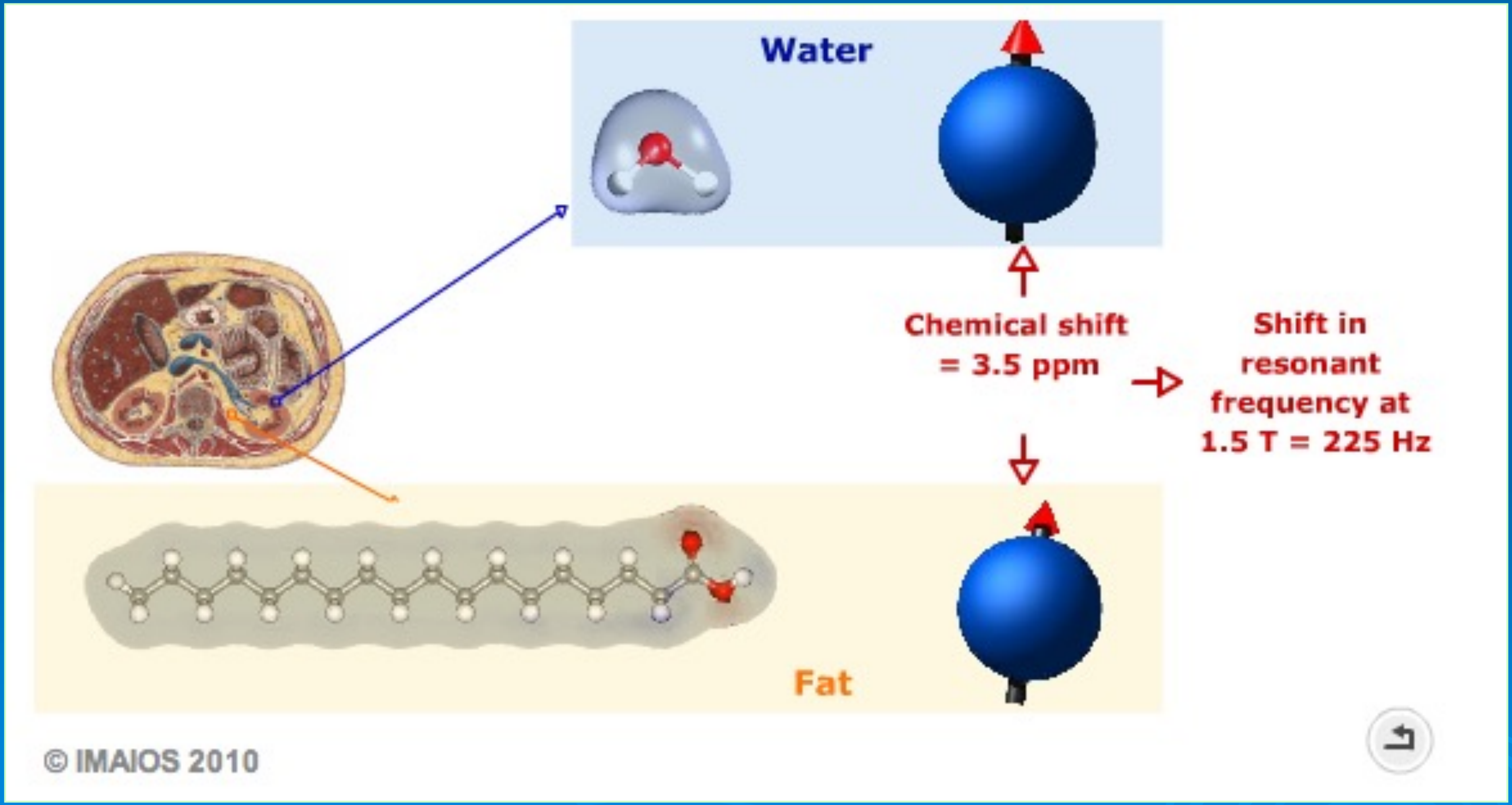
MRS
Magnetic Resonance Spectroscopy

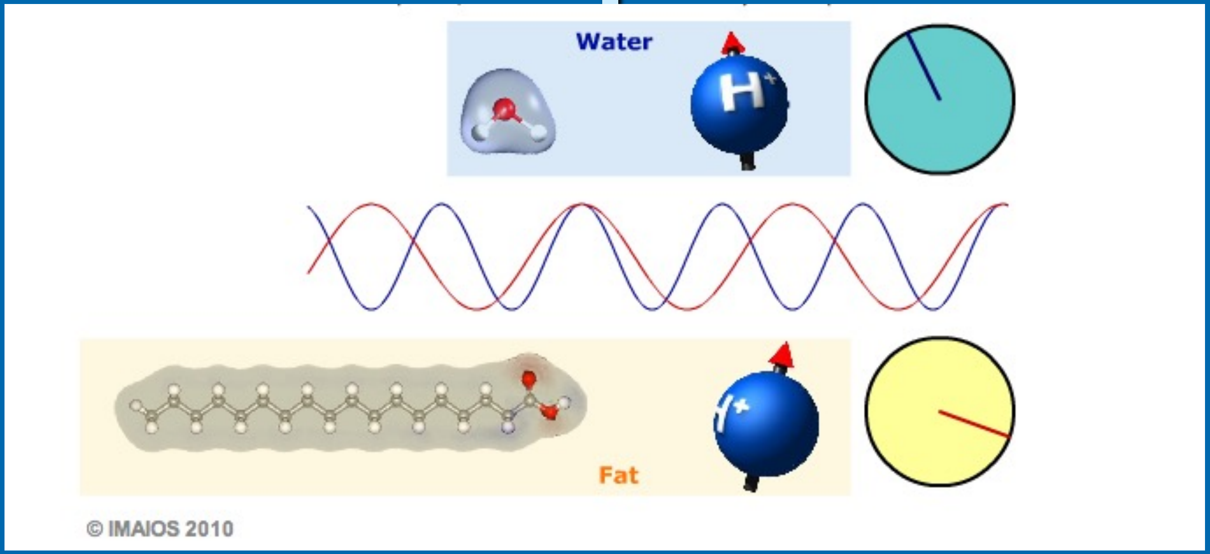
In vivo biochemistry

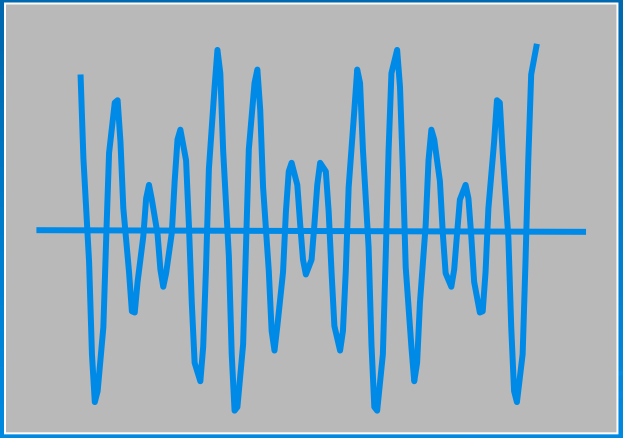
Chemical shift



- www.imaios.com/en/e-Courses/e-MRI/Image-quality-and-artifacts/chemical-shift

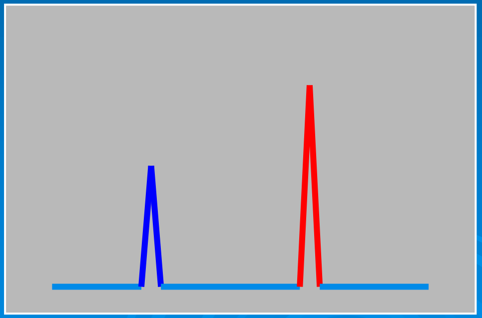
