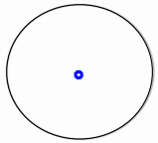
$$S(b) = S(0)e^{-bD}$$



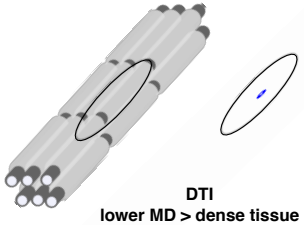


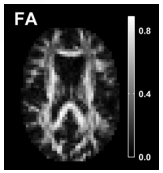
Diffusion - a sensitive marker of tissue density

Free isotropic diffusion (same in all directions)



Hindered and restricted anisotropic diffusion in WM

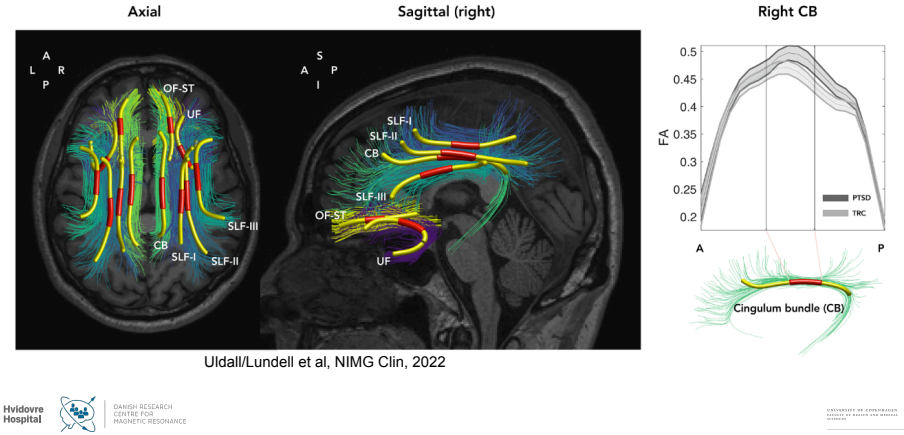




DTI
lower MD > dense tissue
high FA > aligned and tubular restrictions
direction reflect axonal direction

Hahn, 1954
Stejskal and Tanner, 1965
le Bihan et al 1985
Basser et al 1994

Diffusion - versatile but unspecific



Uldall/Lundell et al, NIMG Clin, 2022

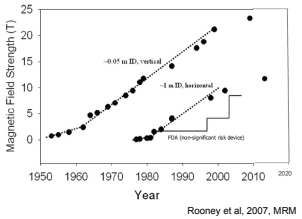
Hvidovre Hospital

DANISH RESEARCH CENTRE FOR MAGNETIC RESONANCE

Ultra-high field

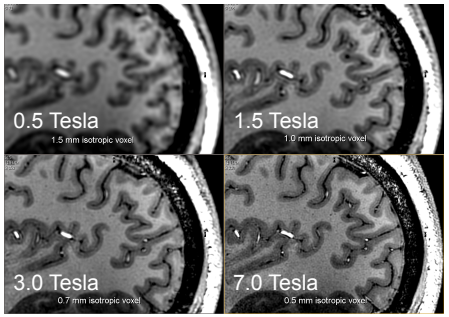
Why 7T

- More signal
- Different relaxation properties
- Higher spectral resolution



Rooney et al, 2007, MRM

T1W images with the same acquisition time



Courtesy: Fredy Visser, UMC Utrecht

High resolution at 7T

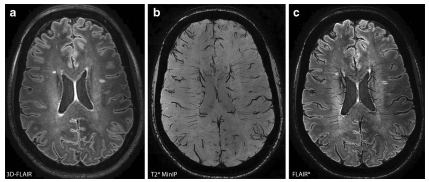
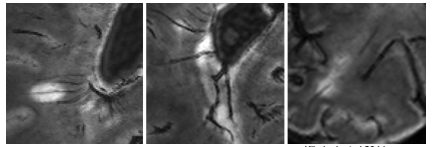


Fig. 1 **a** Axial FLAIR and **b** axial T2* MinIP images combined into **c** axial FLAIR* images at 7-T MRI, in an MS patient

