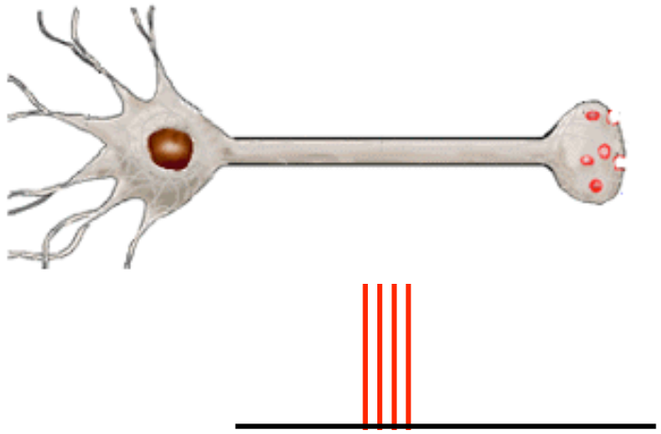
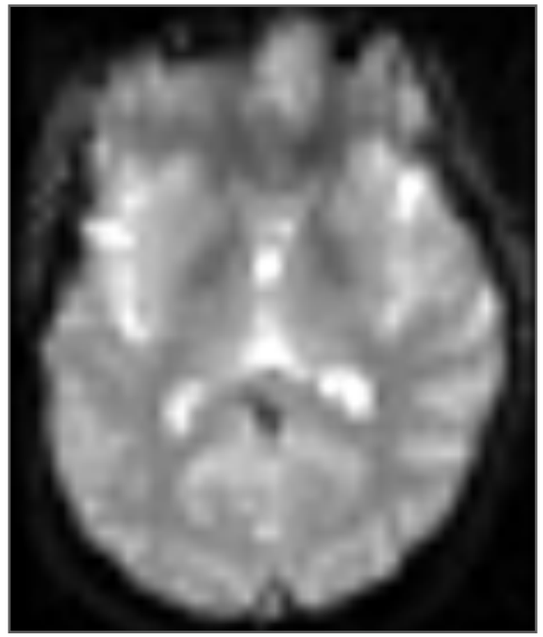
fMRI 101 , Part 1

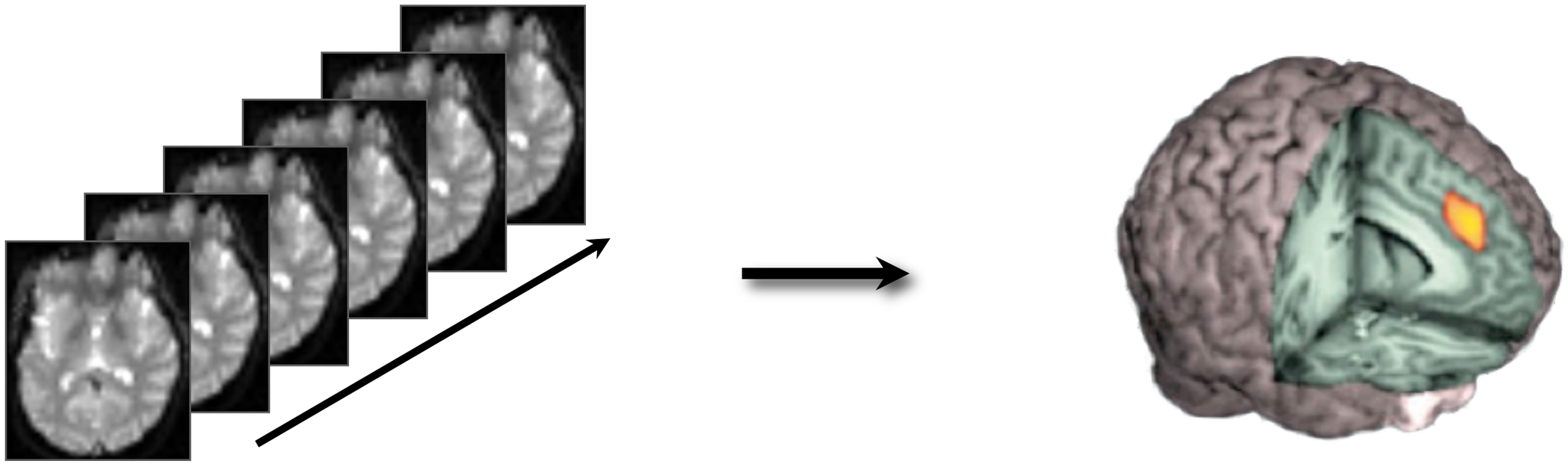
Geoffrey K Aguirre, MD, PhD

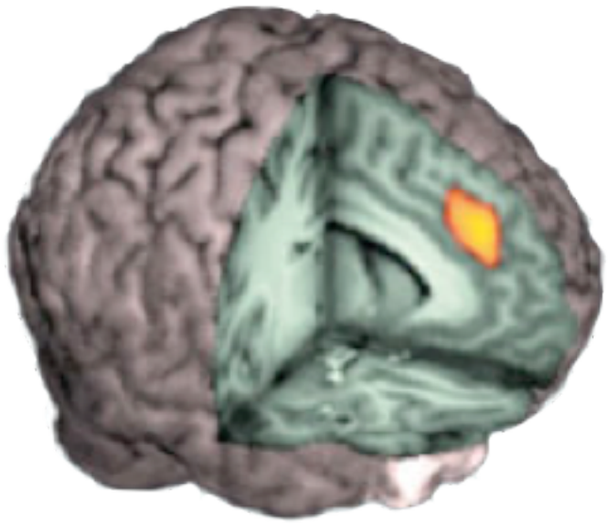
Penn

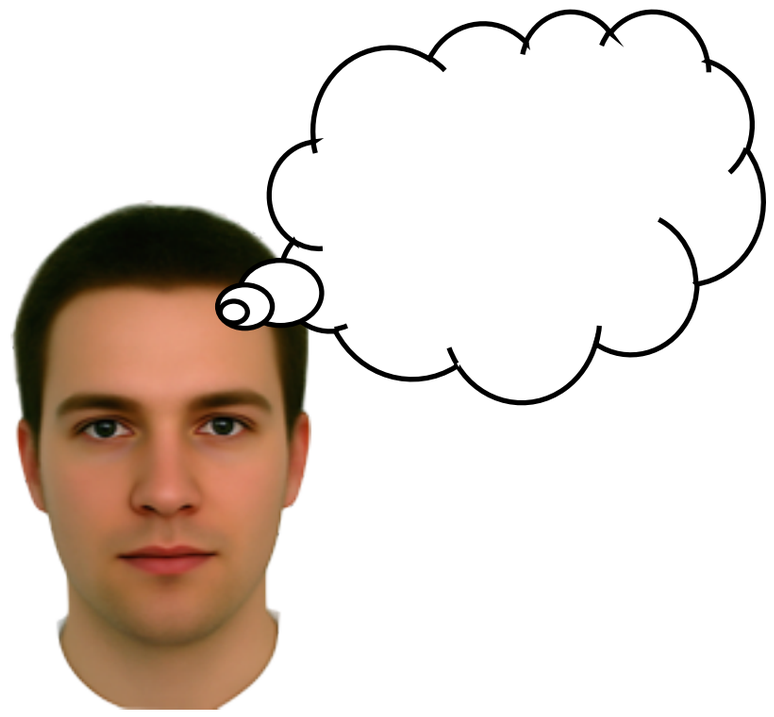
CENTER FOR COGNITIVE NEUROSCIENCE

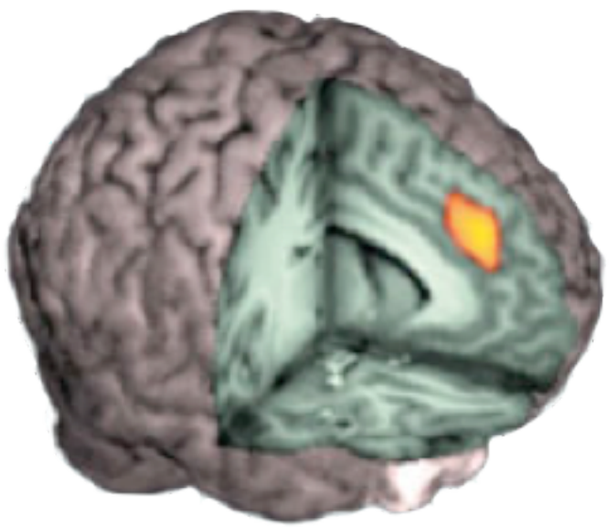




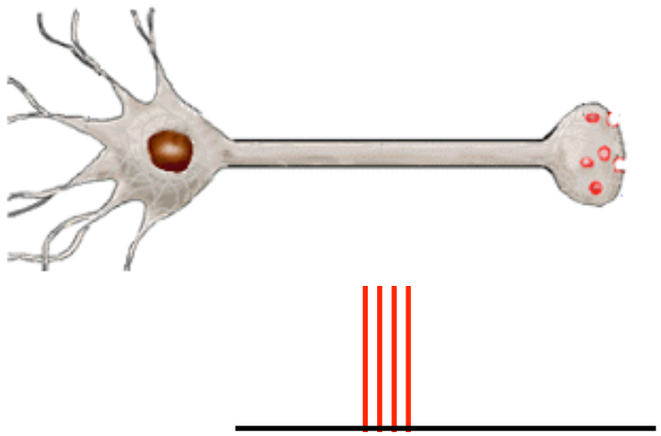






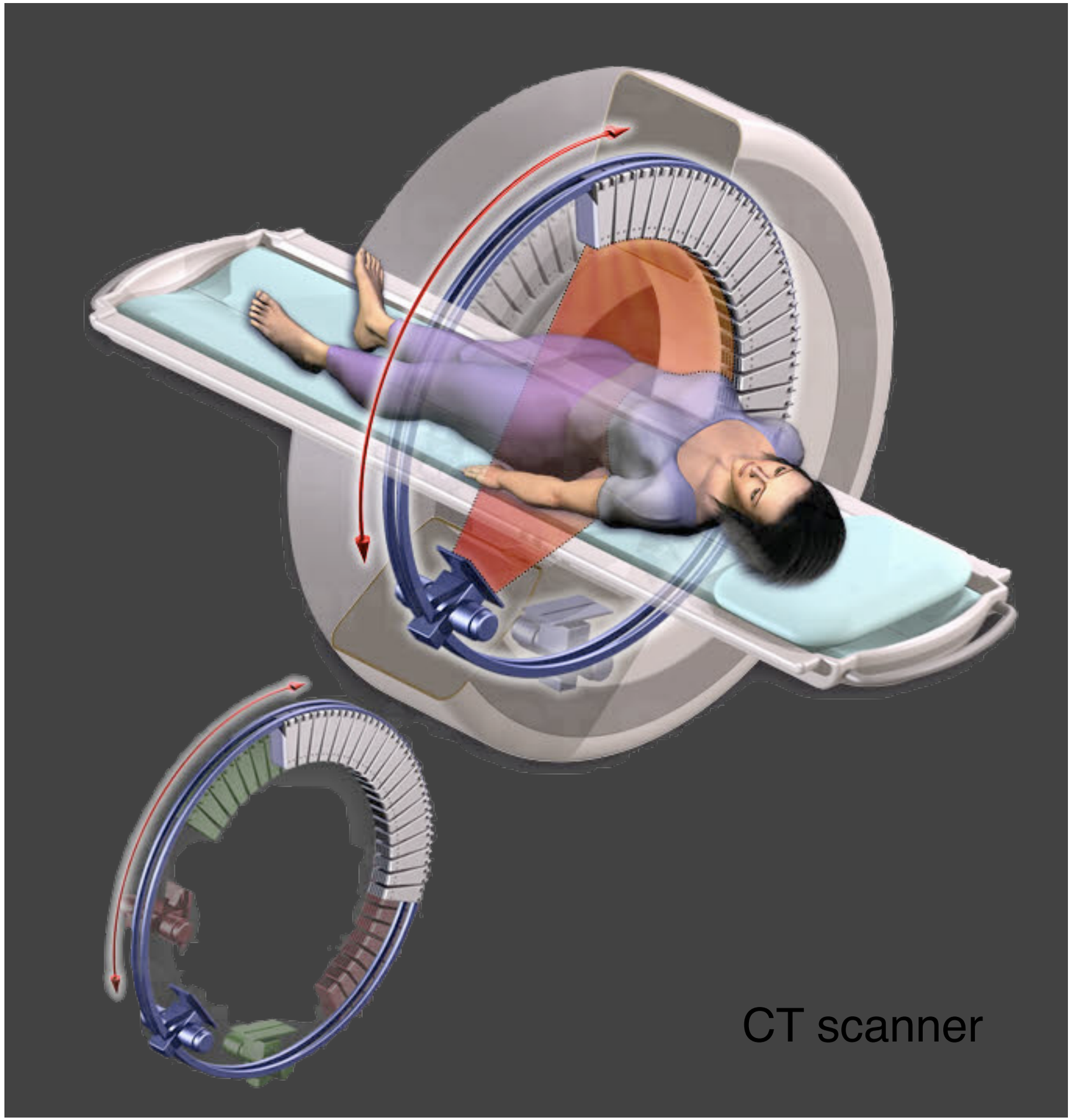


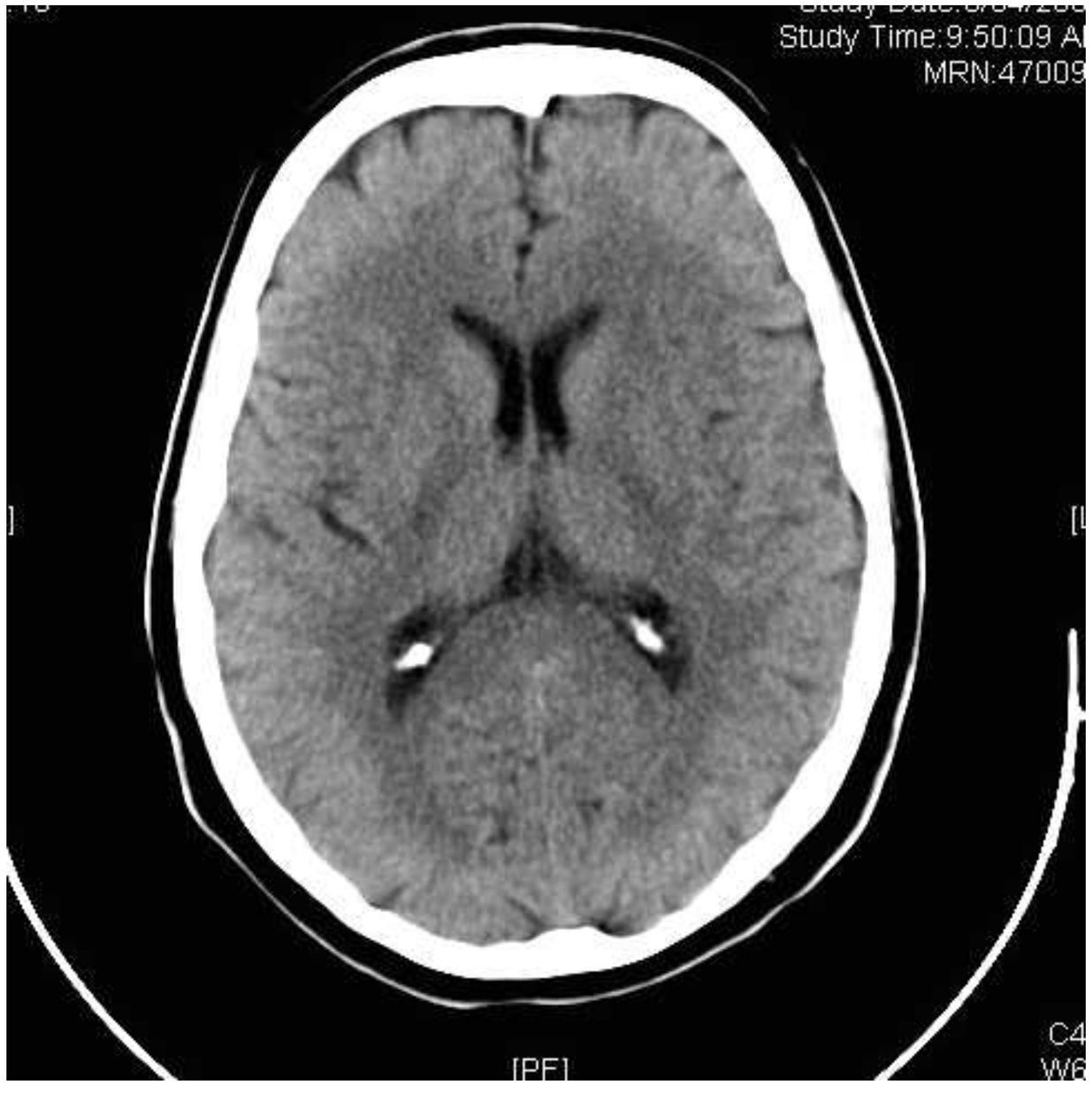

MIND & BODY SPECIAL ISSUE
THE MYSTERY OF CONSCIOUSNESS By Steven Pinker
HOW THE BRAIN REWIRES ITSELF By Sharon Begley
SIX WAYS TO HANDLE STRESS By Christine Gorman
THE NATURE OF MEMORY By Michael D. Lemonick
TIME
SENSATION
movement
vision
behavior
speech
emotion
me
THE BRAIN
A USER'S GUIDE
BUSH'S GONZALES GAMBLE
THE GLOBAL WATER CRISIS
Newsweek
THE NEW WAR ON PAIN
FROM BRAIN SCIENCE TO
BATTLEFIELD MEDICINE
DOCTORS ARE FINDI
INNOVATIVE WAYS
COMBAT SHORT-T
AND CHRONIC
Barack Around The Clock
The Stem-Cell Breakthrough
Holiday Hits And Misses
TIME
What Makes Us Good / Evil