Chemical shift and MR spectrum





Received Signal

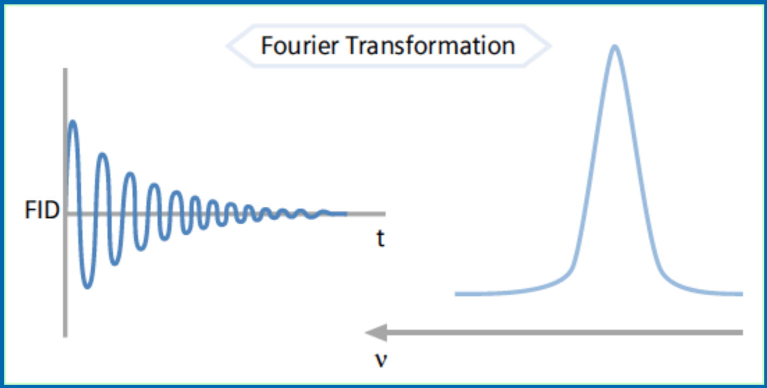
Fourier Transform

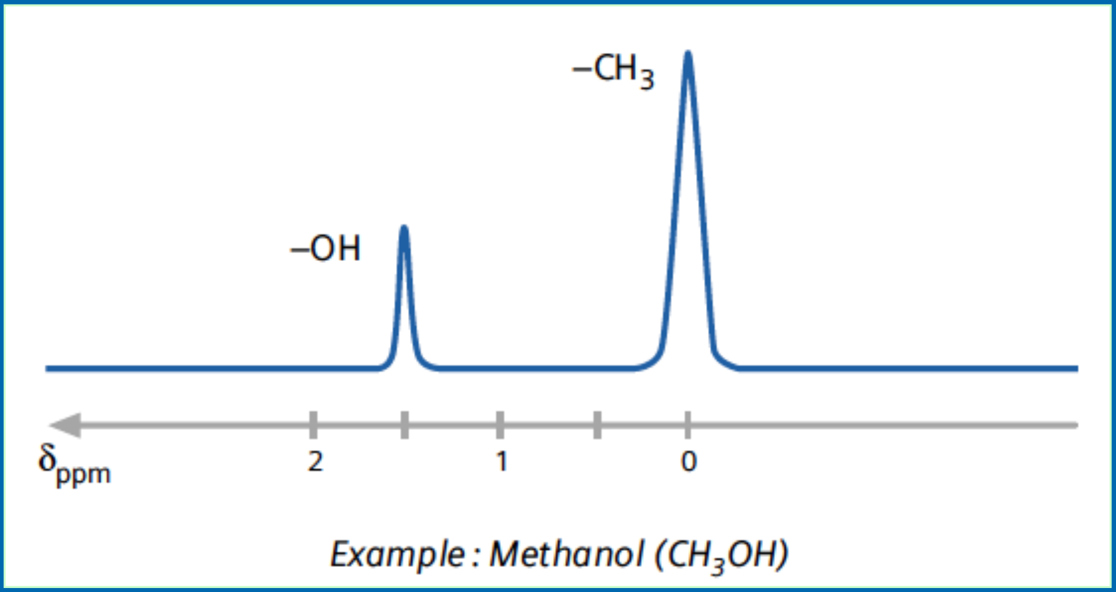


Image

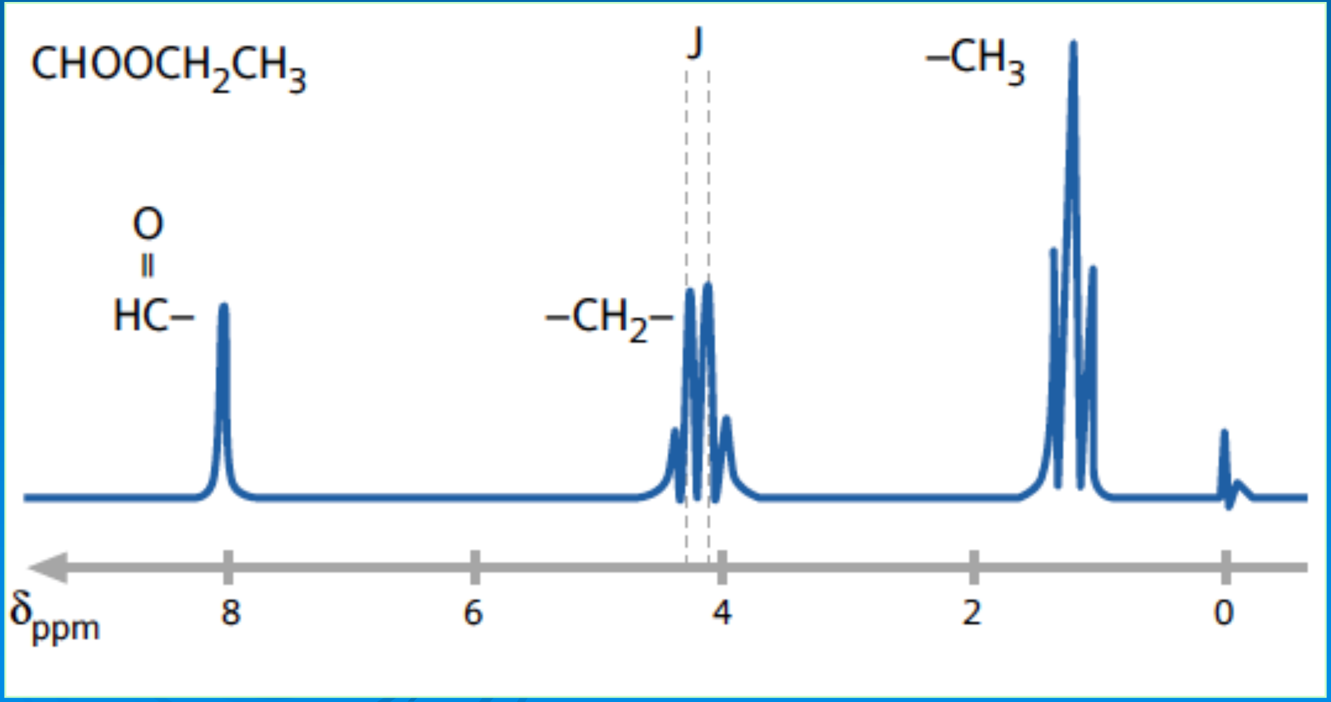
- www.imaios.com/en/e-Courses/e-MRI/Image-quality-and-artifacts/chemical-shift