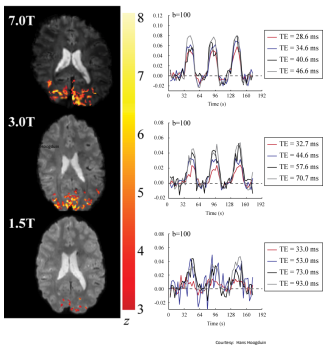


Axial 7-T FLAIR* images of MS patients showing MS lesions with central vessel

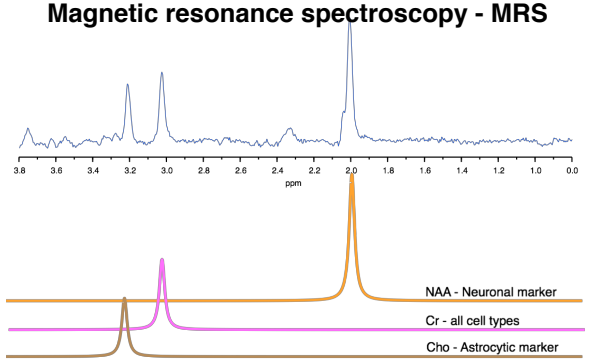
Kilsdonk et al 2014

Functional MRI t2*

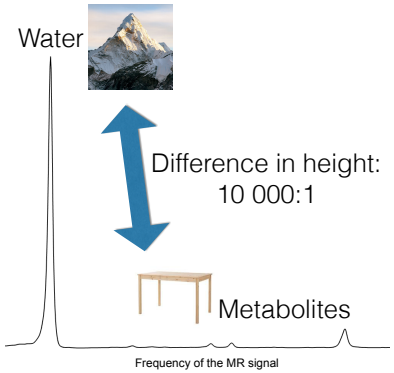
- BOLD (blood oxygenation level dependent contrast) utilise the different magnetic properties of haemoglobin in oxygenated and deoxygenated.
- Fast imaging is done during different tasks and regions with activation is detected through statistical analysis.
- t2* effects are enhanced at higher fields.



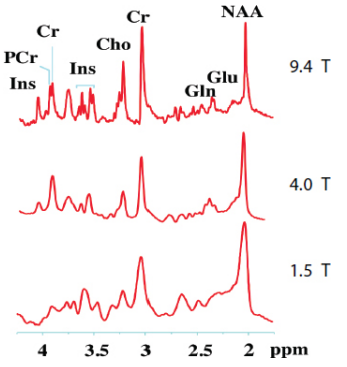
Magnetic resonance spectroscopy - MRS



Lundell/DRCMR



SNR and spectral resolution



Gruetter et al MRM

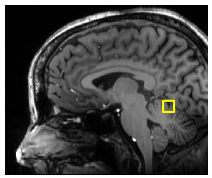
Henrik Lundell

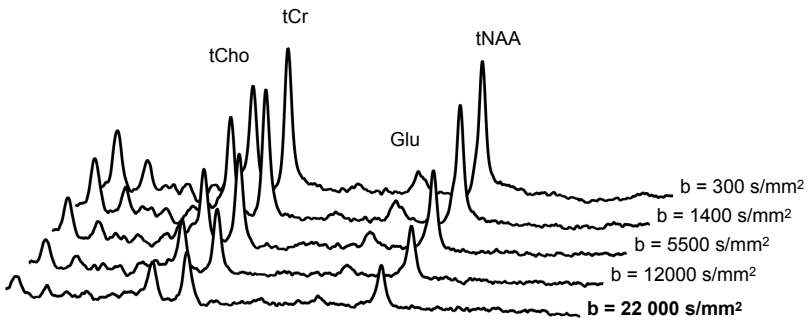
Combining diffusion and 1H-MRS - DWS

+ Specific to intra-intracellular space in contrast to water DWI

+ Specific to cell types, infer cell specific morphologies

+ Separate multiple components of a metabolite





7T Data: Lundell/DRCMR

The other end - ultra low field ~50 μT

MAGNETIC RESONANCE IN MEDICINE 15, 386–391 (1990)