x-ray human head

pneumoencephalography


CT scanner



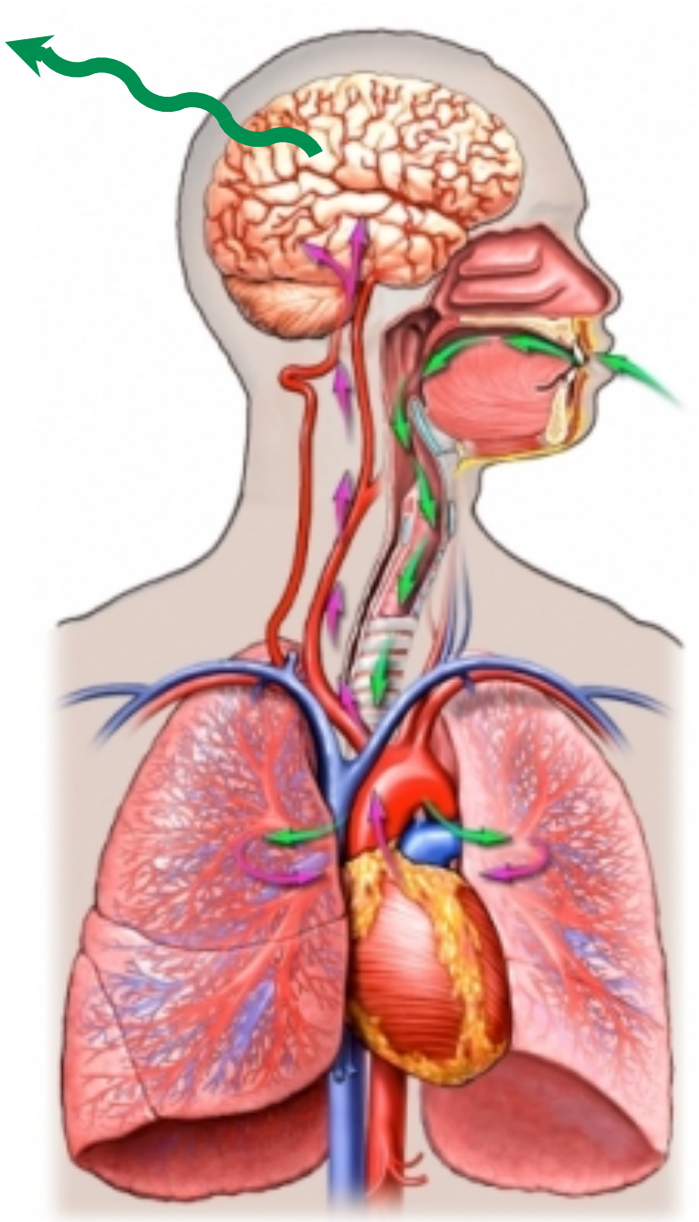
axial CT scan of the brain

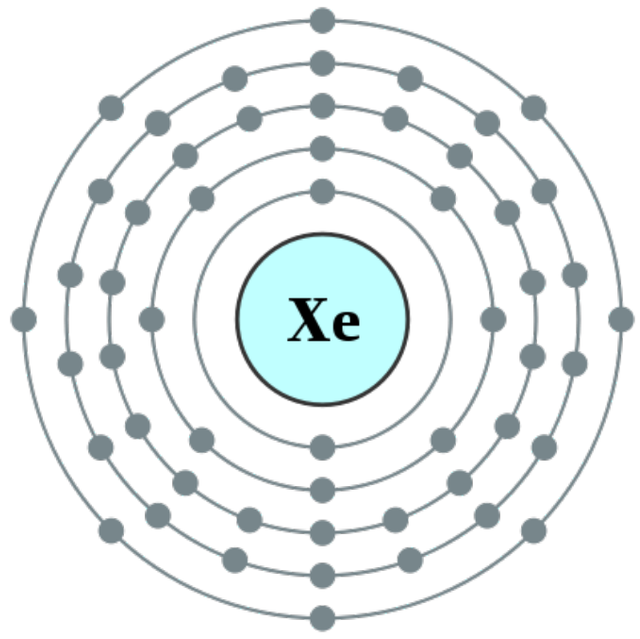
Allan M. Cormack

Godfrey Hounsfield

1979 Nobel Prize in Physiology or Medicine

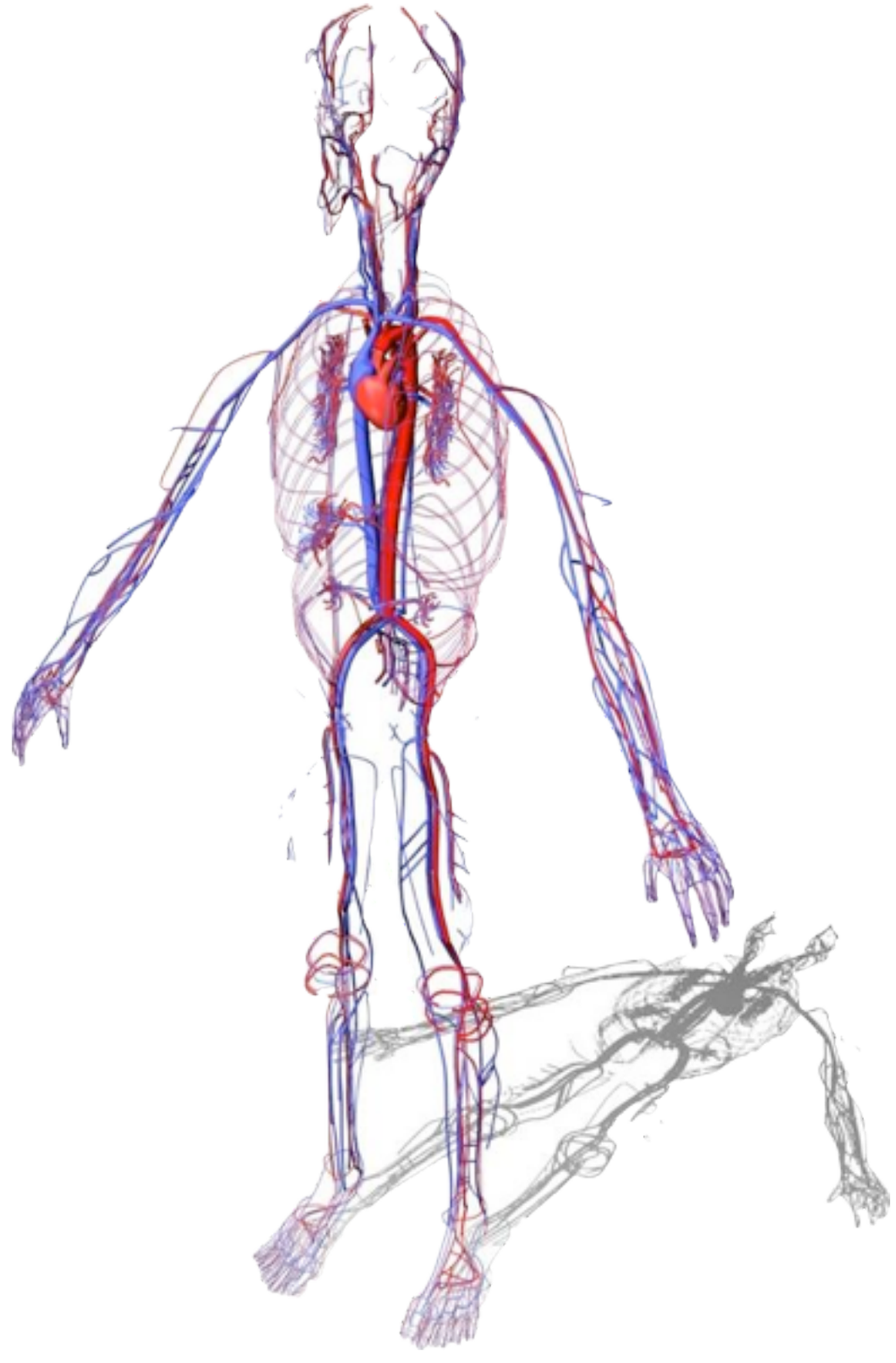
quantify radioactive decay



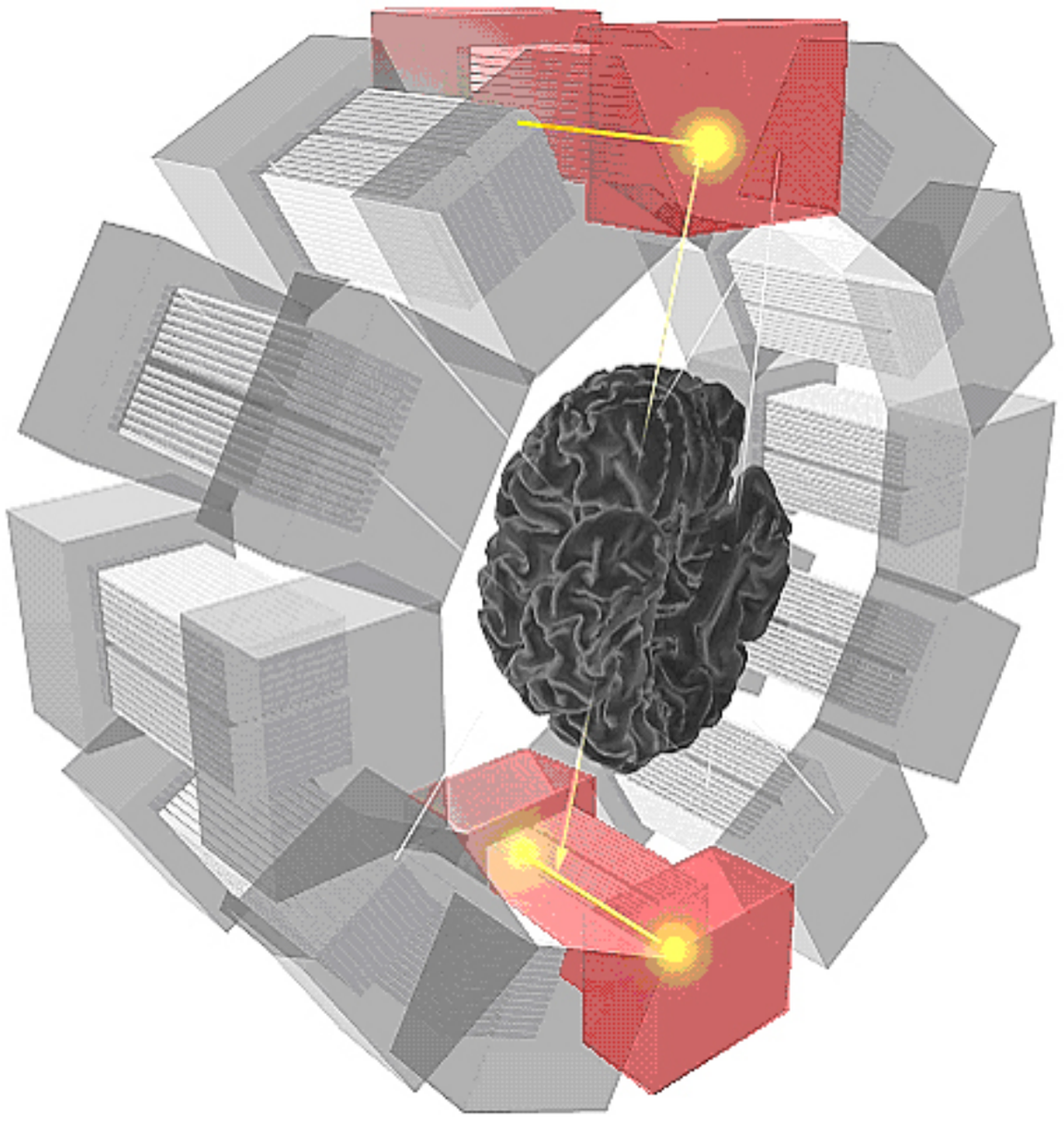


radioactive Xenon gas isotope

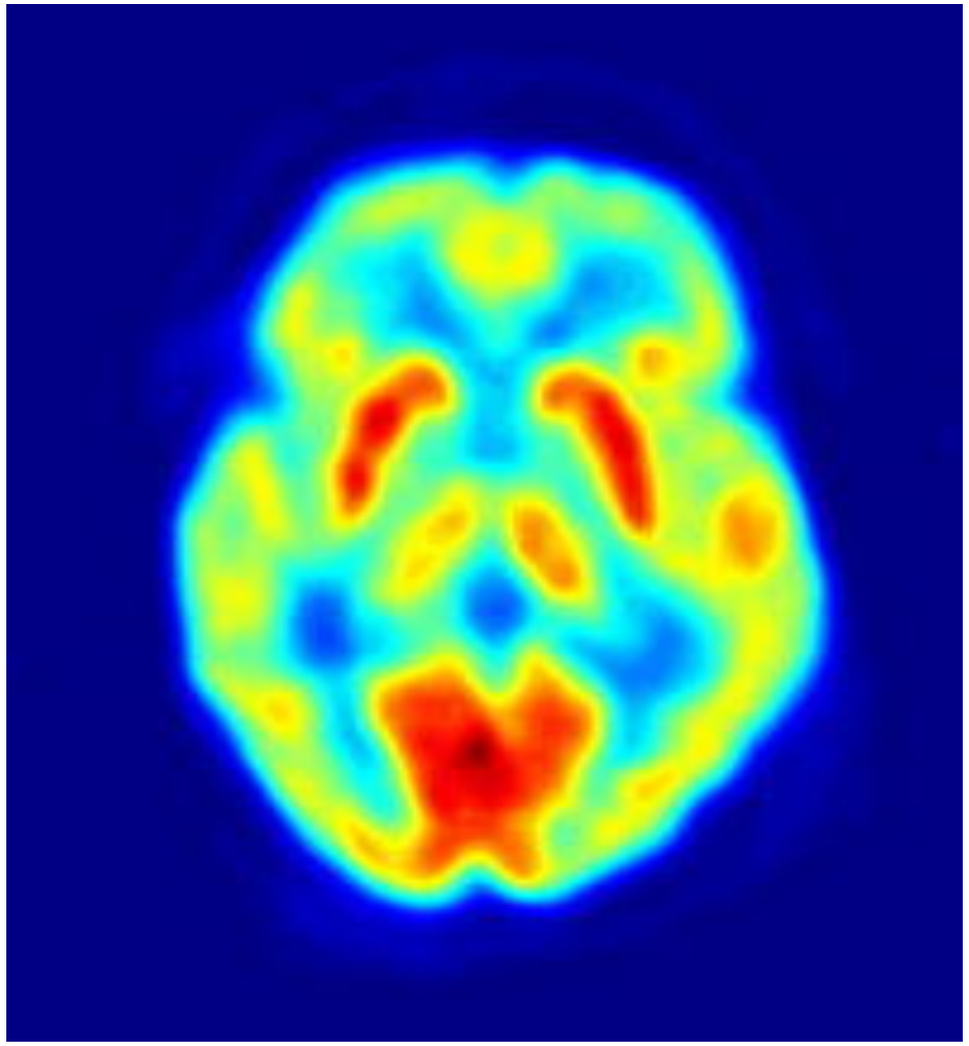
Glass and Harper (1963) measure global cerebral blood flow