^1H NMR spectra





- ✓ **Peaks pattern is footprint of molecules**
- ✓ **Peak area is proportional to the number of ^1H nuclei**



Proton spectroscopy

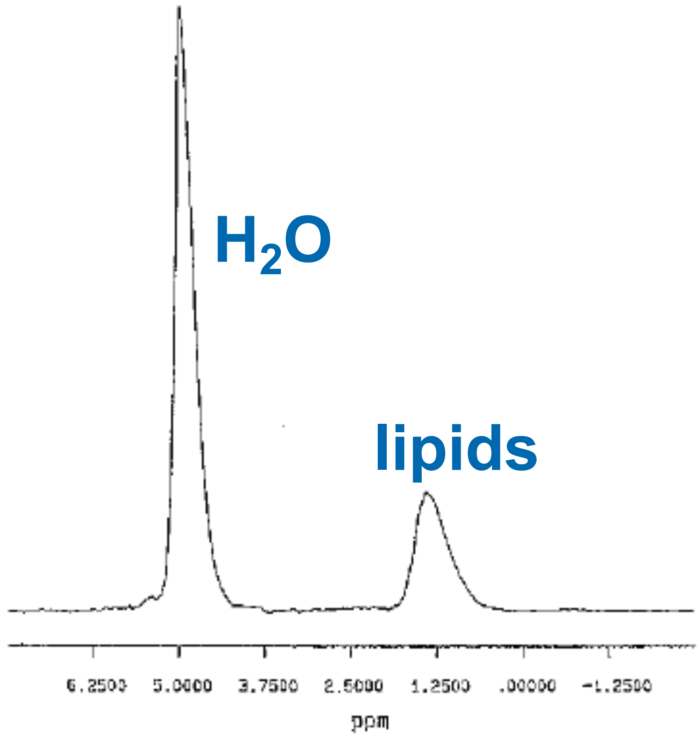
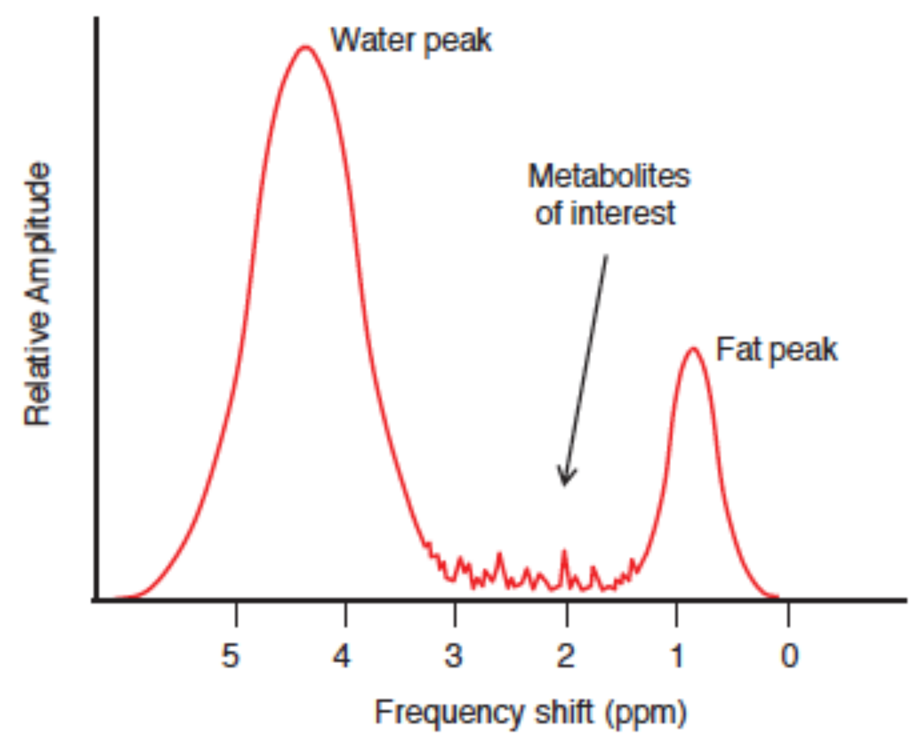
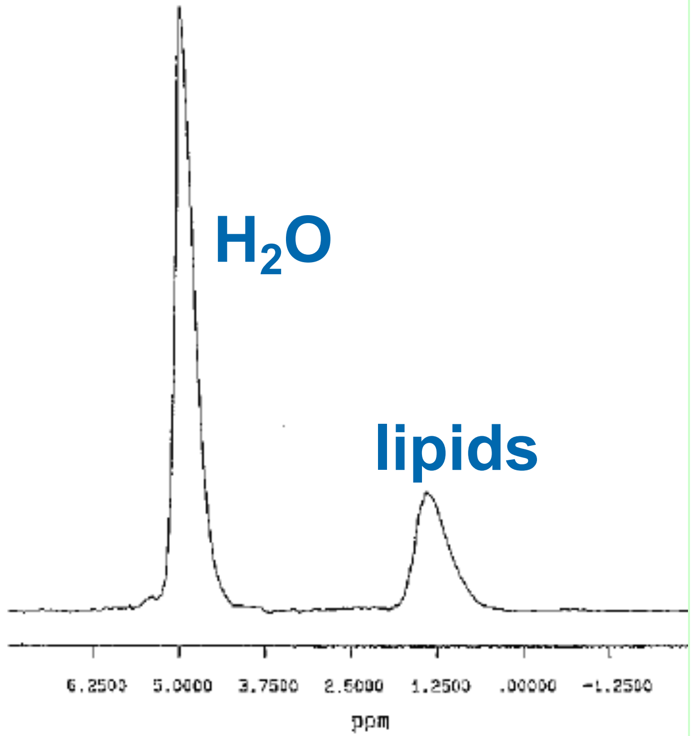


Figure 1. Typical in vivo H-1 spectrum from a steatotic liver (TR = 3 seconds, TE = 24 and 50 msec, four signals acquired, 262 cm³ volume of interest). No signal filtering before Fourier transformation and no baseline correction were applied.