NMR Imaging in the Earth's Magnetic Field

J. STEPIŠNIK, V. ERŽEN, AND M. KOS

University E. Kardelj, Physics Department and J. Stefan Institute, 61000 Ljubljana, Jadranska 19, Yugoslavia

Received March 2, 1989; revised October 12, 1989

The most important and very expensive part of a magnetic resonance imaging set-up is the magnet, which is capable of generating a constant and highly homogeneous magnetic field. Here a new MR imaging technique without the magnet is introduced. This technique uses the earth's magnetic field instead of a magnetic field created by a magnet. This new method has not yet reached the stage of medical application, but the first images obtained by MRIE (magnetic resonance imaging in the earth's field) show that the resolution is close to that expected based on sensitivity estimations.

Stepisnik et al 1990

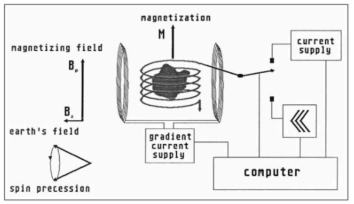
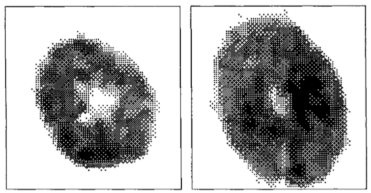


FIG. 1. NMR imaging in the earth's field—the scheme of experimental setup.

Pear and apple imaged while growing in nature



Contra trend - ultra low field

- Low cost
- Safer
- Potentially very different acquisition techniques, hardware design and contrasts possible

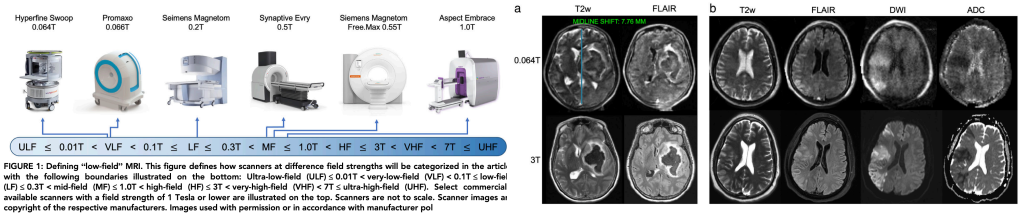


FIGURE 1: Defining "low-field" MRI. This figure defines how scanners at difference field strengths will be categorized in the articl with the following boundaries illustrated on the bottom: Ultra-low-field (ULF) ≤ 0.01T < very-low-field (VLF) < 0.1T ≤ low-fiel (LF) ≤ 0.3T < mid-field (MF) ≤ 1.0T < high-field (HF) ≤ 3T < very-high-field (VHF) < 7T ≤ ultra-high-field (UHF). Select commercial available scanners with a field strength of 1 Tesla or lower are illustrated on the top. Scanners are not to scale. Scanner images a copyright of the respective manufacturers. Images used with permission or in accordance with manufacturer pol

Arnold et al 2023

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- Explain strategies for collecting k-space data and how to reconstruct the image from it.

MRI Teaching material

- Lecture notes by Lars G. Hanson (47 pages) available in English and Danish. (Links in course plan).
- Chapter 12 and 13 in Prince and Links.
- Matlab exercise on November 27 (Links in course plan)
- Youtube videos on https://www.drcmr.dk/education-material

Simulators
Lars Hanson

- Go to https://www.drcmr.dk/CompassMR/ on laptop or phone
- Go to https://www.drcmr.dk/BlochSimulator/ (best on laptop)

More MRI

22506 - Medical magnetic resonance imaging
English | 5 ECTS | 2023/2024 | Spring F1B (Thurs 13-17)
MSc

22507 - Advanced magnetic resonance imaging
English | 5 ECTS | 2023/2024 | Autumn E2B (Thurs 8-12)
MSc

22610 - Physics in Health Technology
English | 5 ECTS | 2023/2024 | Autumn E2B (Thurs 8-12)
MSc

22611 - Research immersion - Physics in Health Technology, MSc
English | 5 ECTS | 2023/2024 | January
MSc