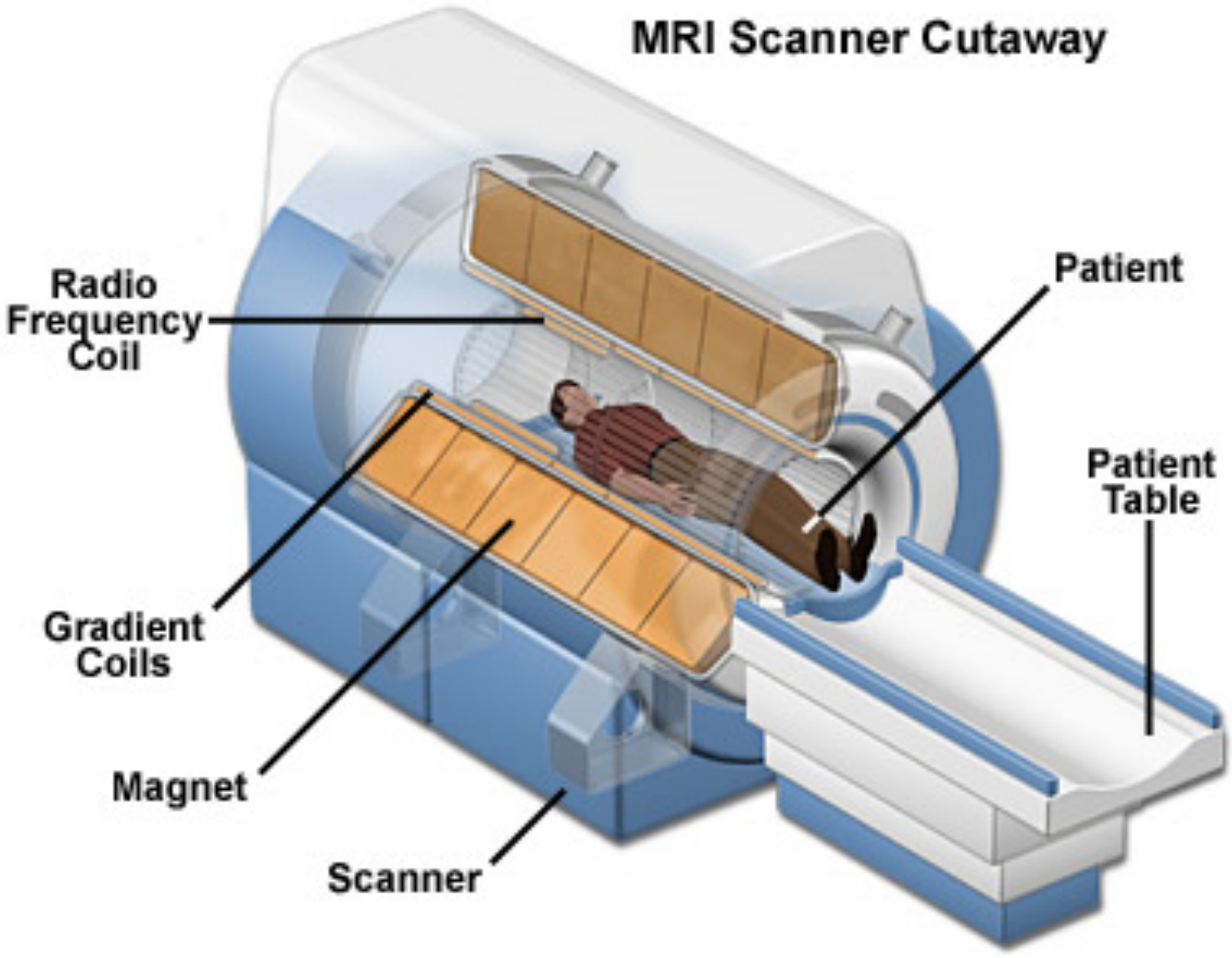
inject radio-labeled sugar or water

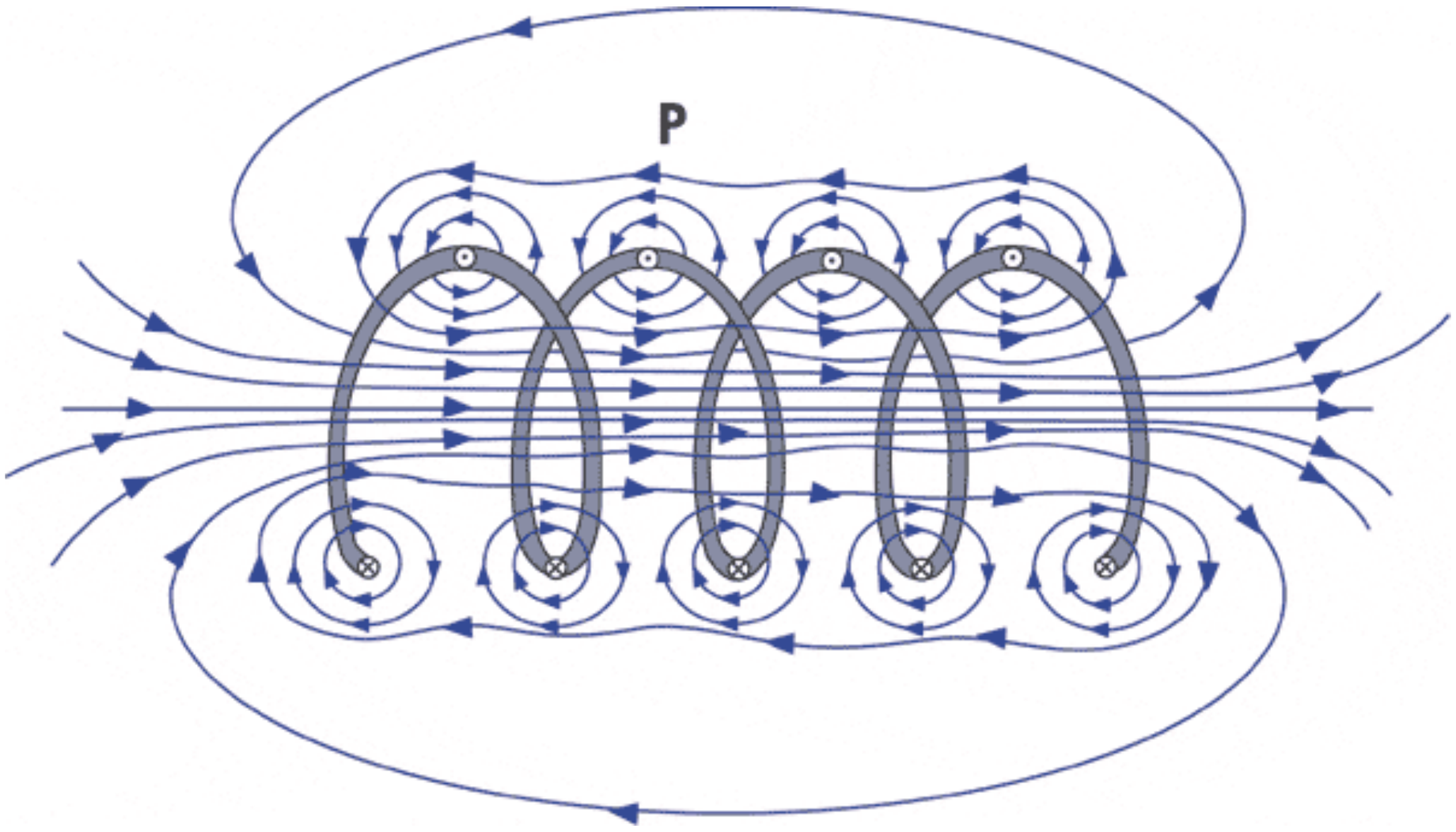


co-incidence detection for positron emission tomography



PET scan of the brain


MRI Scanner Cutaway
Radio Frequency Coil
Patient
Patient Table
Gradient Coils
Magnet
Scanner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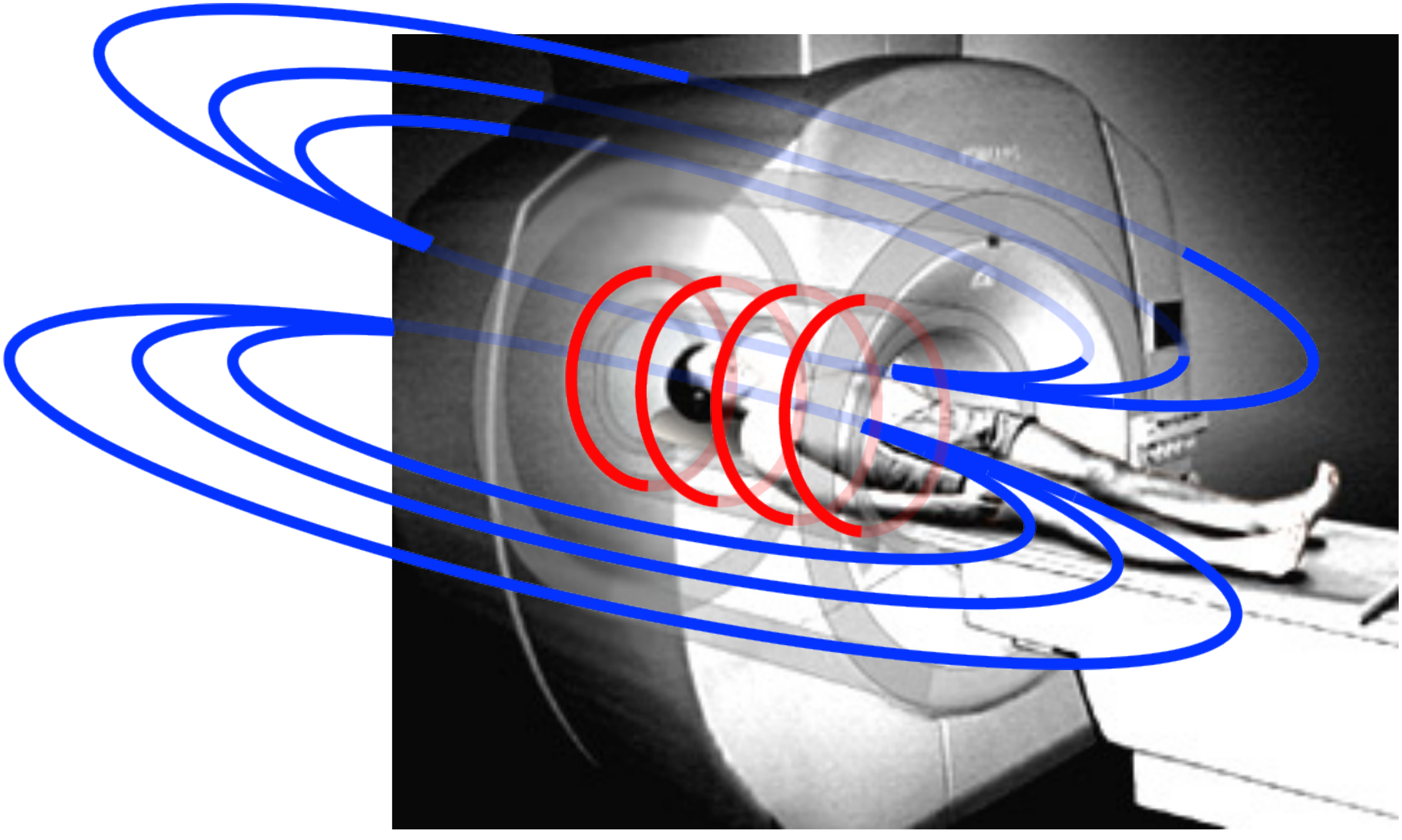
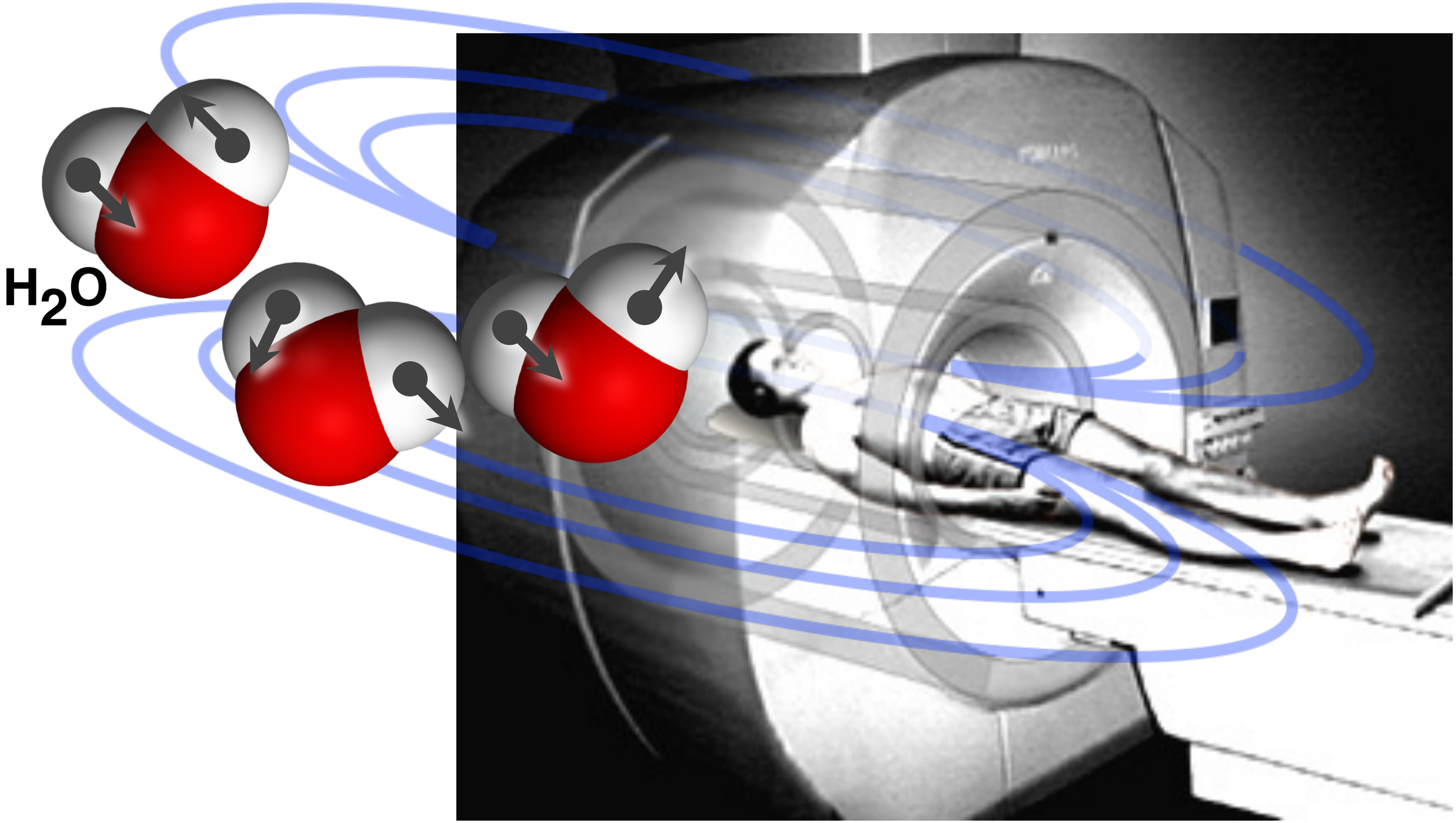
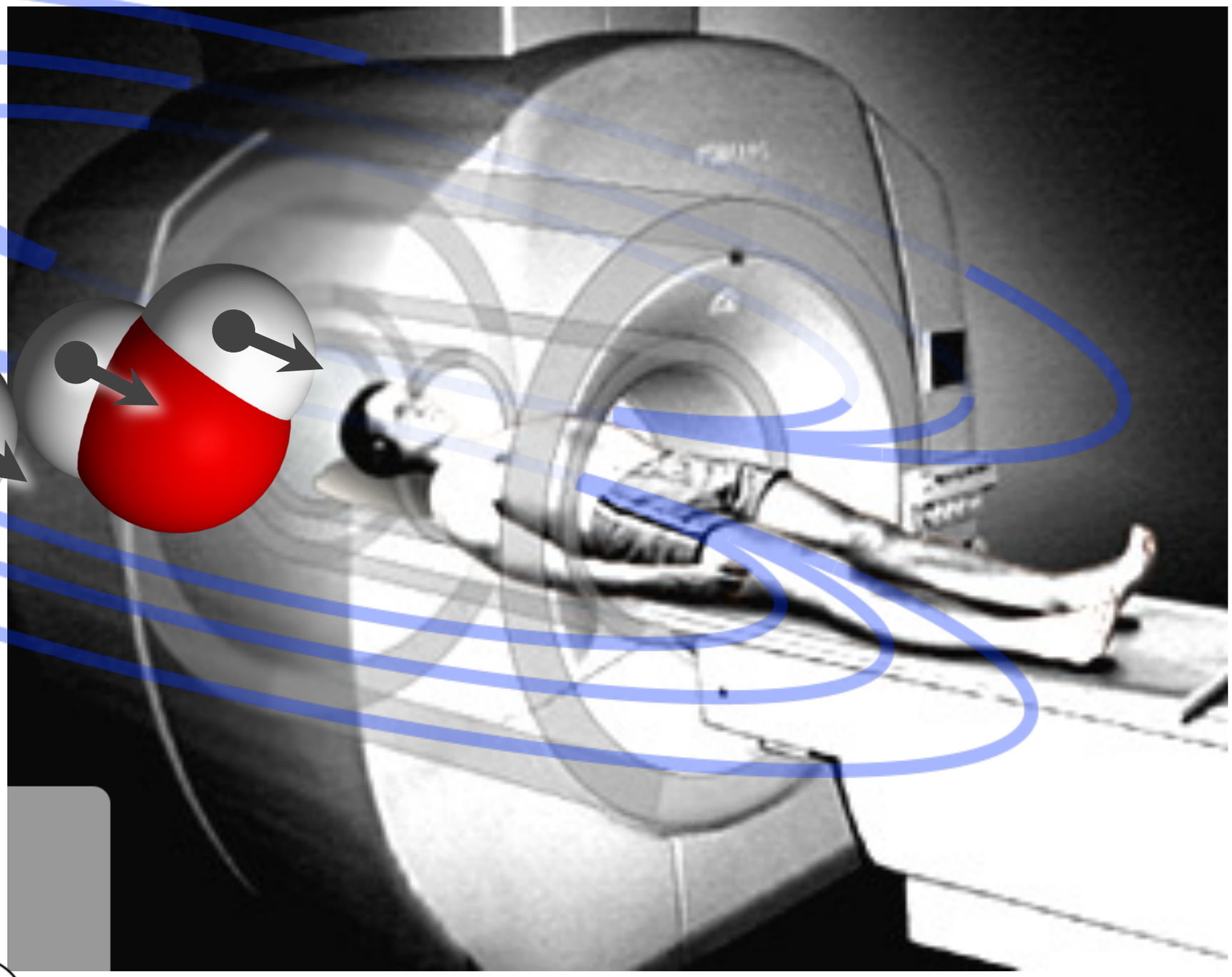
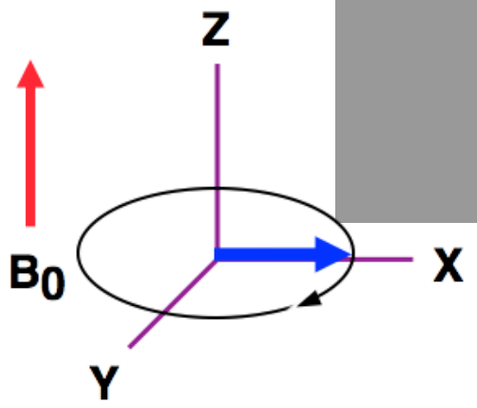
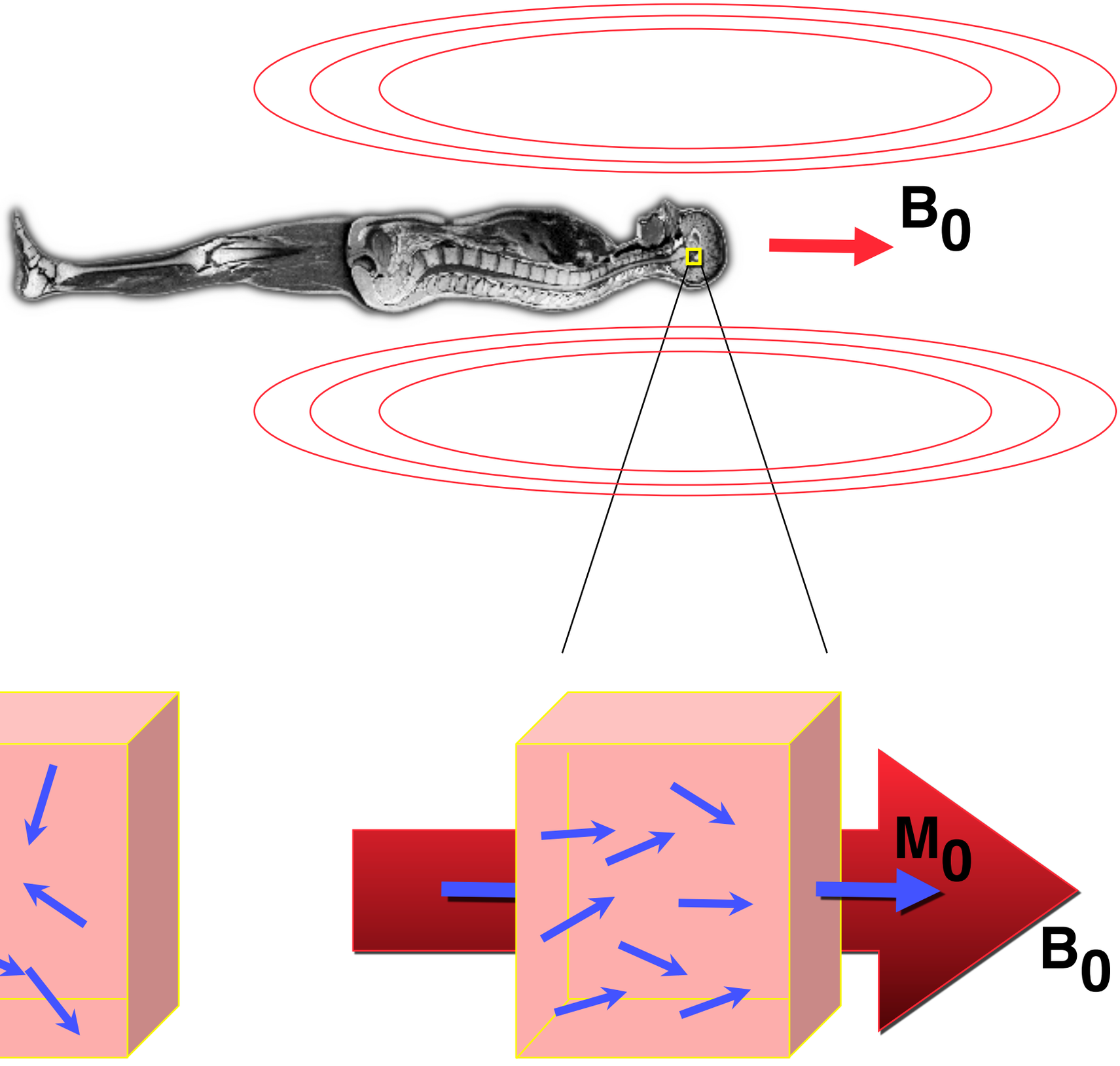