- The water signal has to be suppressed

Proton spectroscopy



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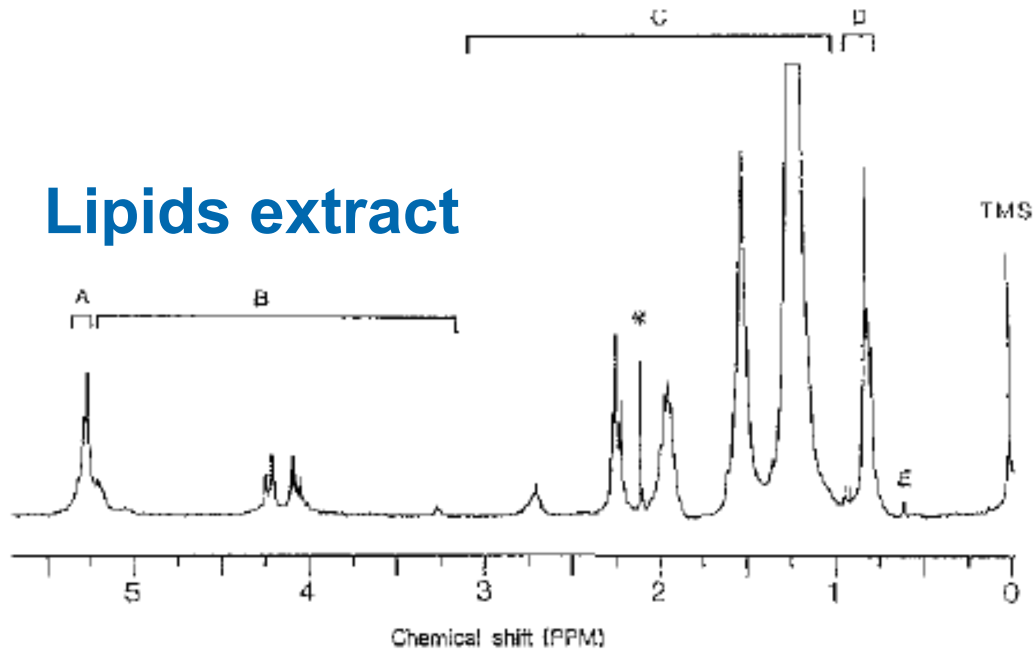
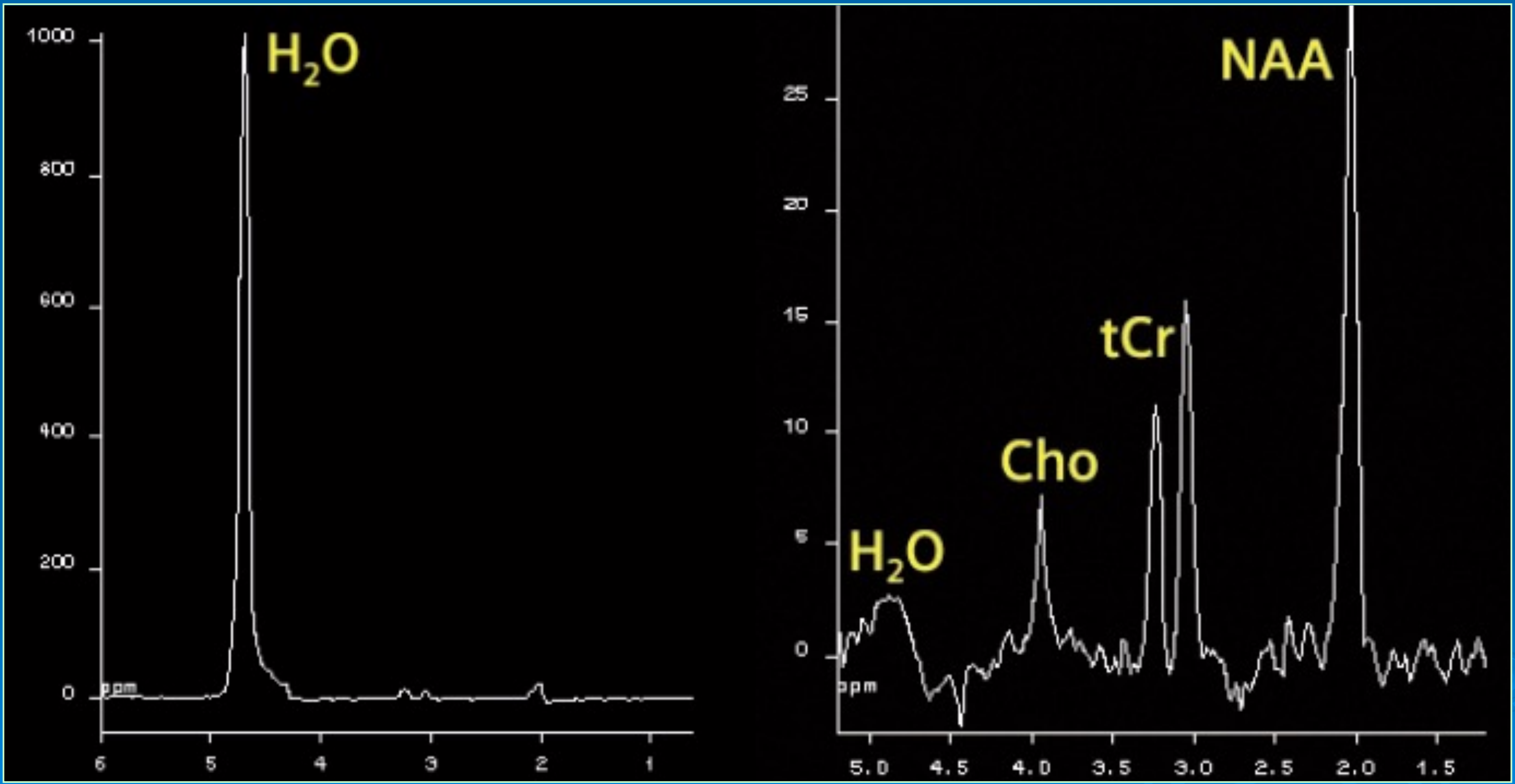


Figure 2. H-1 300-MHz spectrum of lipid extract obtained from a steatotic liver specimen. The major peaks assignable to protons in different positions on lipid molecules are *(A)* double bonds, *(B)* protons belonging to di- or triacylated glycerol and to the phosphocholine and phosphoethanolamine components of phospholipids, *(C)* methylene groups, *(D)* methyl groups, and *(E)* methyl signal assigned to carbon-18 of cholesterol. Acetone (*) and tetramethylsilane (*TMS*) (internal standard) are also shown.

- The water signal has to be suppressed

Water suppression



Spectrum without and with water suppression
Different scaling

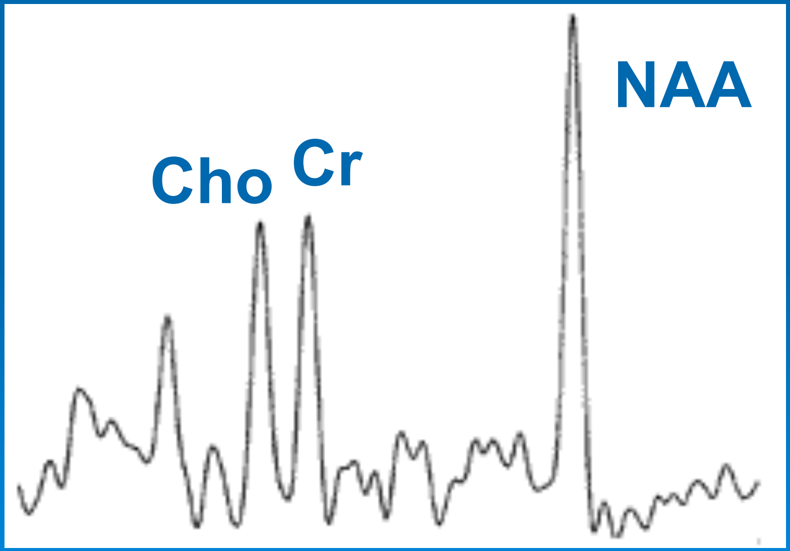
^{1}H MRS metabolites

ABBREVIATION	METABOLITE	SHIFT (PPM)	PROPERTIES/SIGNIFICANCE IN THE BRAIN
Cho	Phosphocholine	3.22	Membrane turnover, cell proliferation
Cr	Creatine	3.02 and 3.93	Temporary store for energy-rich phosphates
NAA	*N*-acetyl-L-aspartate	2.01	Presence of intact glioneural structures
Lactate		1.33 (inverted)	Anaerobic glycolysis
Lipids	Free fatty acids	1.2–1.4	Necrosis

Brain spectroscopy

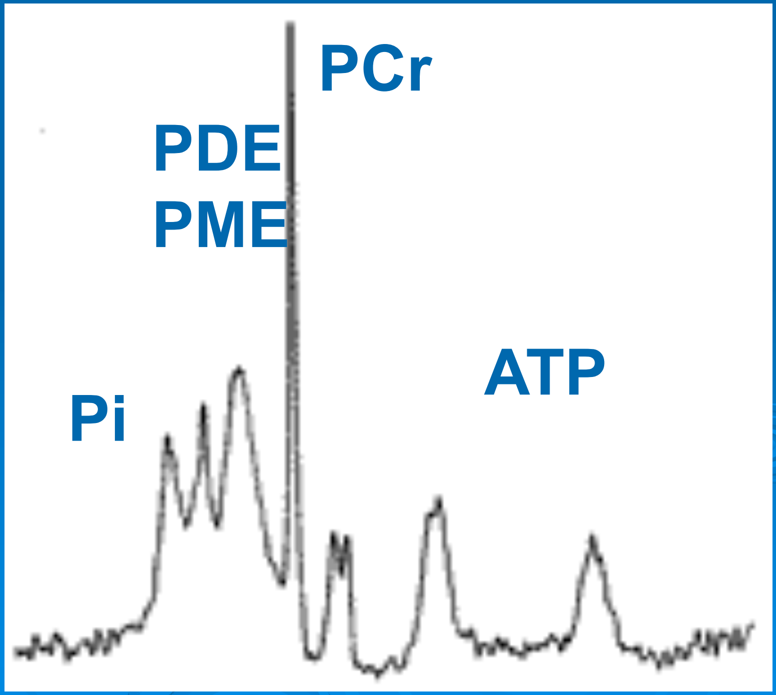
- The ^{1}H (or ^{31}P) nuclei in different molecules have slightly different resonance frequencies
- Each peak is related to a molecules (metabolite)