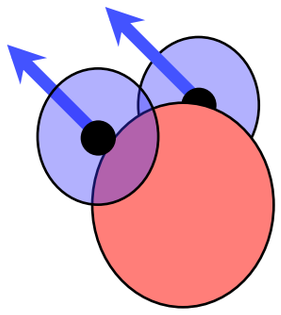

H_2O

H_2O

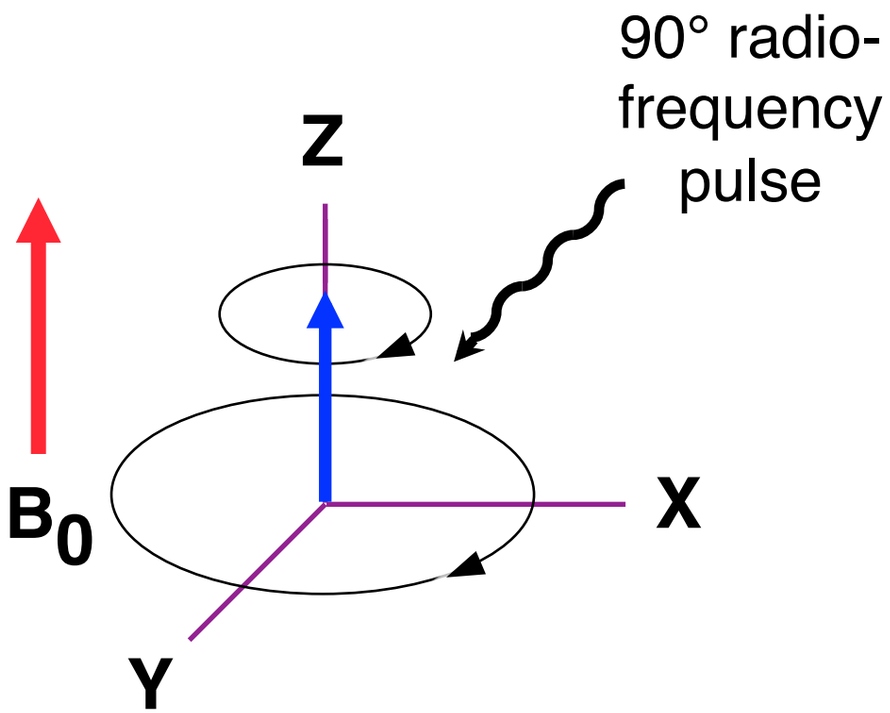






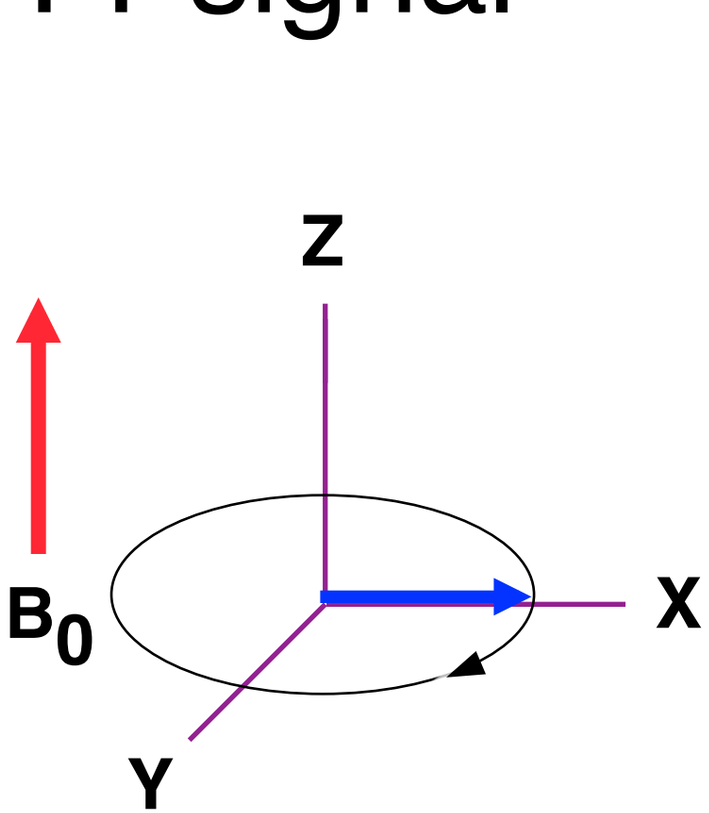


H_2O

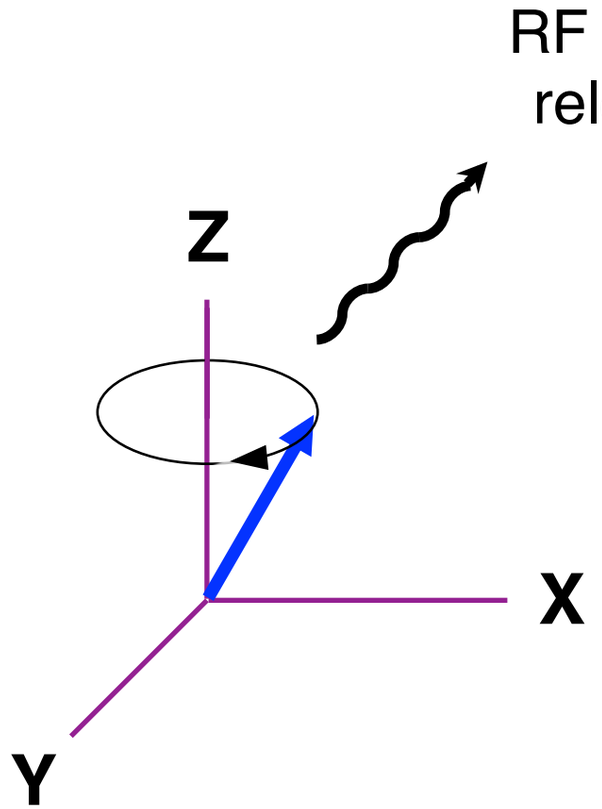


high energy state

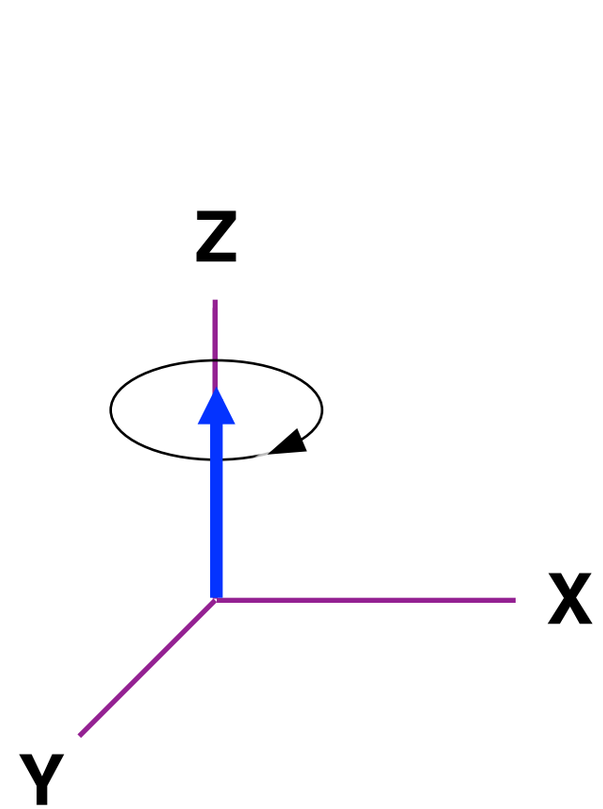
T1 signal



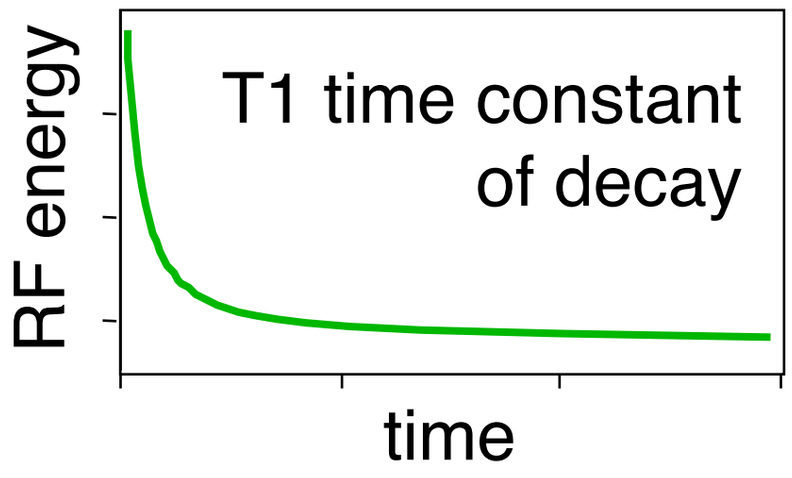
high energy state



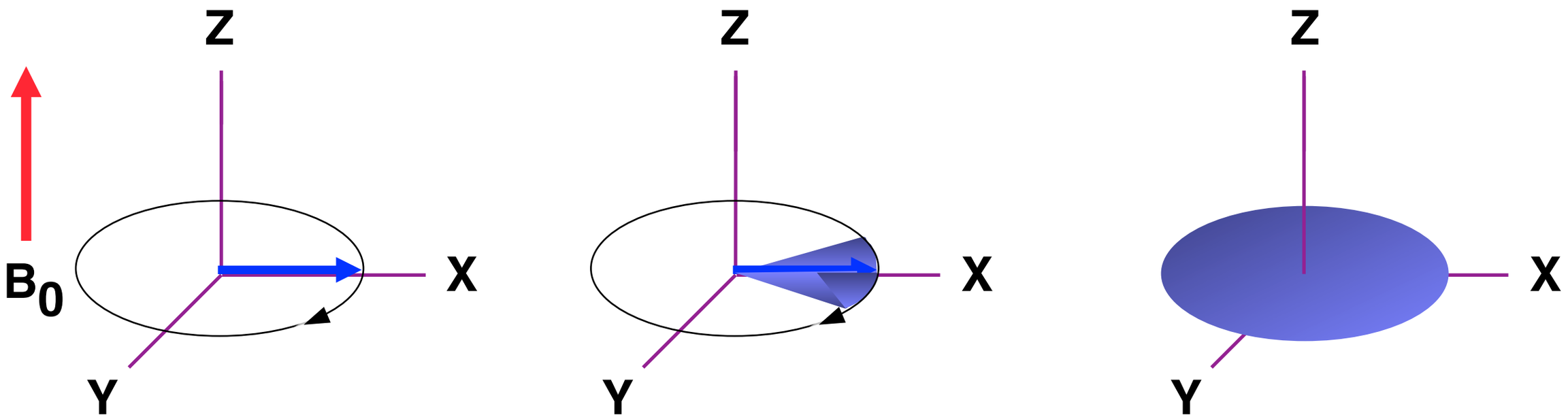
protons relax



low energy state



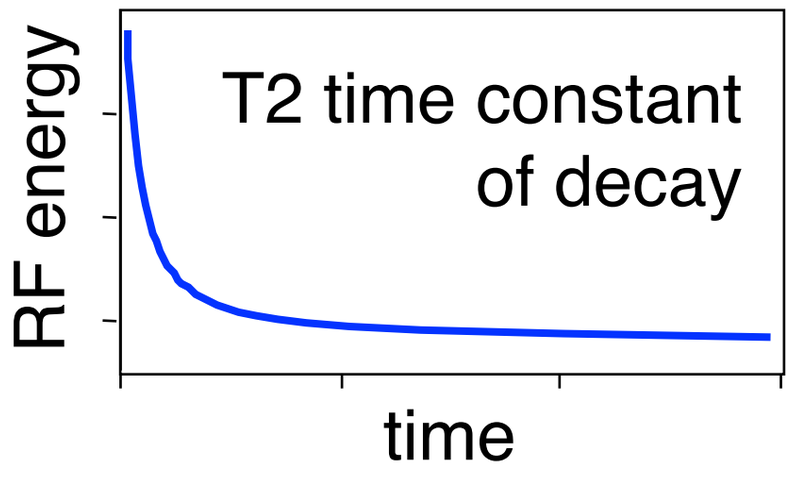
T2 signal



high energy state

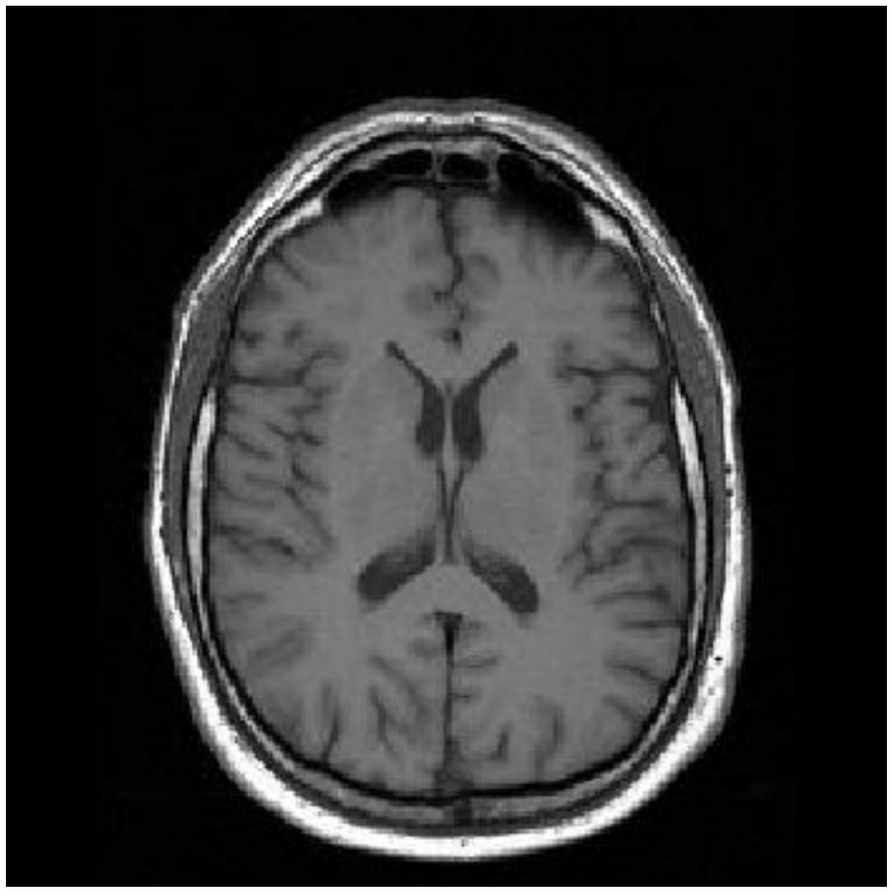
protons de-phase

protons fully de-phased

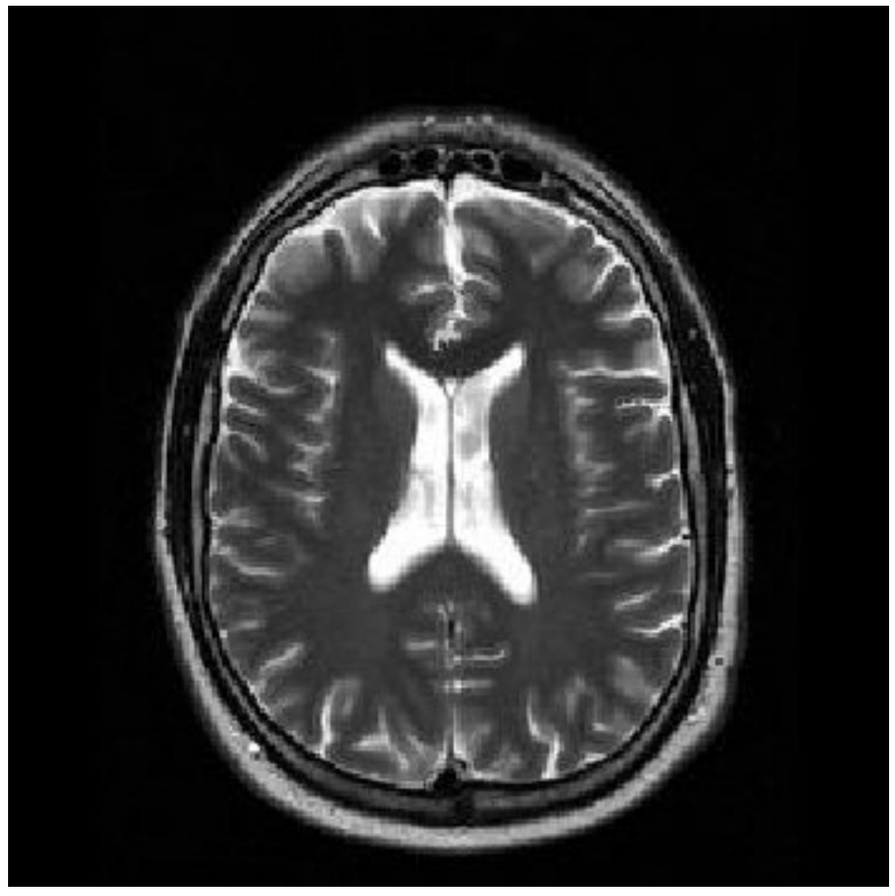


a room-sized Faraday cage

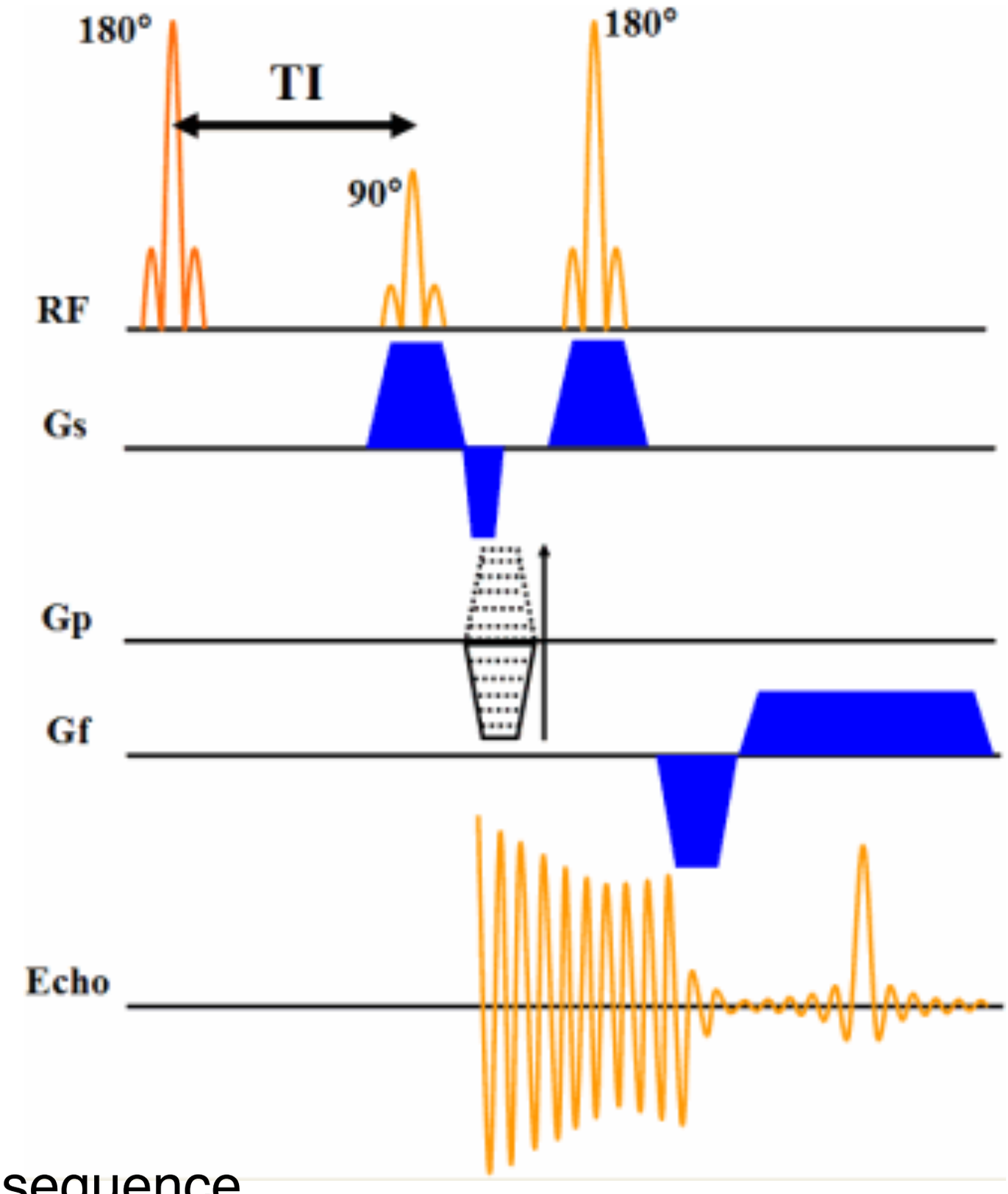
a head coil



T1 weighted



T2 weighted

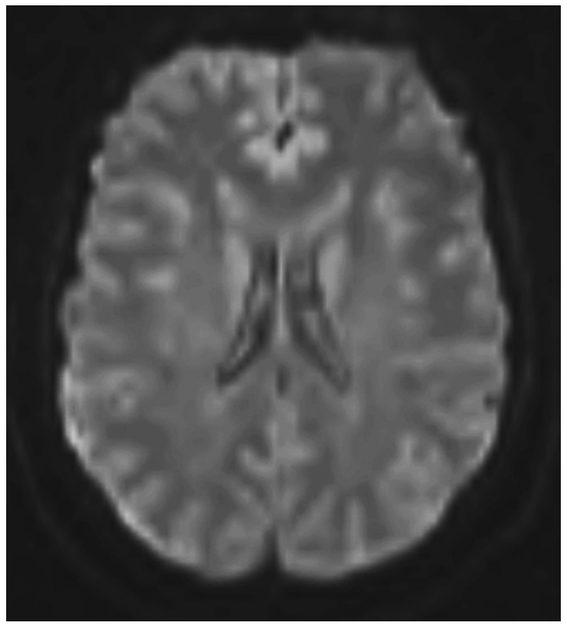


FLAIR pulse sequence

Paul Lauterbur

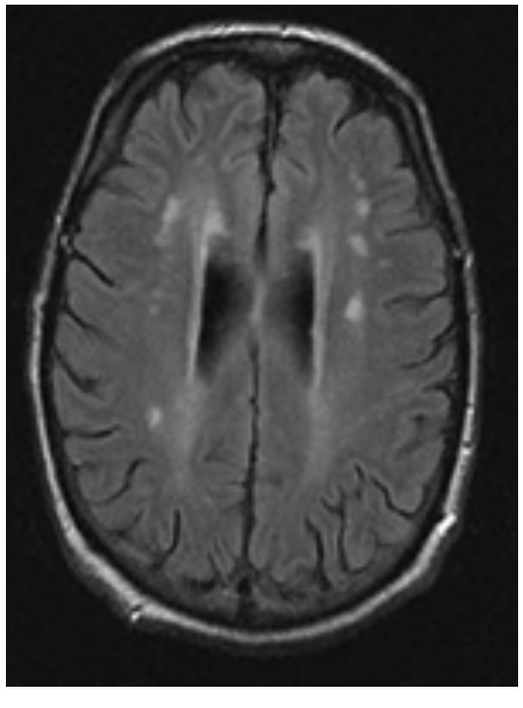
Sir Peter Mansfield

2003 Nobel Prize in Physiology or Medicine



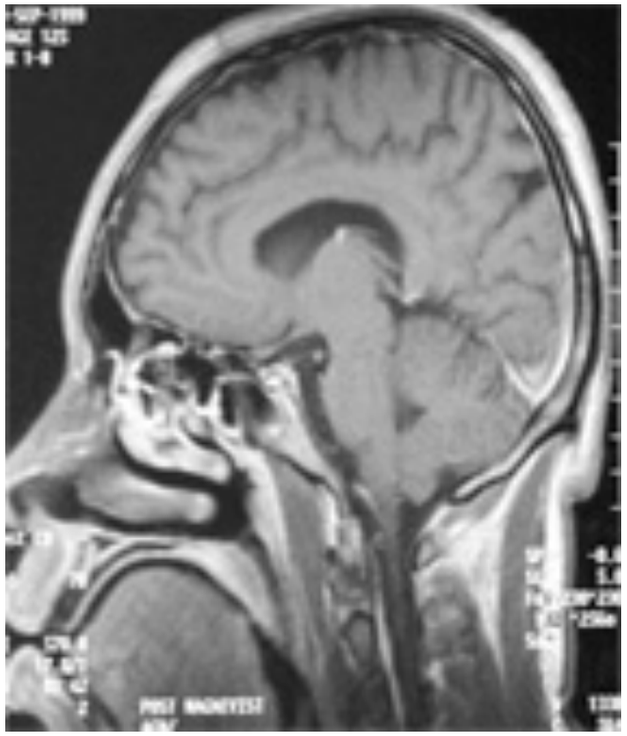
diffusion weighted (DWI)