In vivo ^{1}H spectrum

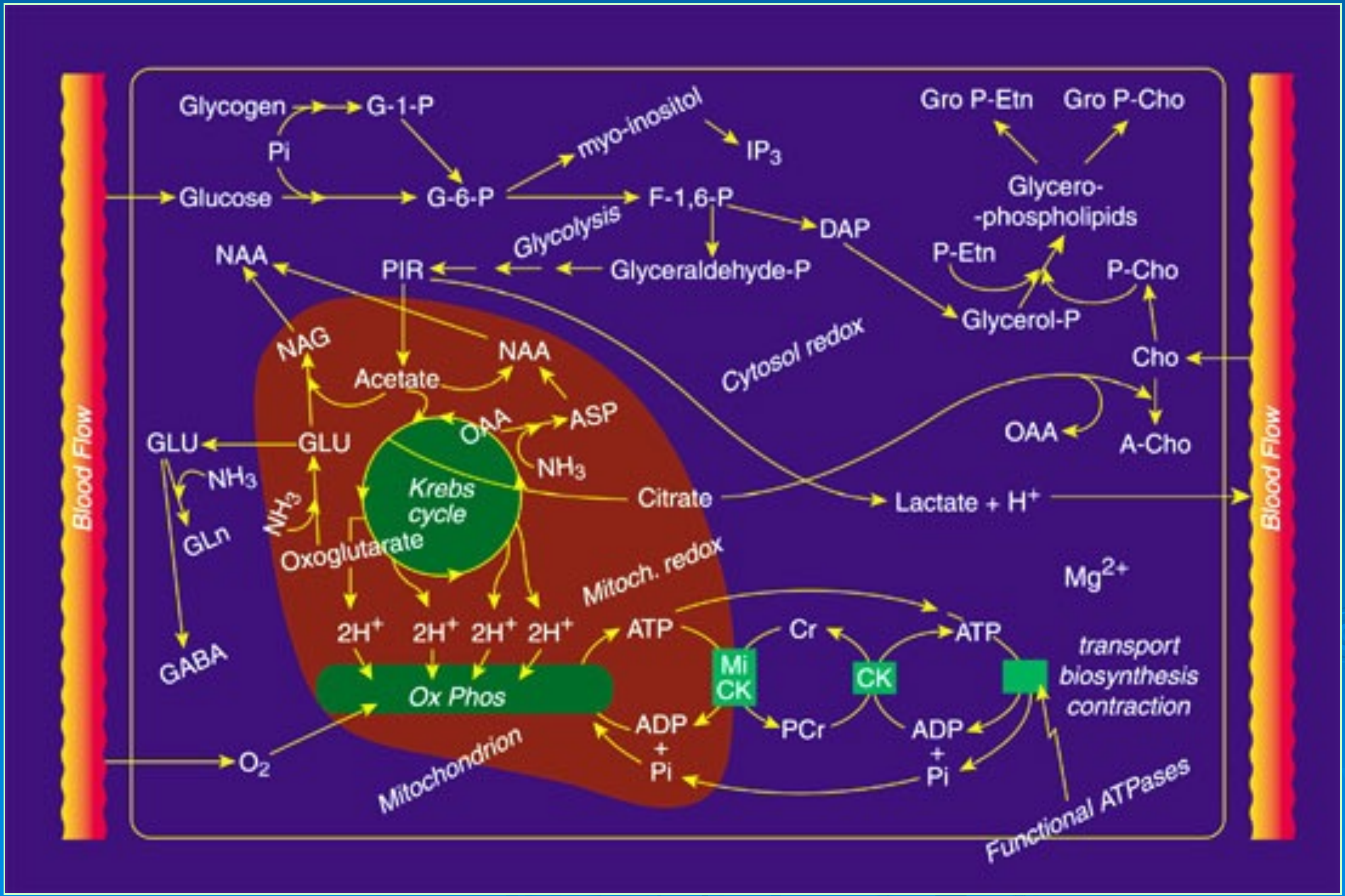


- Occipital cortex

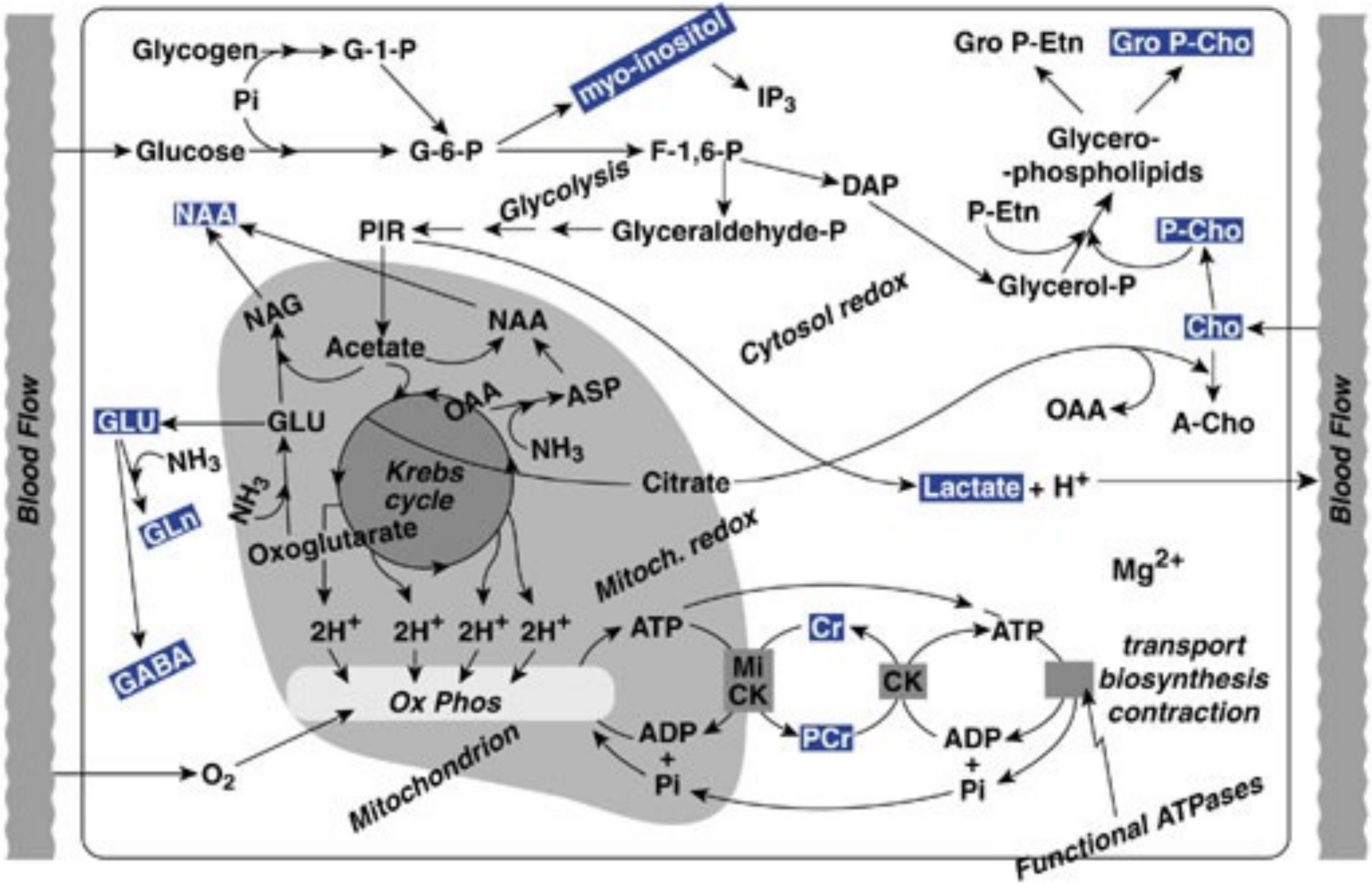
In vivo ^{31}P spectrum



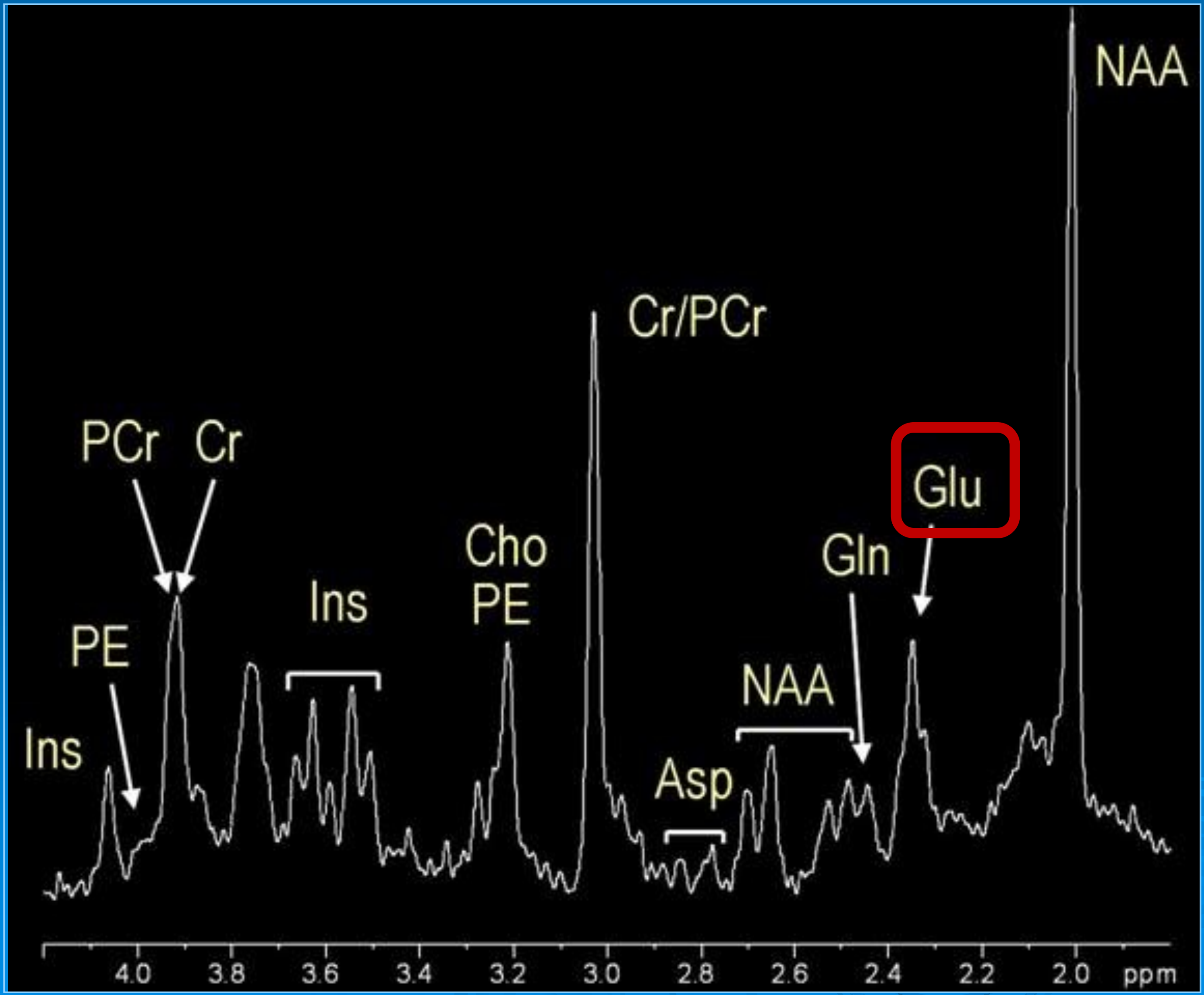
In vivo biochemistry



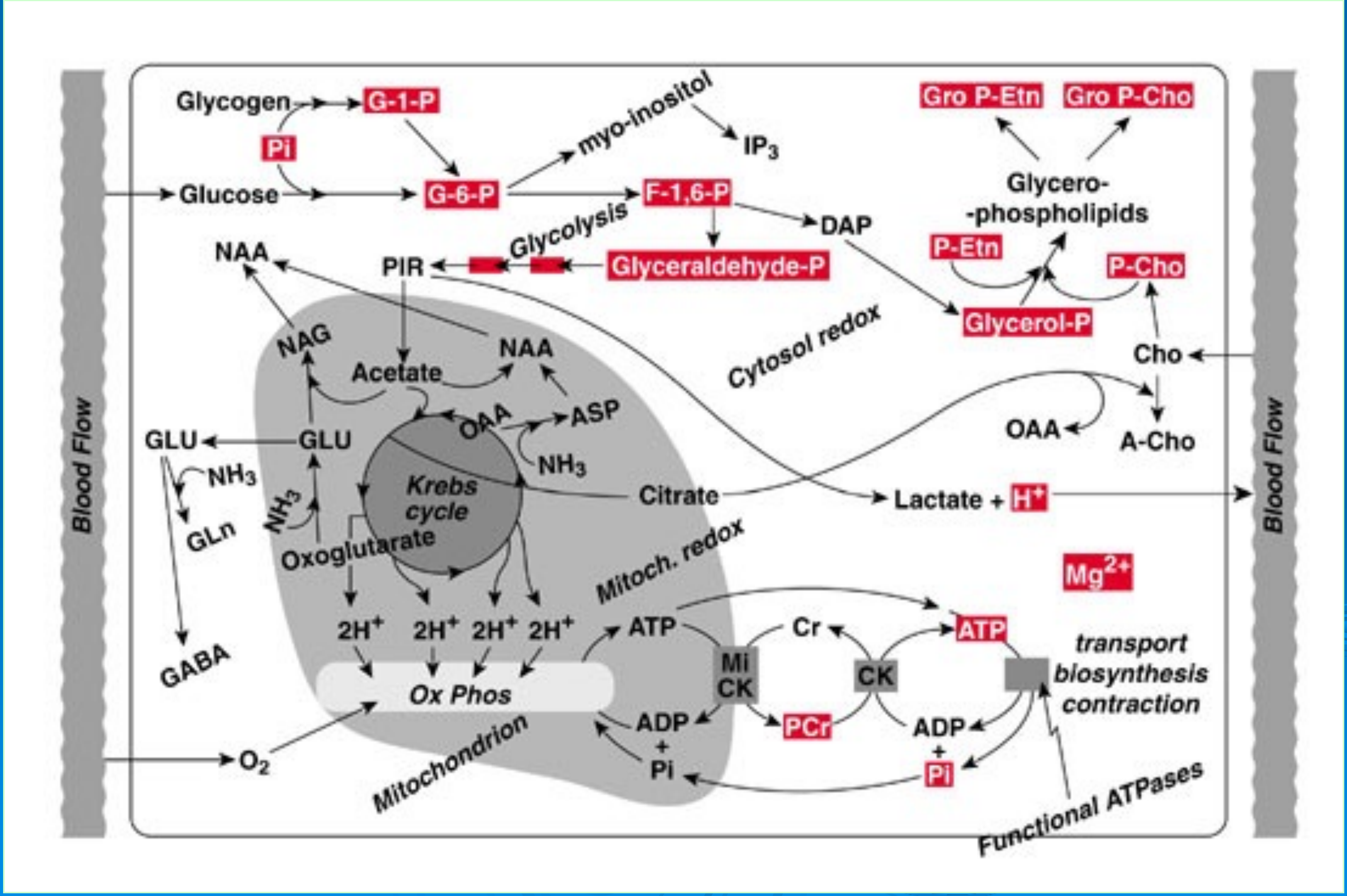
^1H spectroscopy