gradient echo

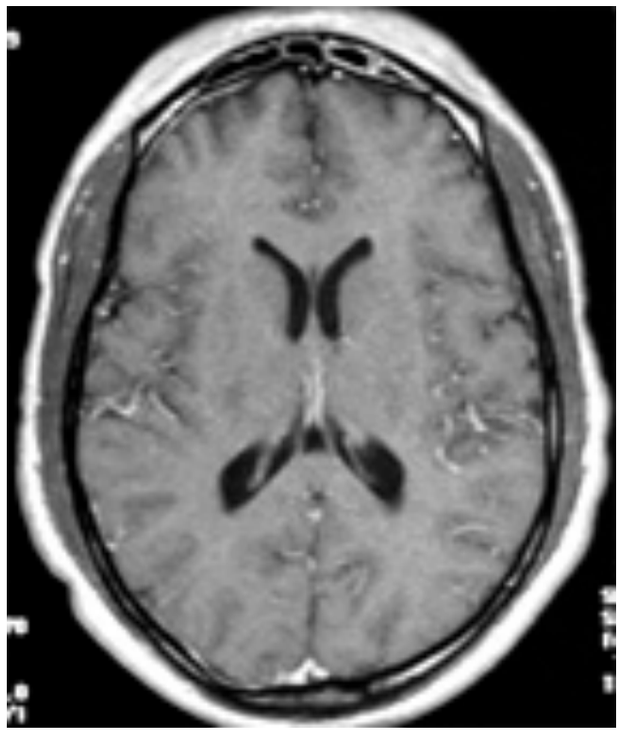


FLAIR

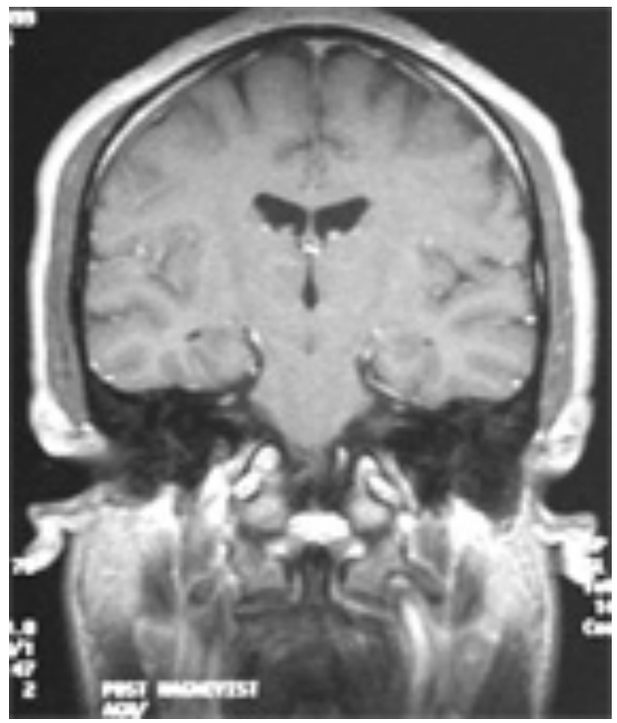
MRA



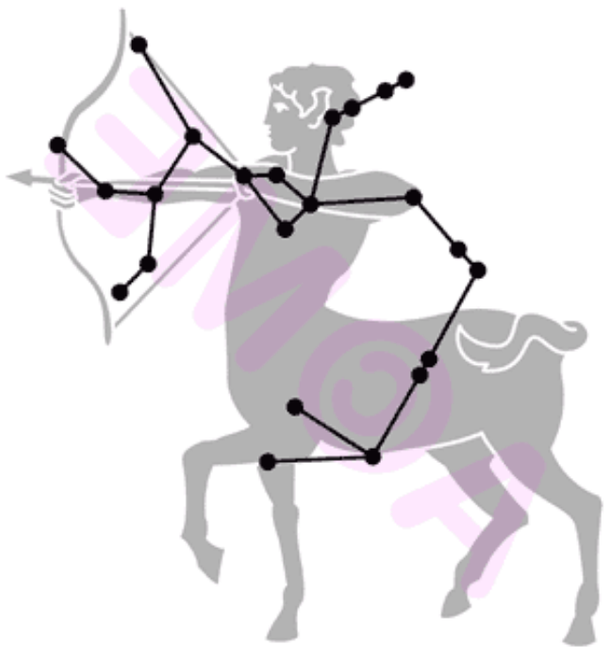
sagittal

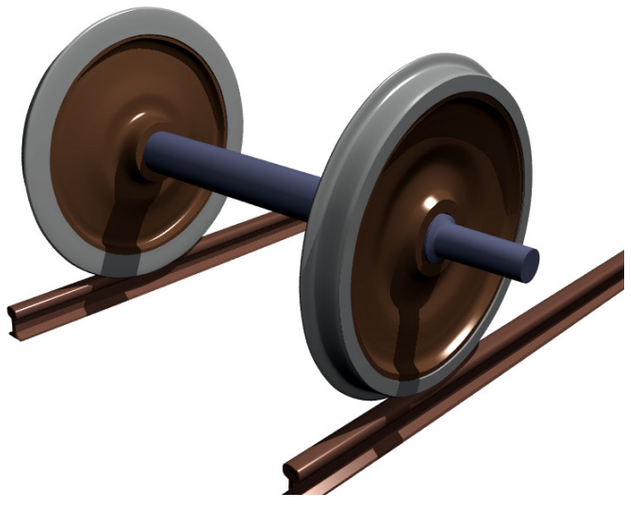


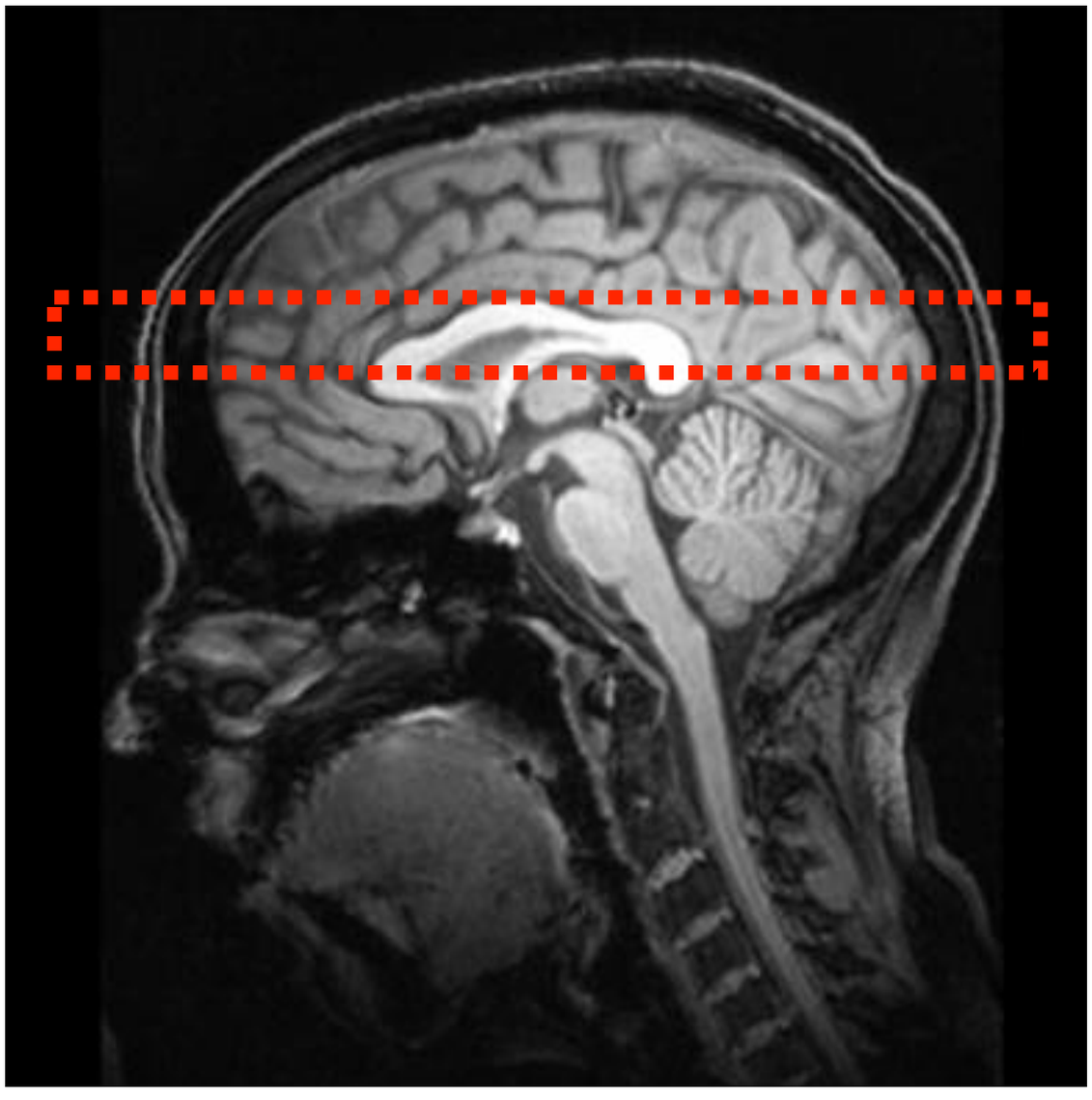
axial

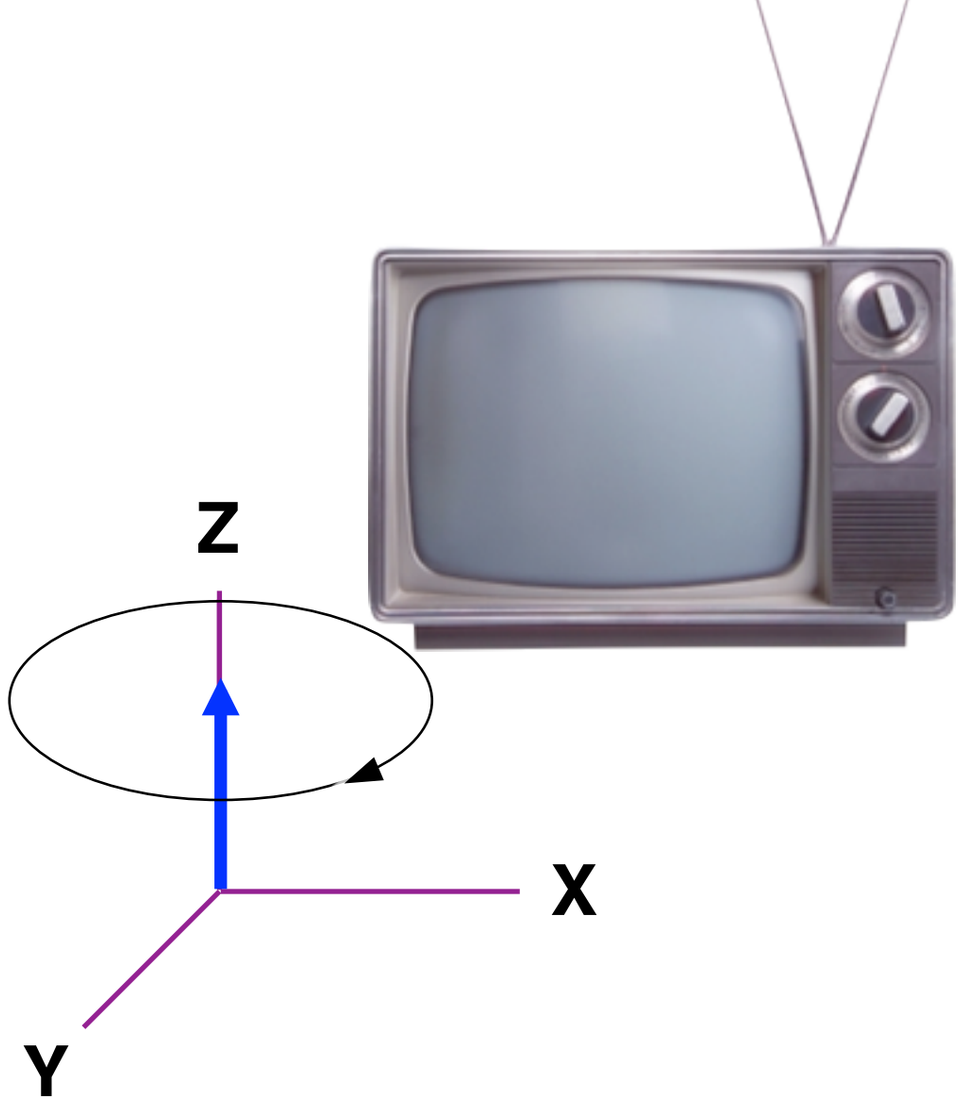


coronal

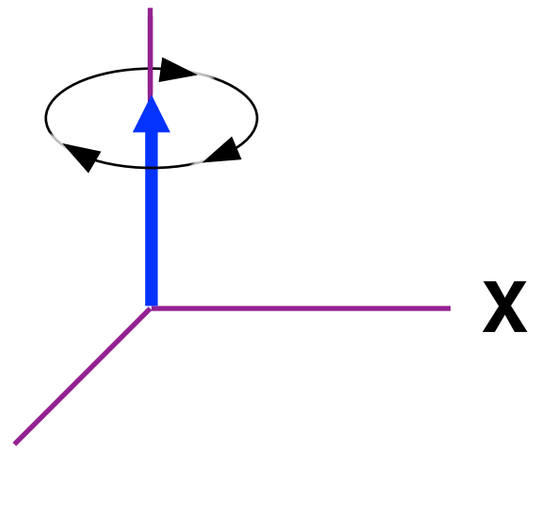








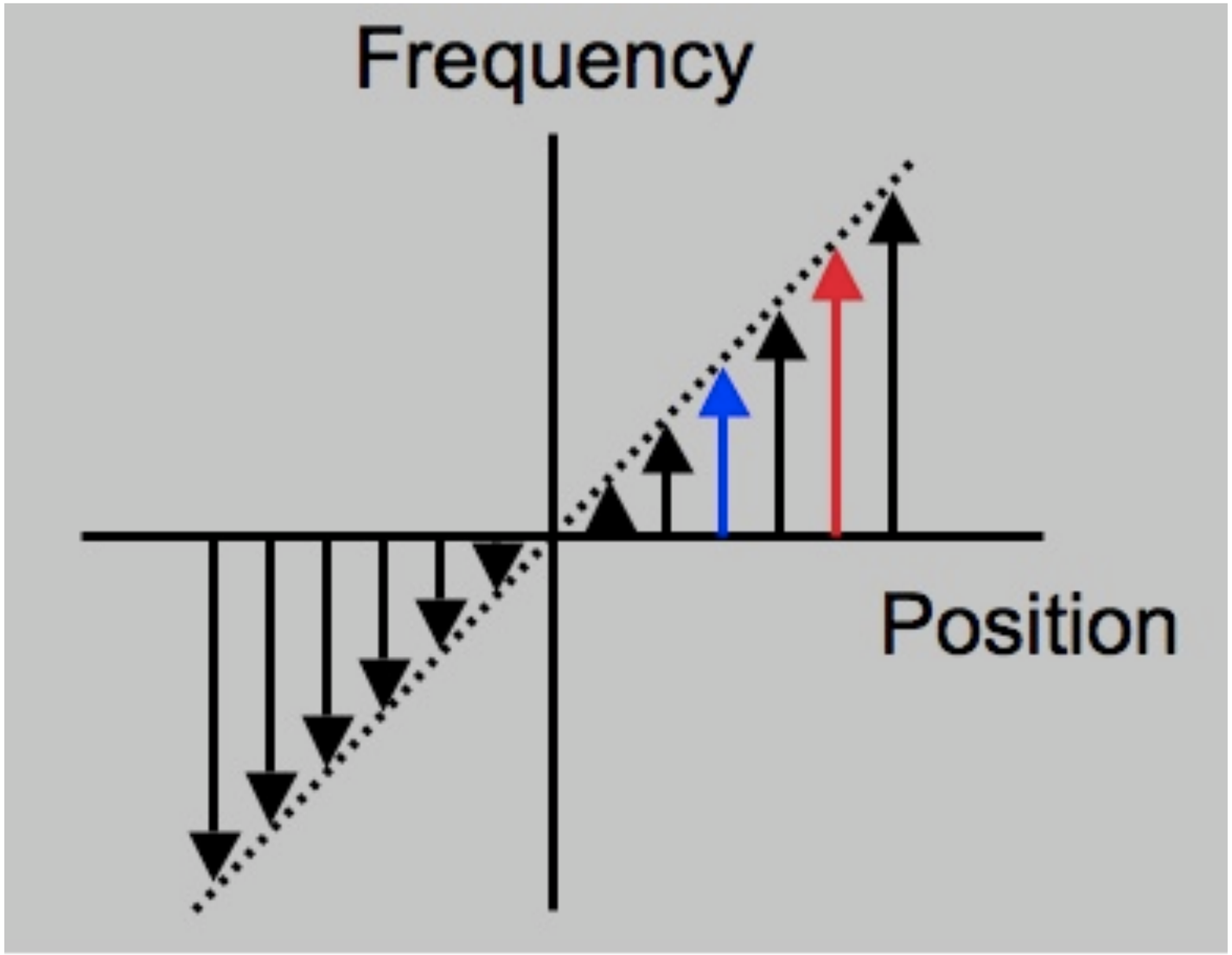
127.6 MHz at 3 Tesla



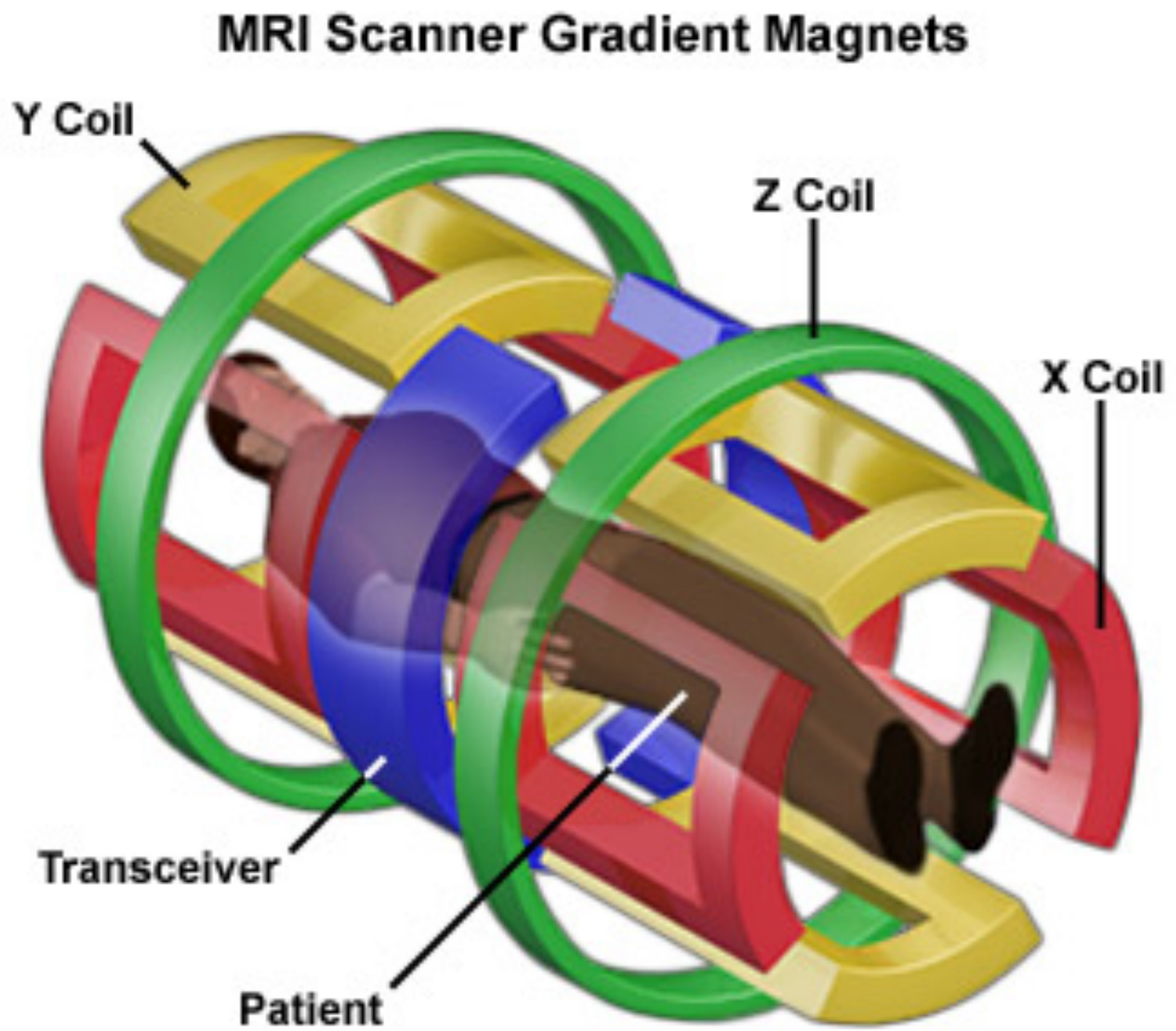
weaker magnetic field

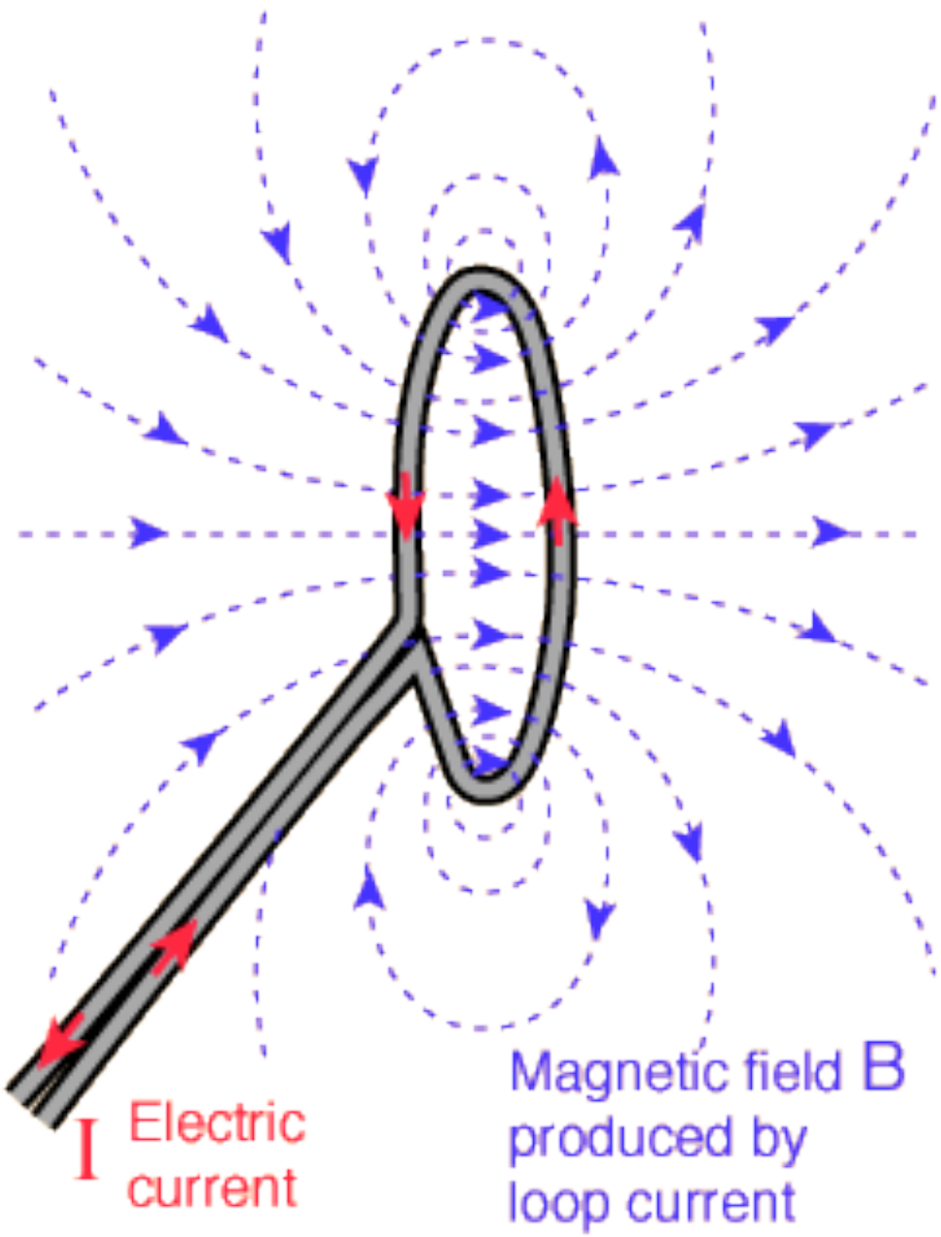
STRONGER magnetic field

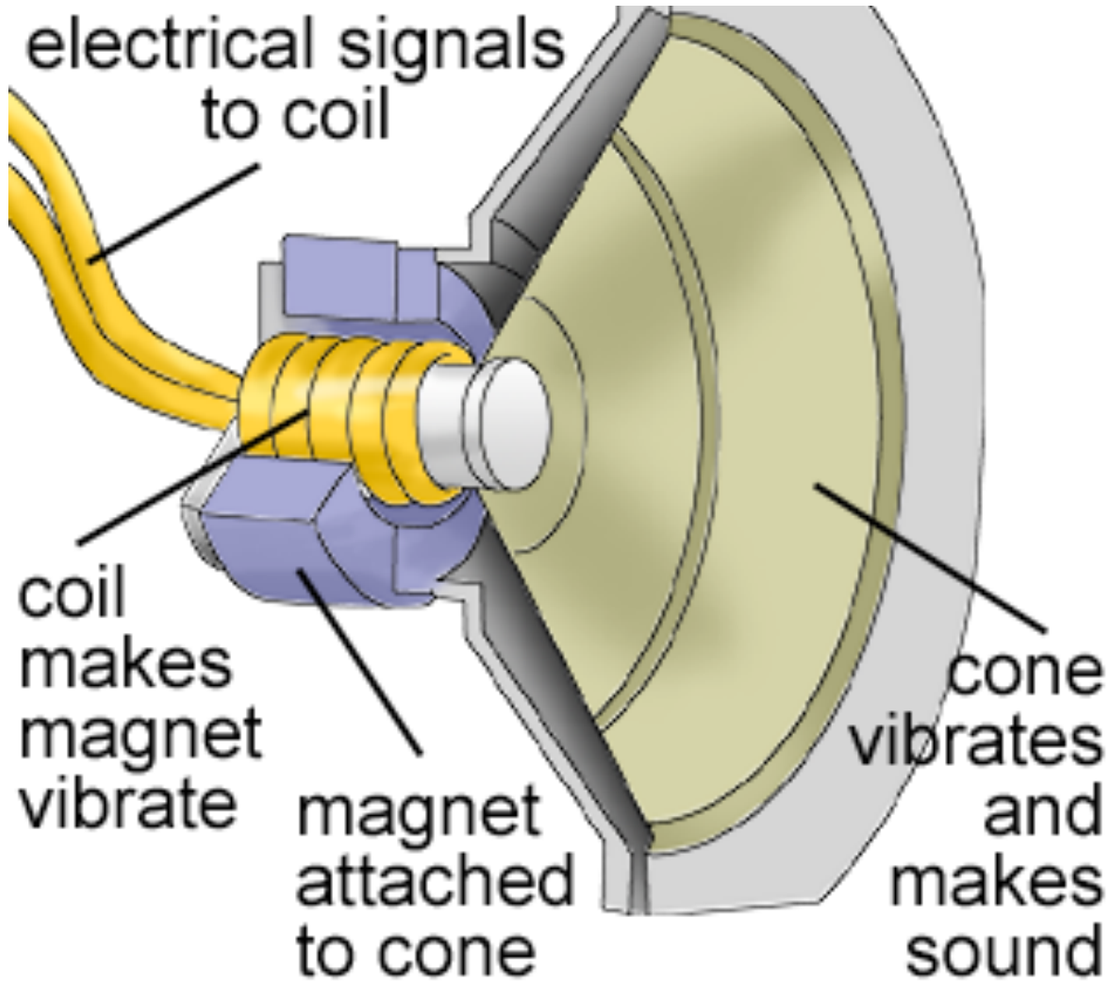
The Larmor frequency is determined
by the strength of the local magnetic field