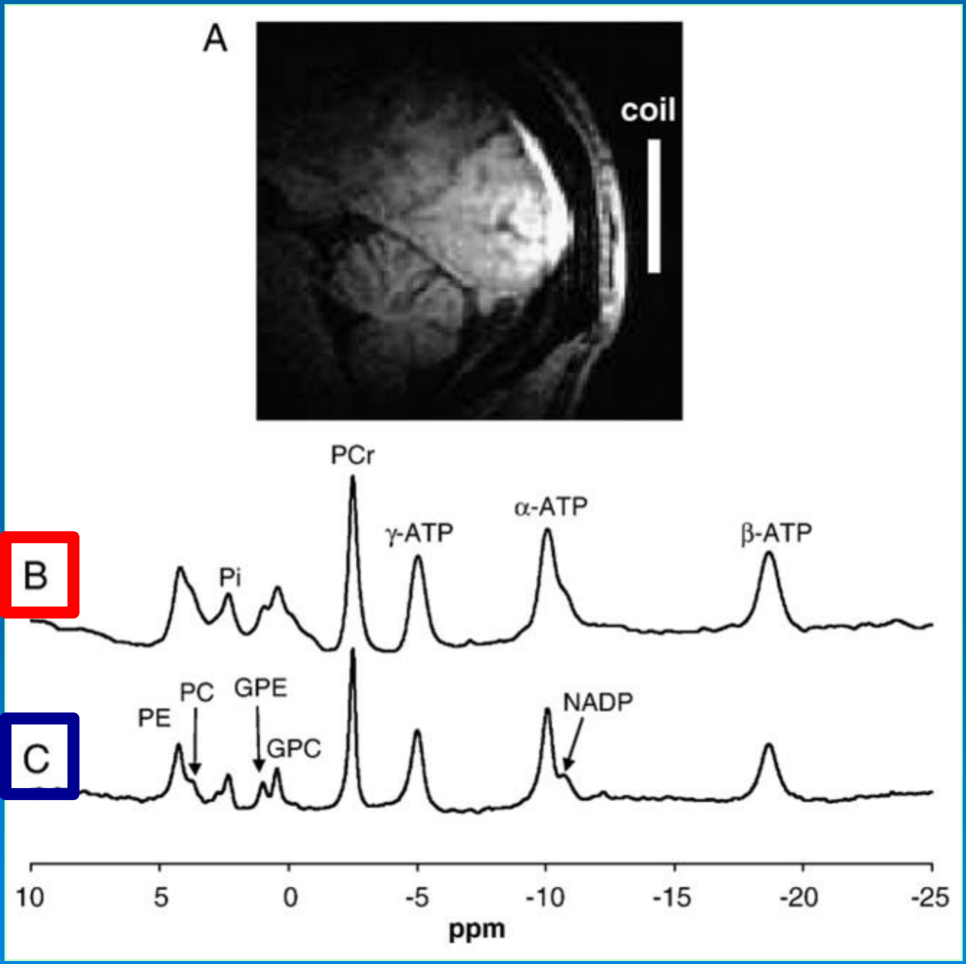
^{1}H spectroscopy



^{31}P spectroscopy



^{31}P MRS



In vivo ^{31}P spectra acquired from the human occipital lobe at (B) 4 T and (C) 7 T:

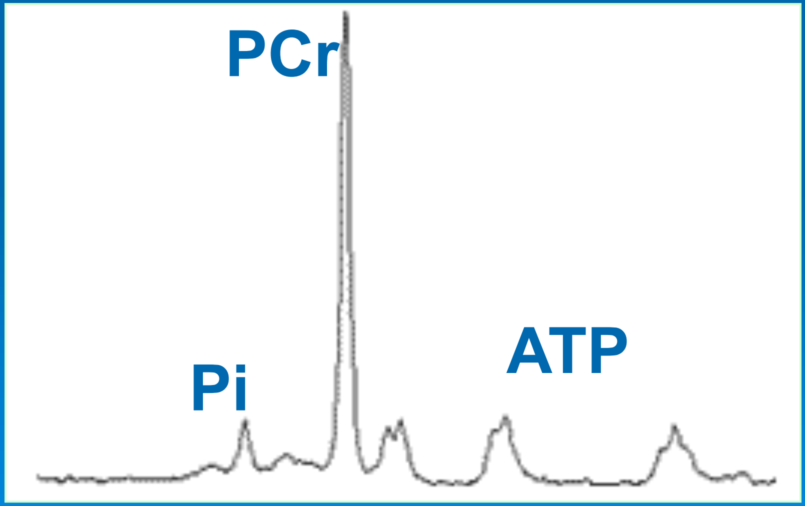
- PE phosphoethanolamine
- PC phosphocholine
- Pi inorganic phosphate
- GPE glycerophosphoethanolamine