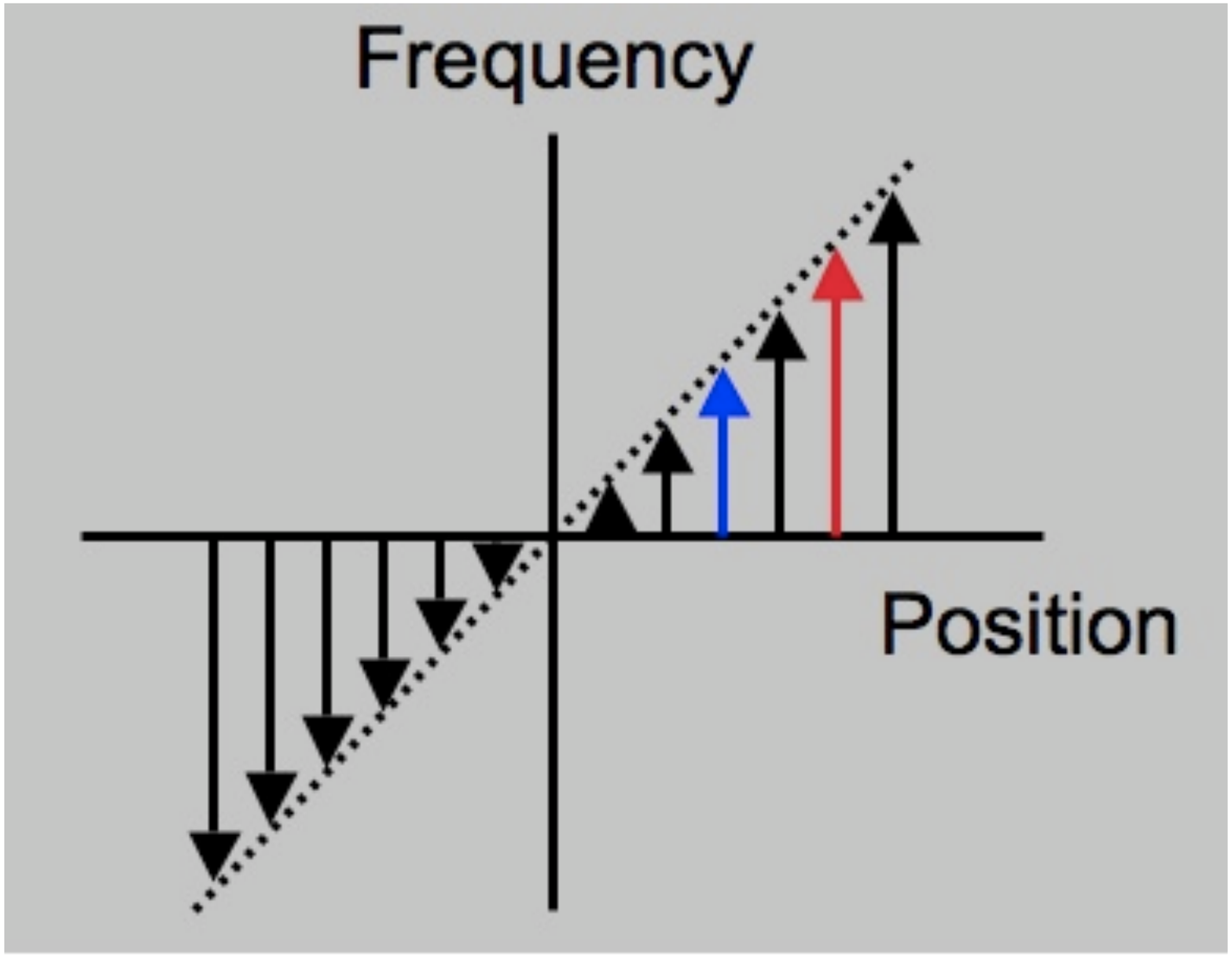


Create a gradient of magnetic field strength across space, allowing the excitation of protons at a given location

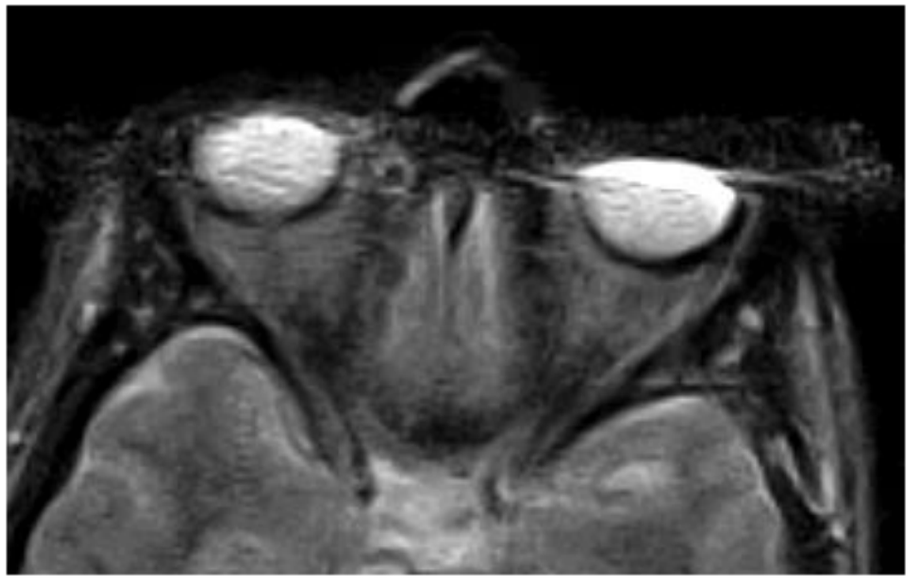

MRI Scanner Gradient Magnets
Y Coil
Z Coil
X Coil
Transceiver
Patient

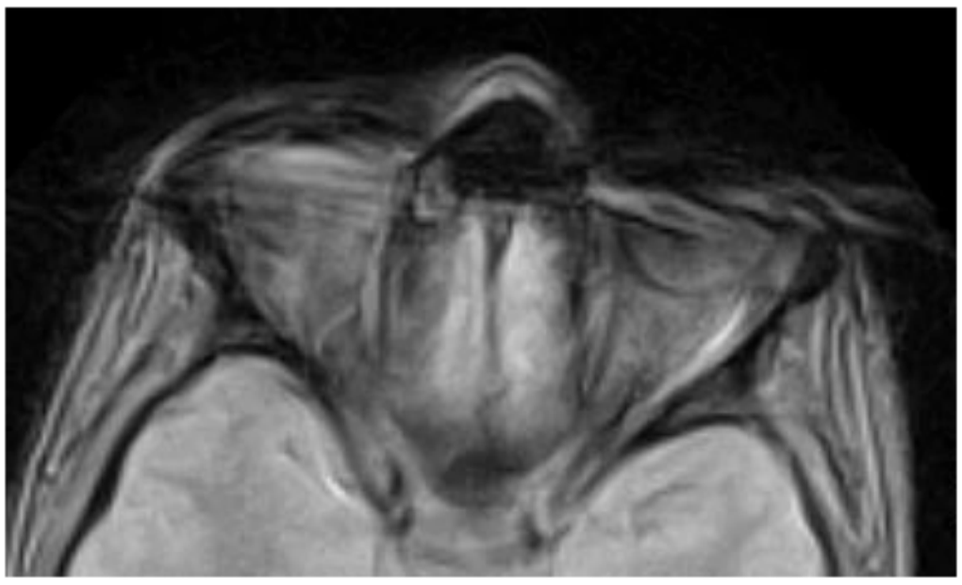

I
Electric
current
Magnetic field B
produced by
loop current


electrical signals
to coil
coil
makes
magnet
vibrate
magnet
attached
to cone
cone
vibrates
and
makes
sound

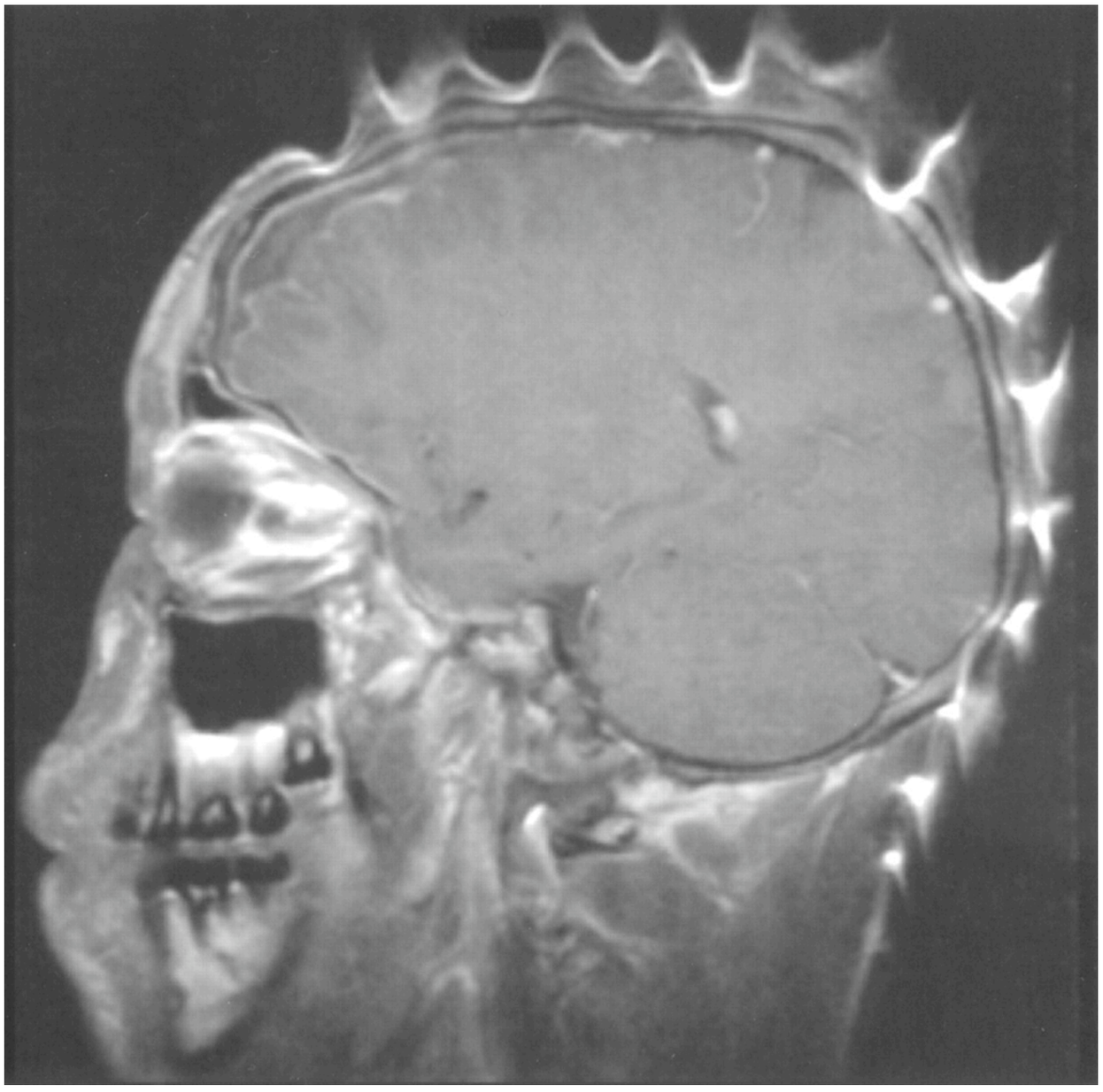


Create a gradient of magnetic field strength across space, allowing the excitation of protons at a given location

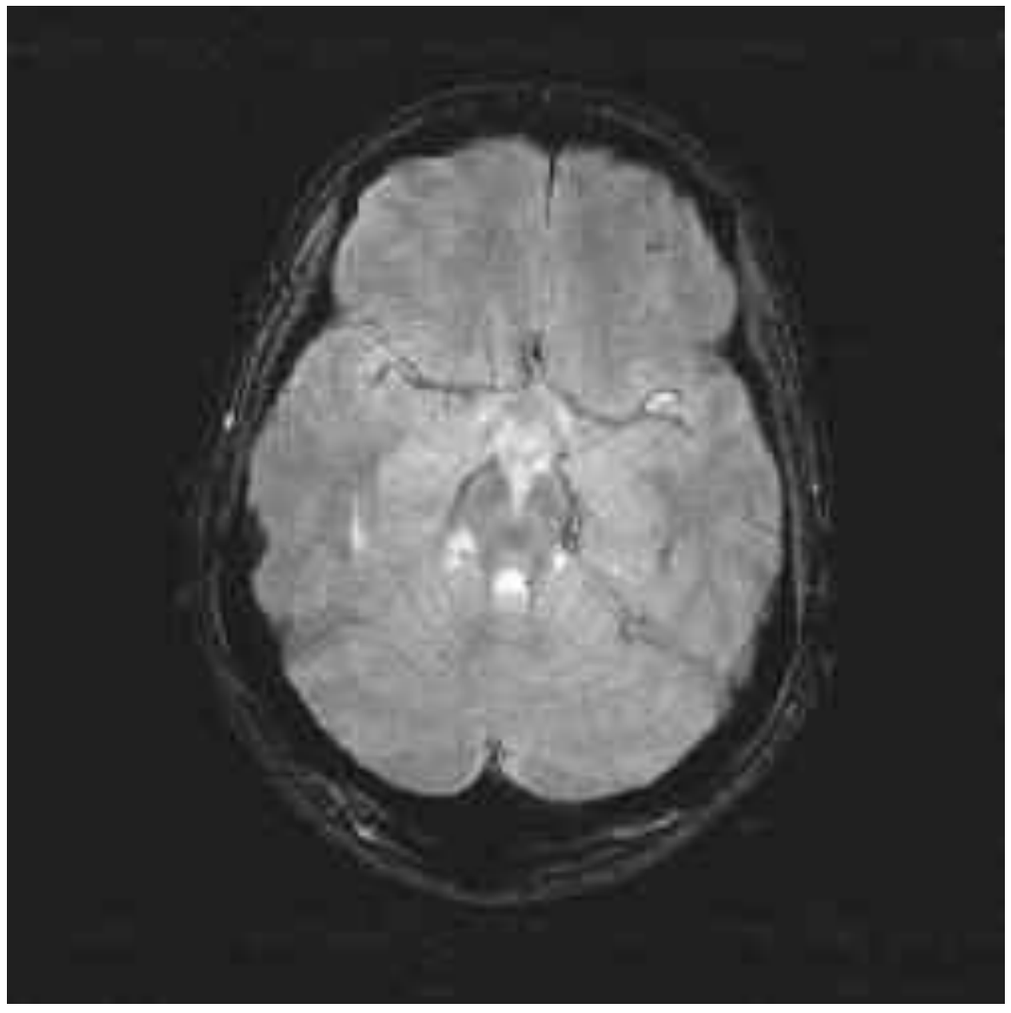


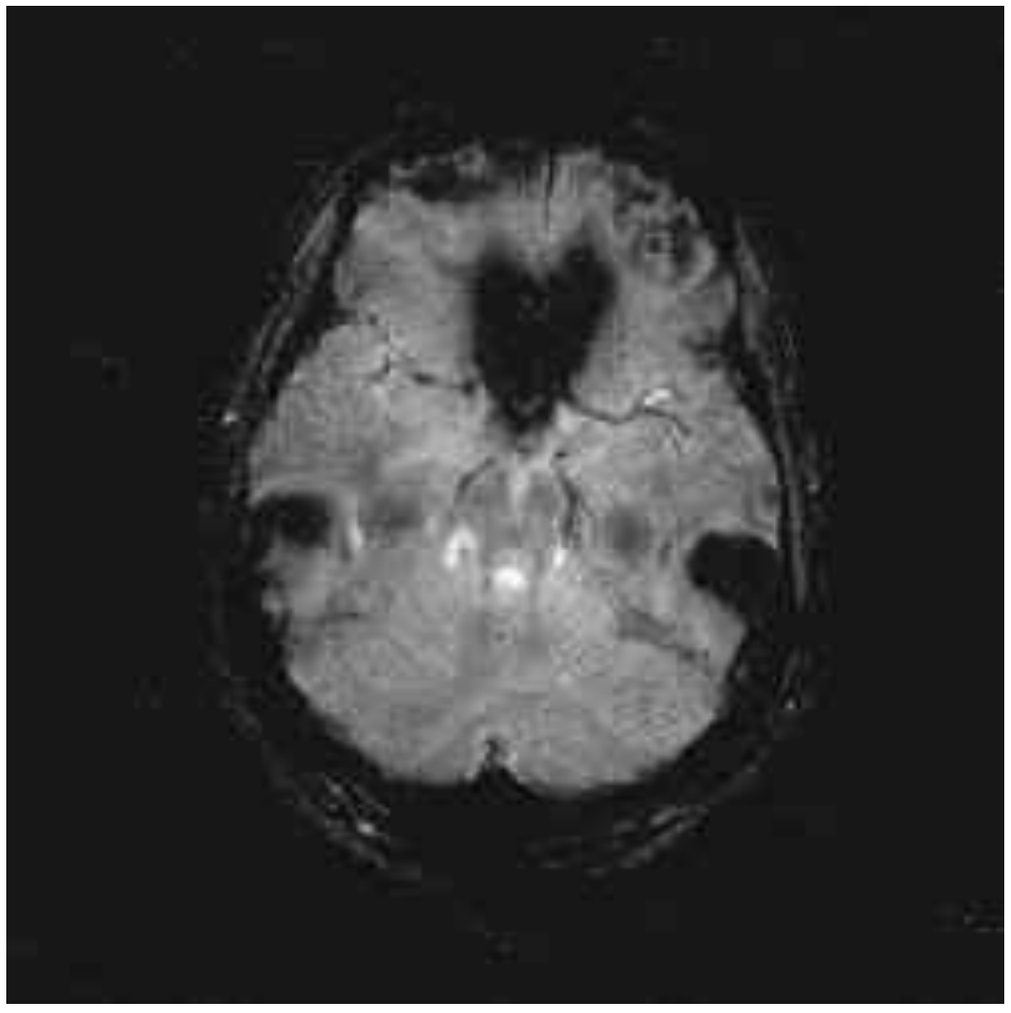


susceptibility artifact from metallic face paint

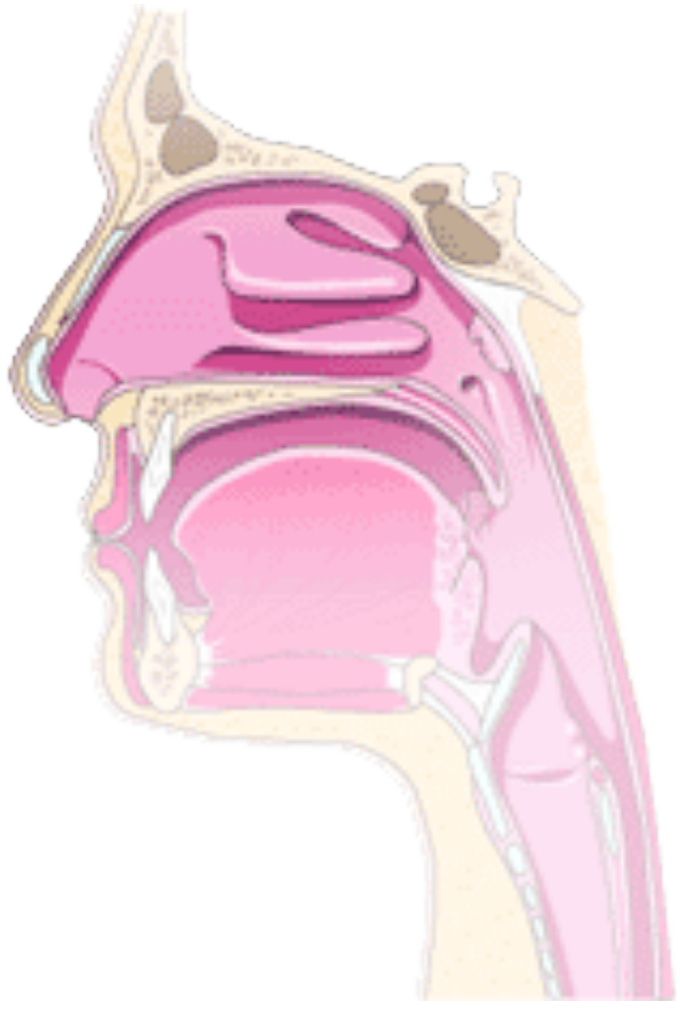


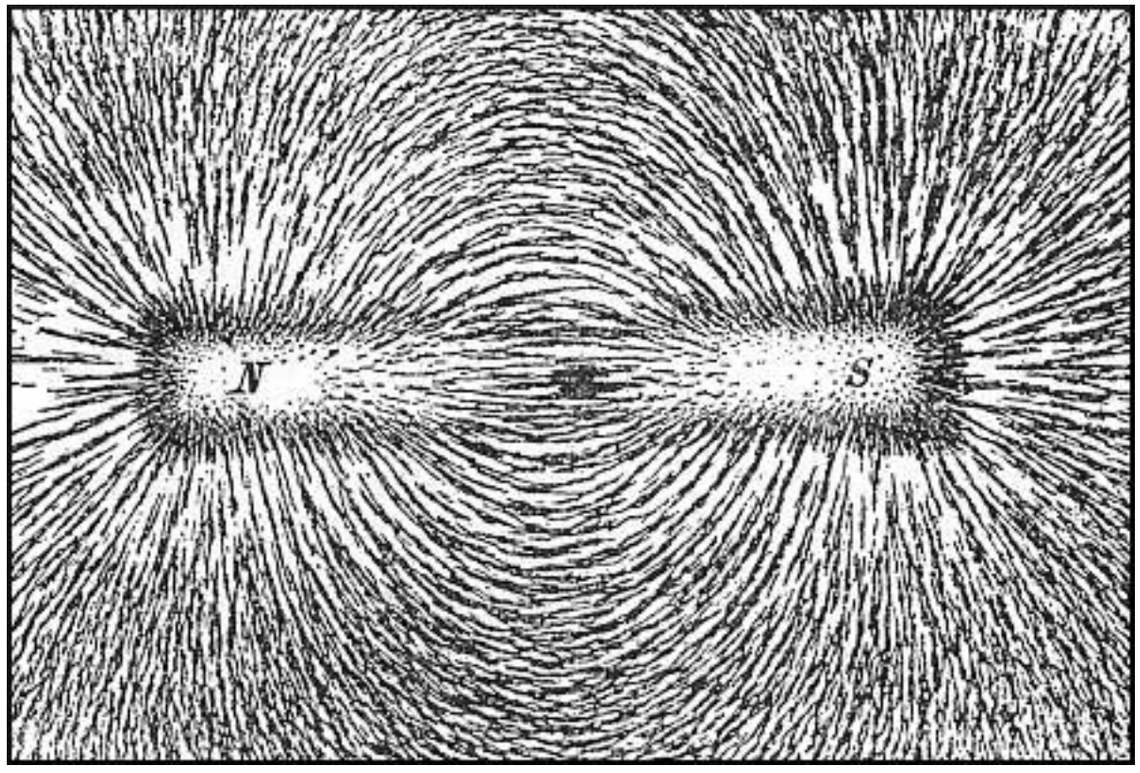
susceptibility artifact from iron oxide particles
suspended in beeswax in hair





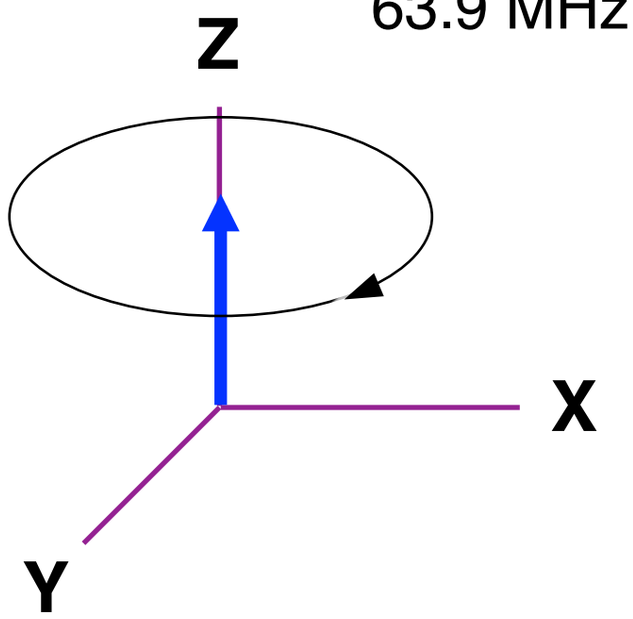
susceptibility from air-tissue interface





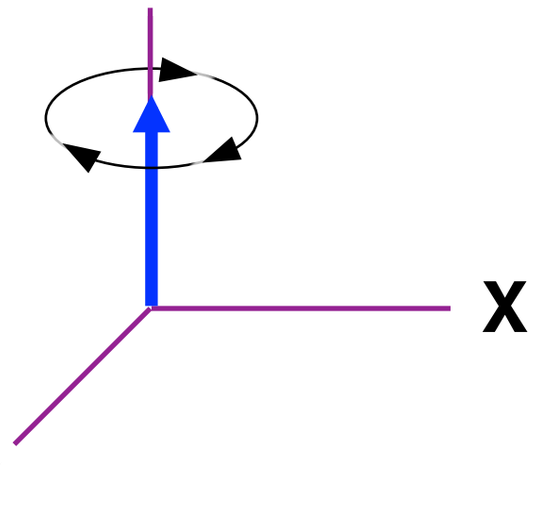
air-tissue interfaces concentrate magnetic field lines

63.9 MHz at 1.5 Tesla



weaker magnetic field

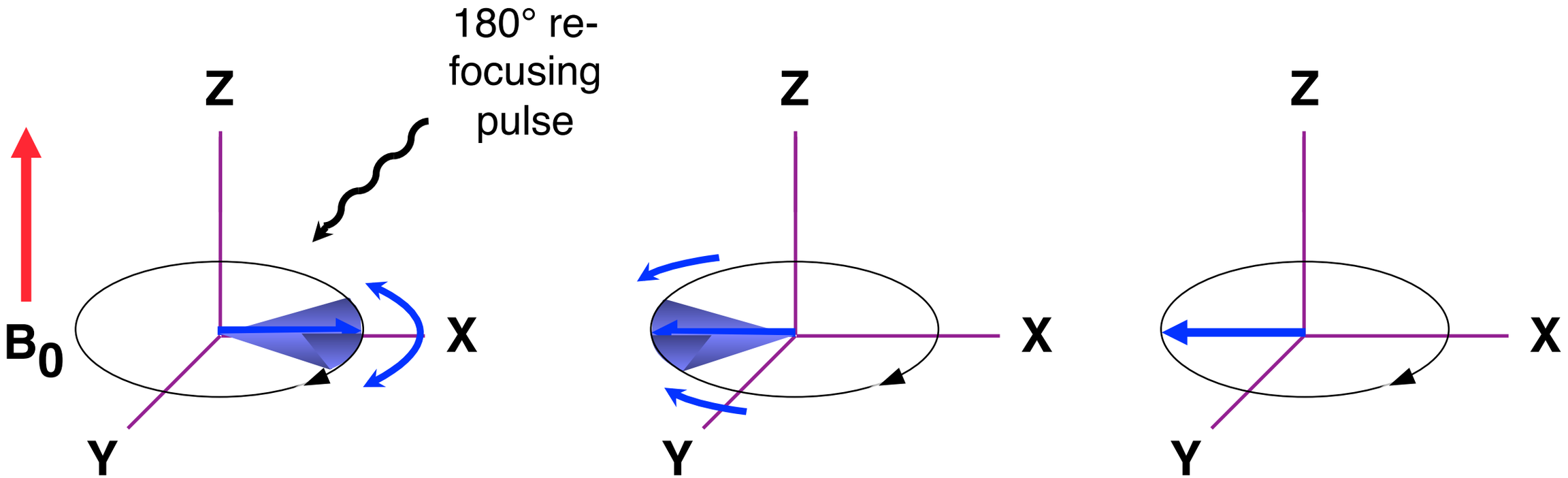
127.6 MHz at 3 Tesla



STRONGER magnetic field

The Larmor frequency is determined
by the strength of the local magnetic field

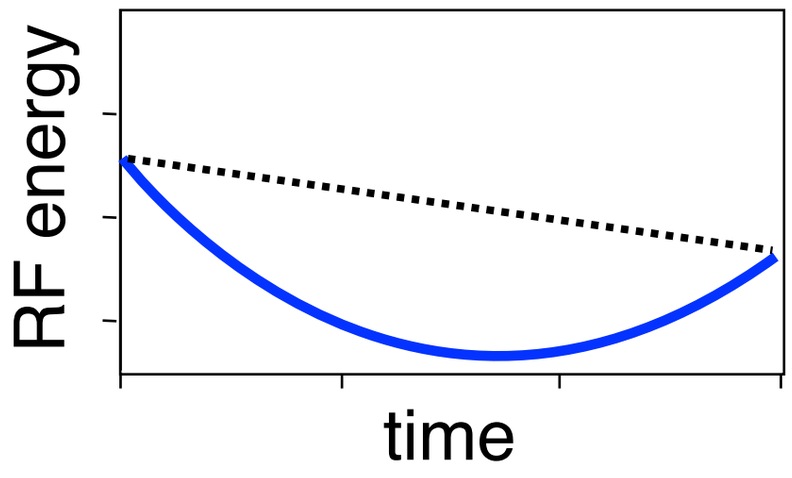
T2* signal



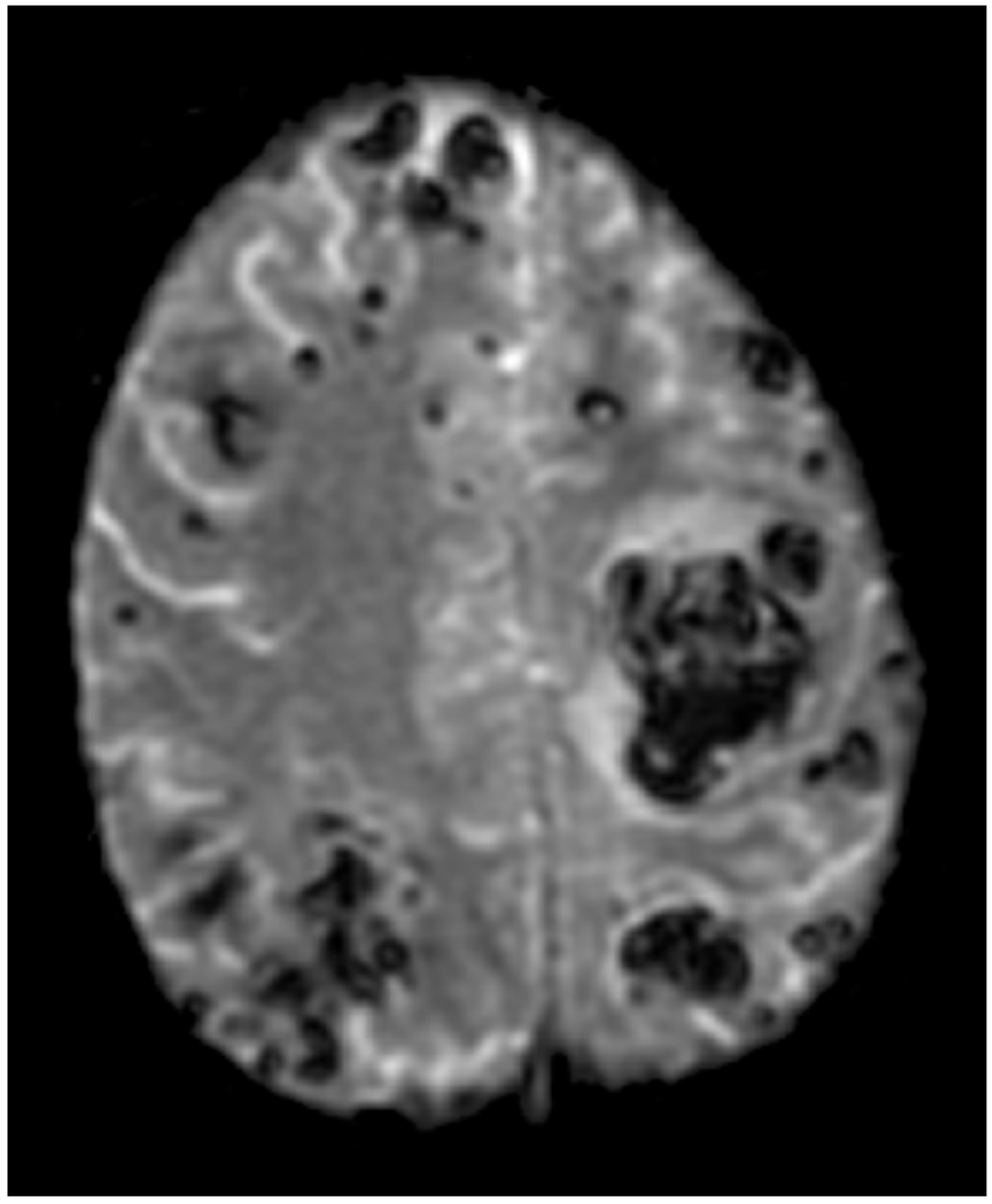
protons de-phase

phases invert

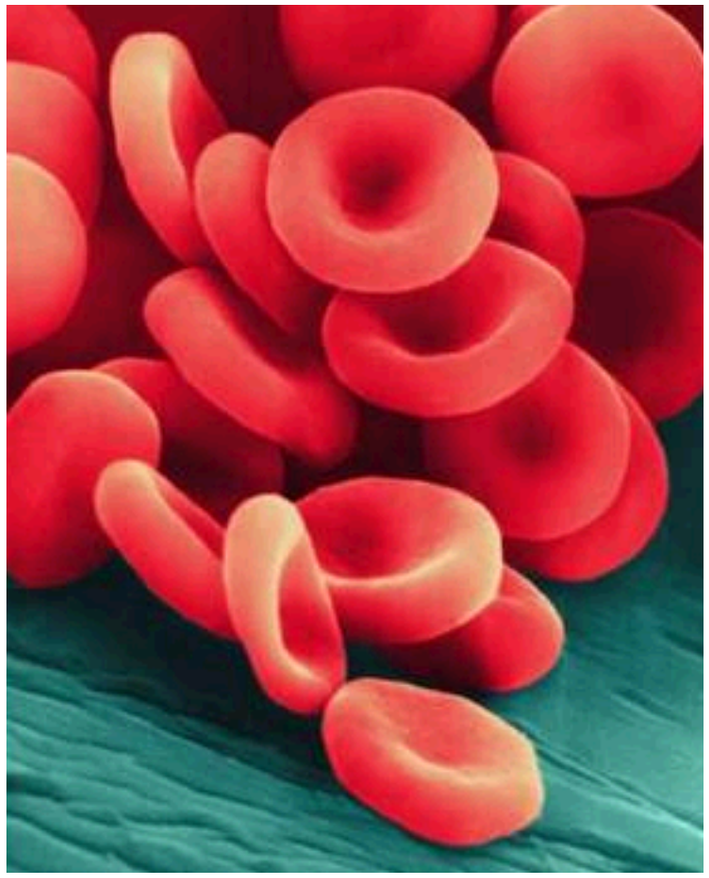
protons re-focus

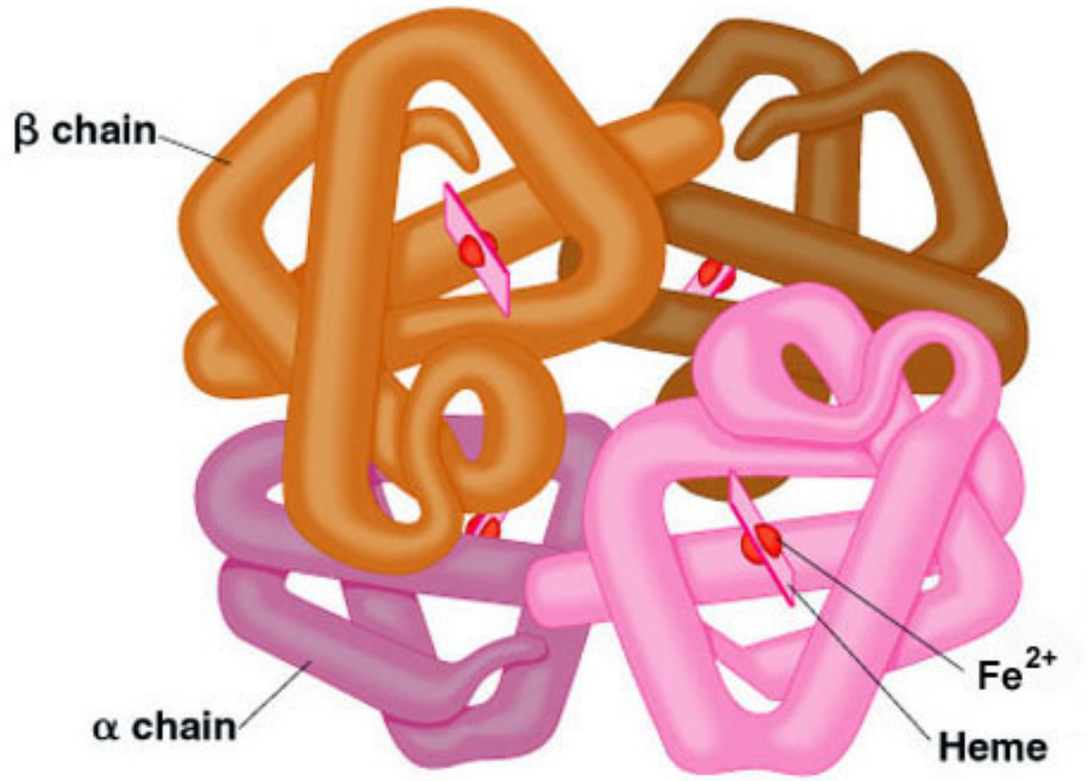


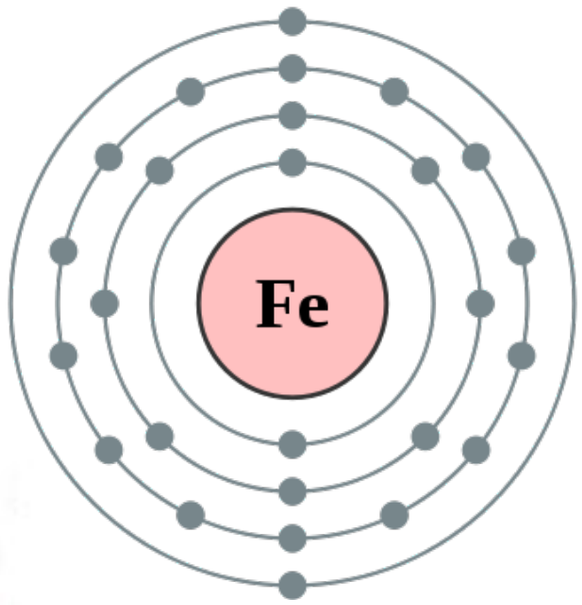
The component that does not refocus is T2*



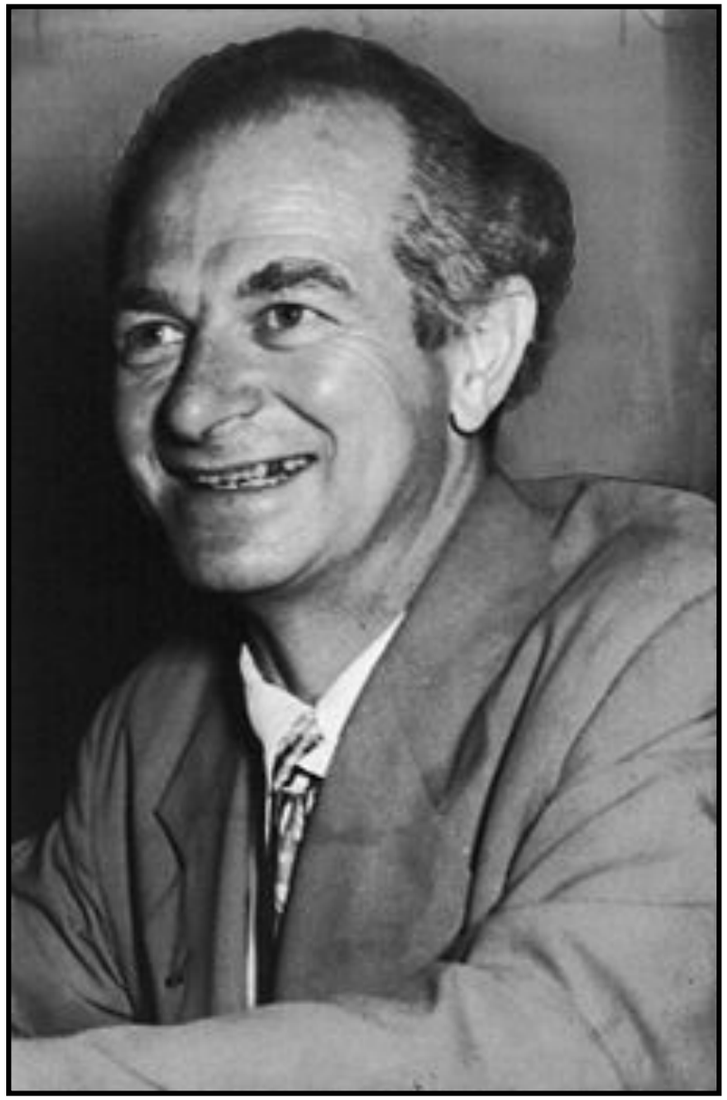
susceptibility effects from bleeding in amyloid angiopathy



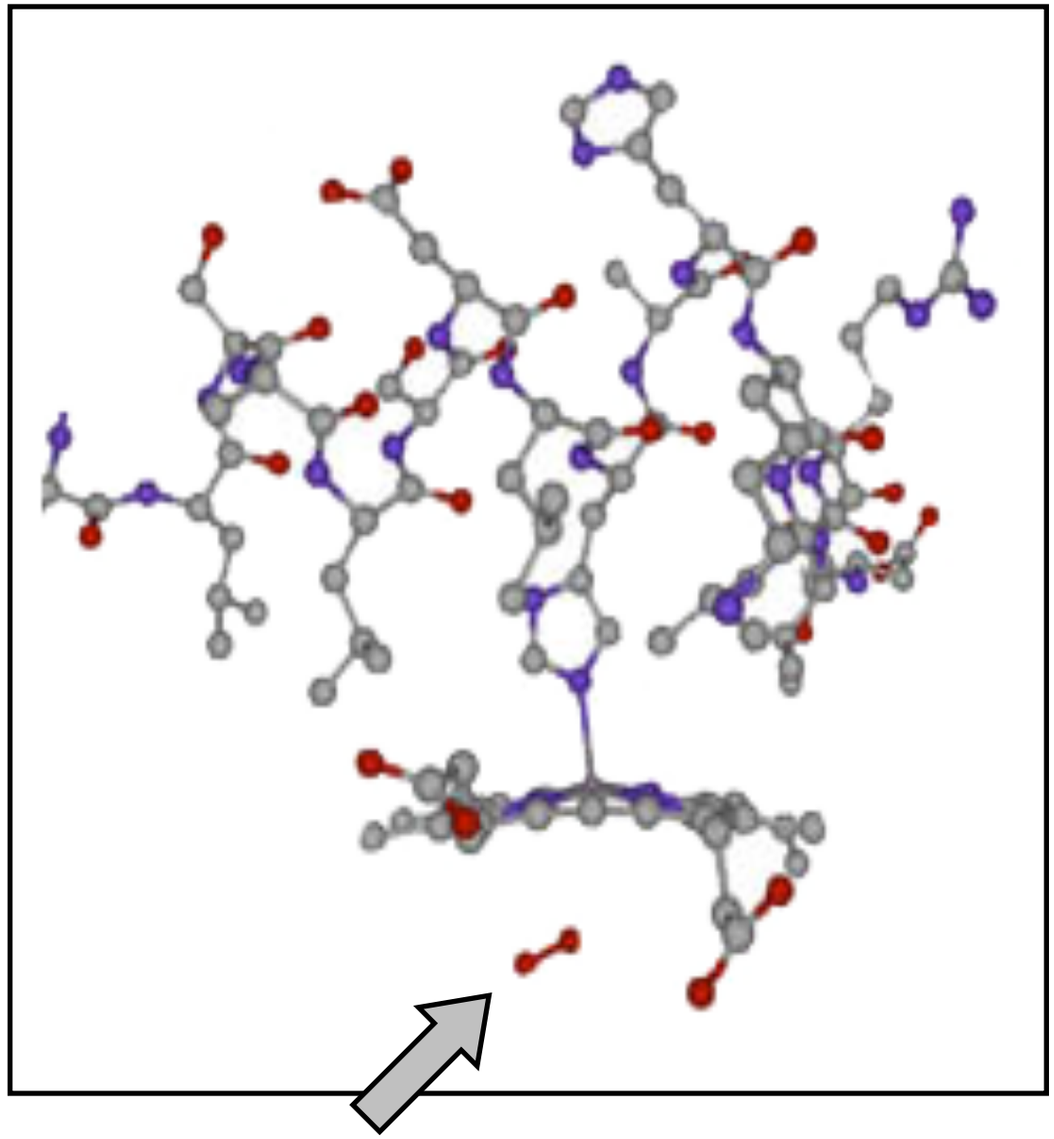




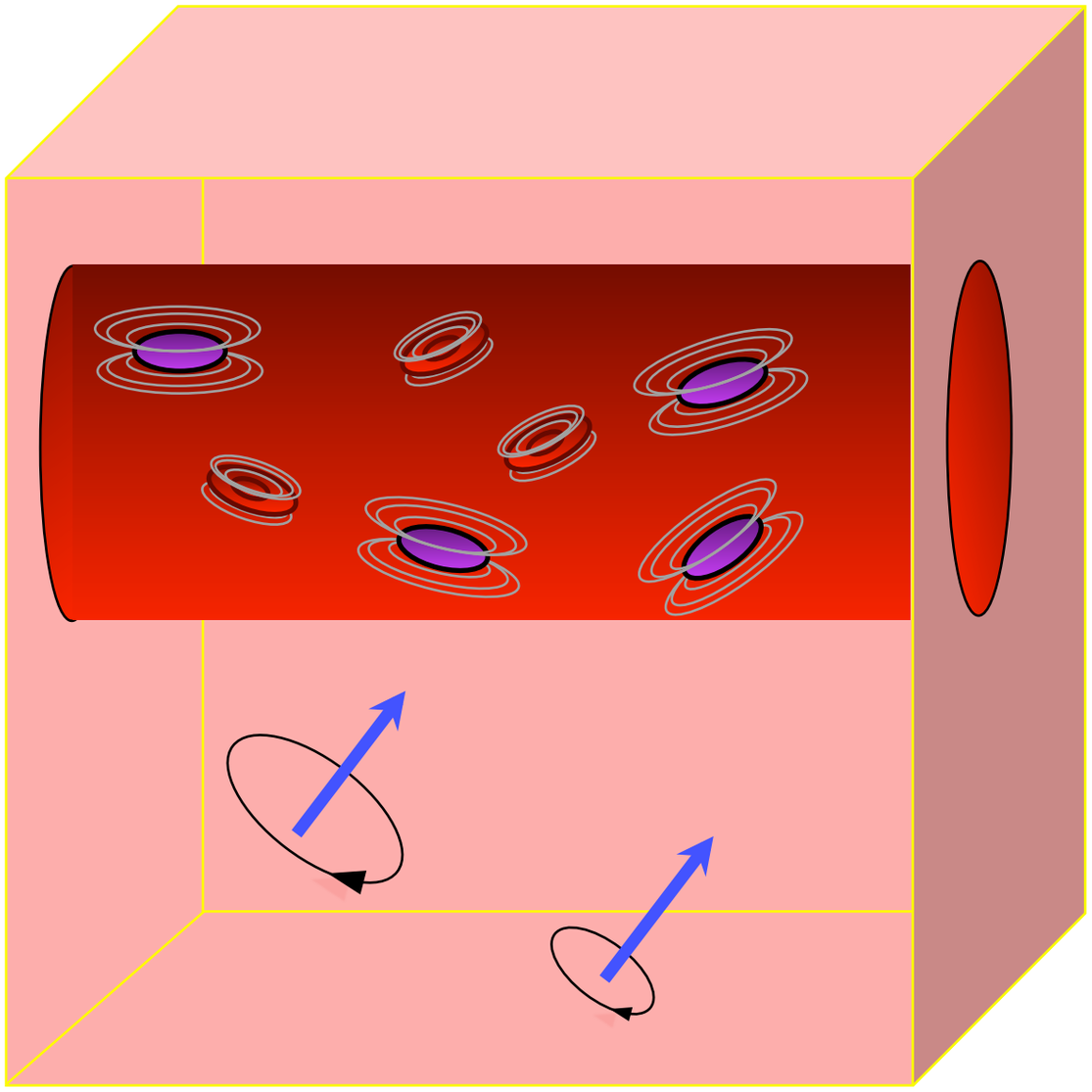
hemoglobin contains iron atoms



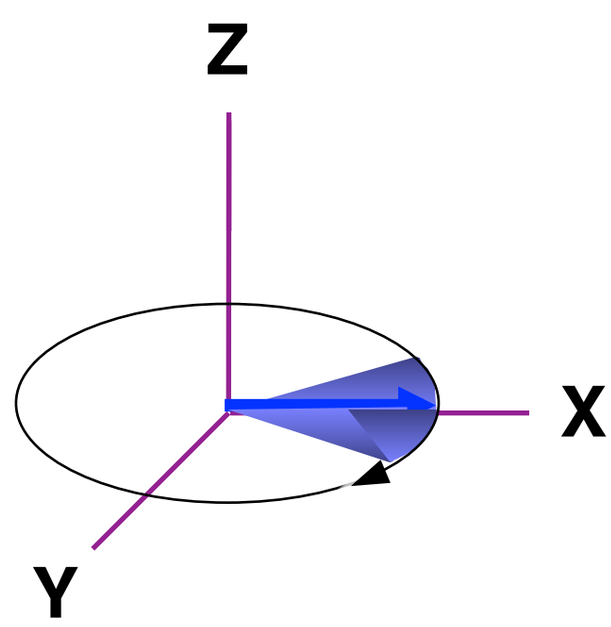
Linus Pauling



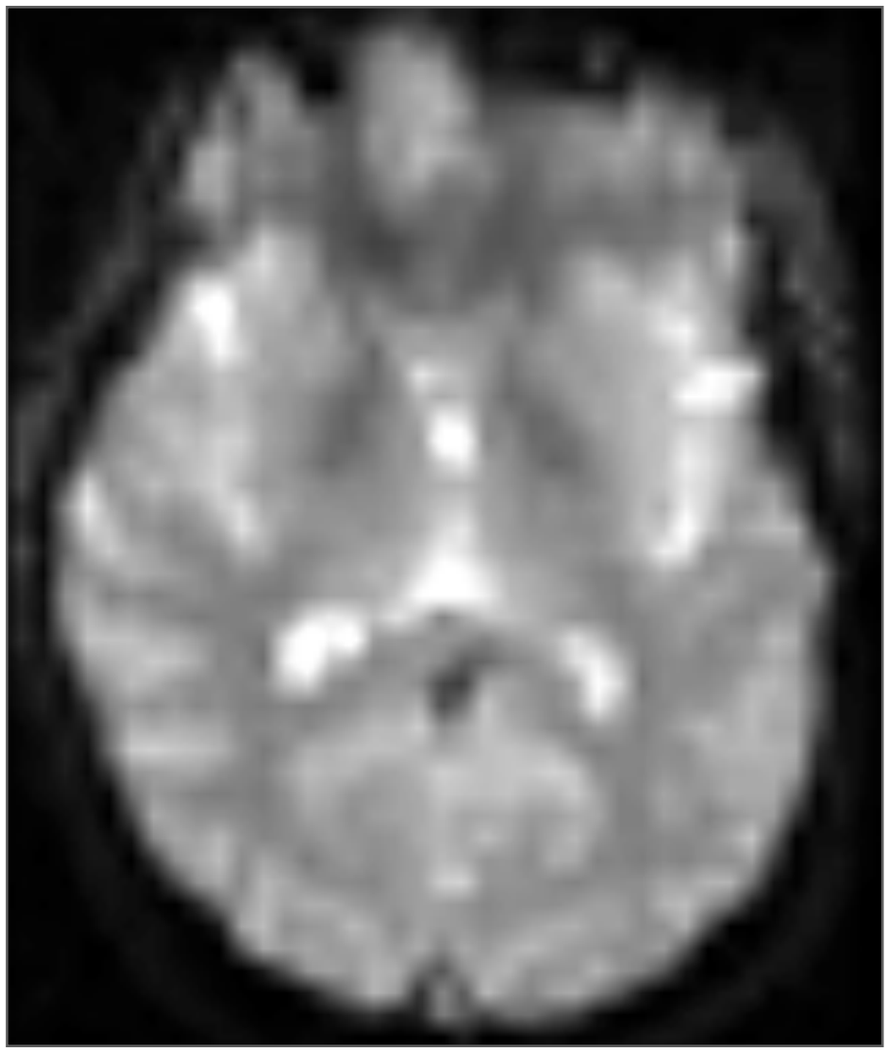
paramagnetic ⟶ diamagnetic



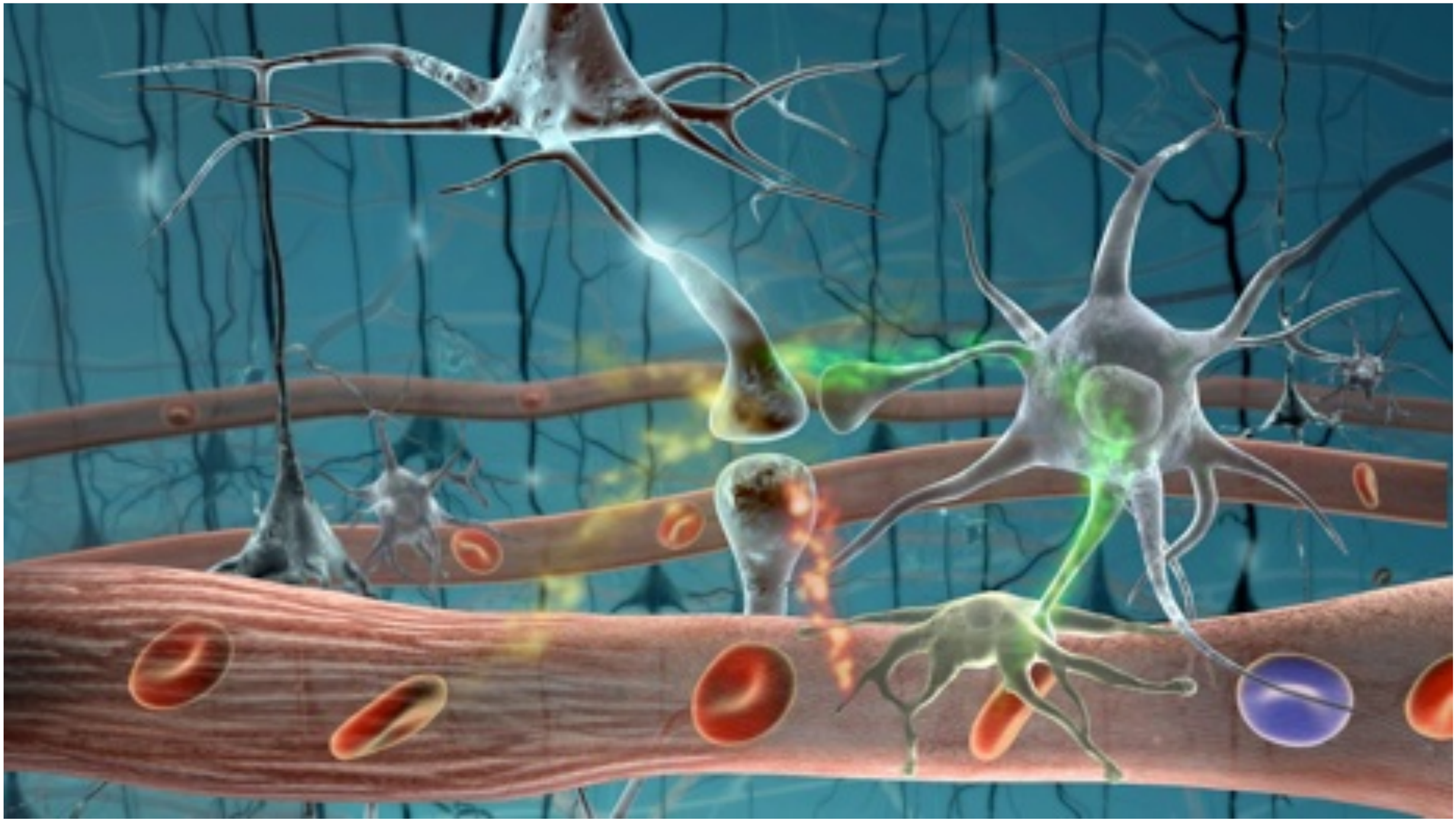
Deoxyhemoglobin creates magnetic field inhomo-geneities, causing spin dephasing



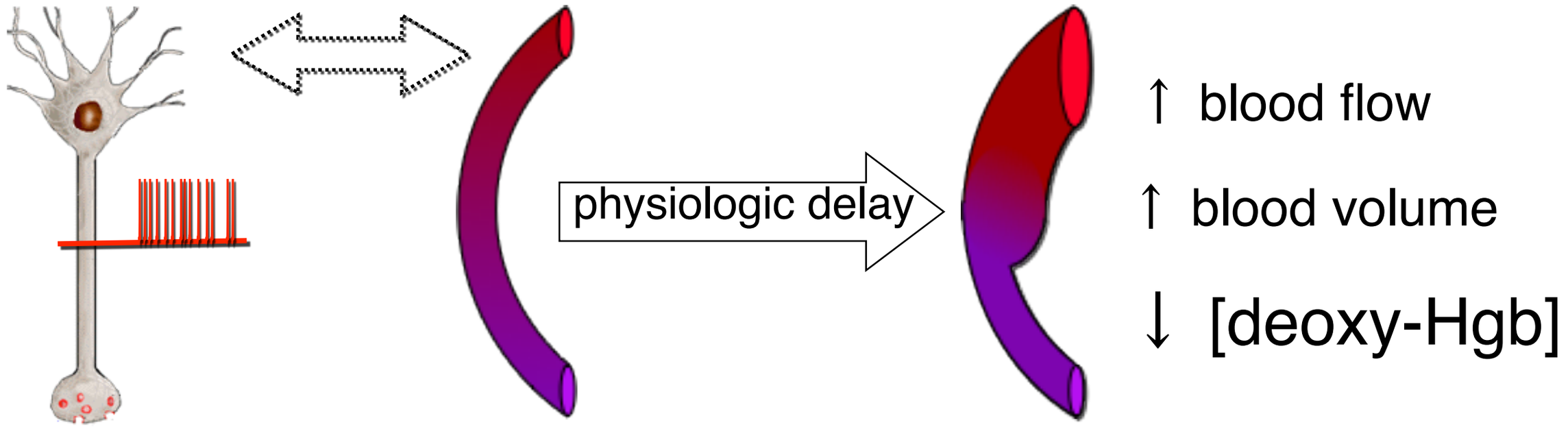
protons de-phase

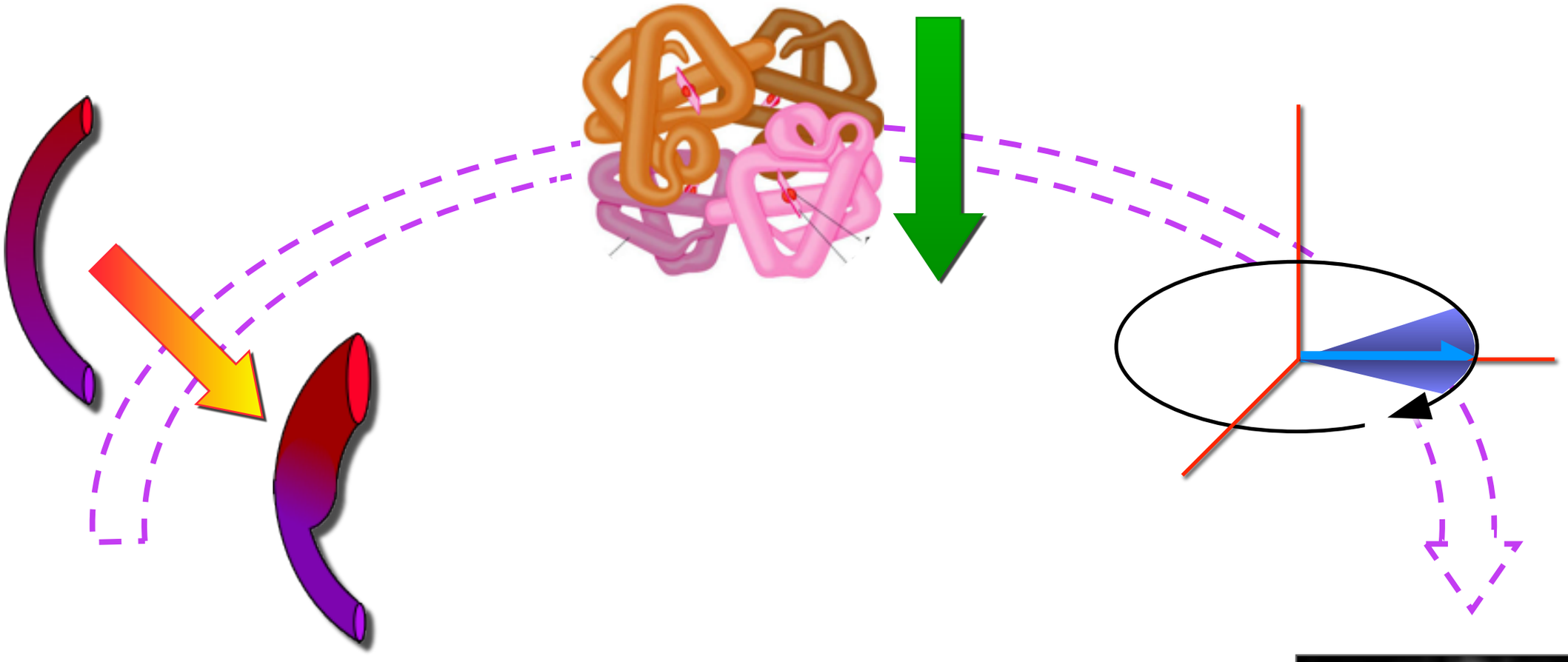


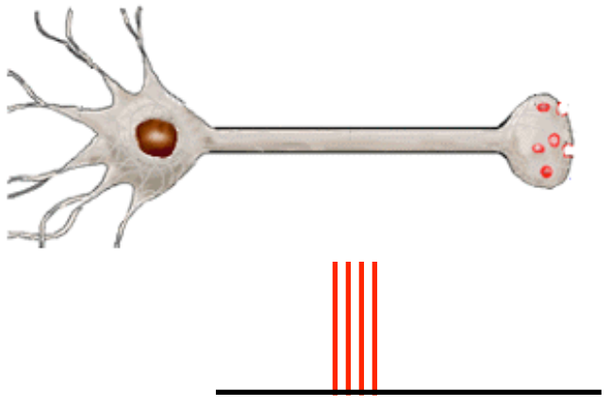
gradient echoplanar image



Neuro-vascular coupling







neuro-imaging coupling