- GPC, glycerophosphocholine
- PCr phosphocreatine
- ATP adenosine triphosphate
- NADP nicotinamide adenine dinucleotide phosphate

Qiao T. et al Magn Reson Imaging. 2006 24:1281-6

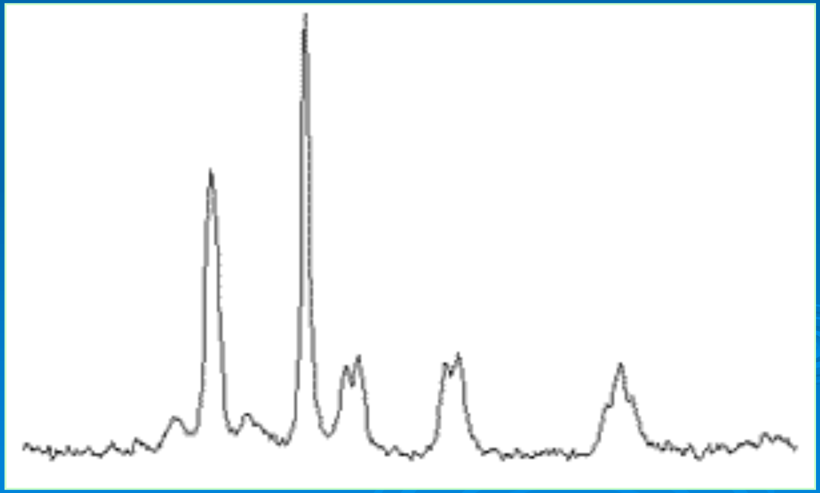
muscle 31PMRS

- Muscoli gastrocnemi normal subject

rest

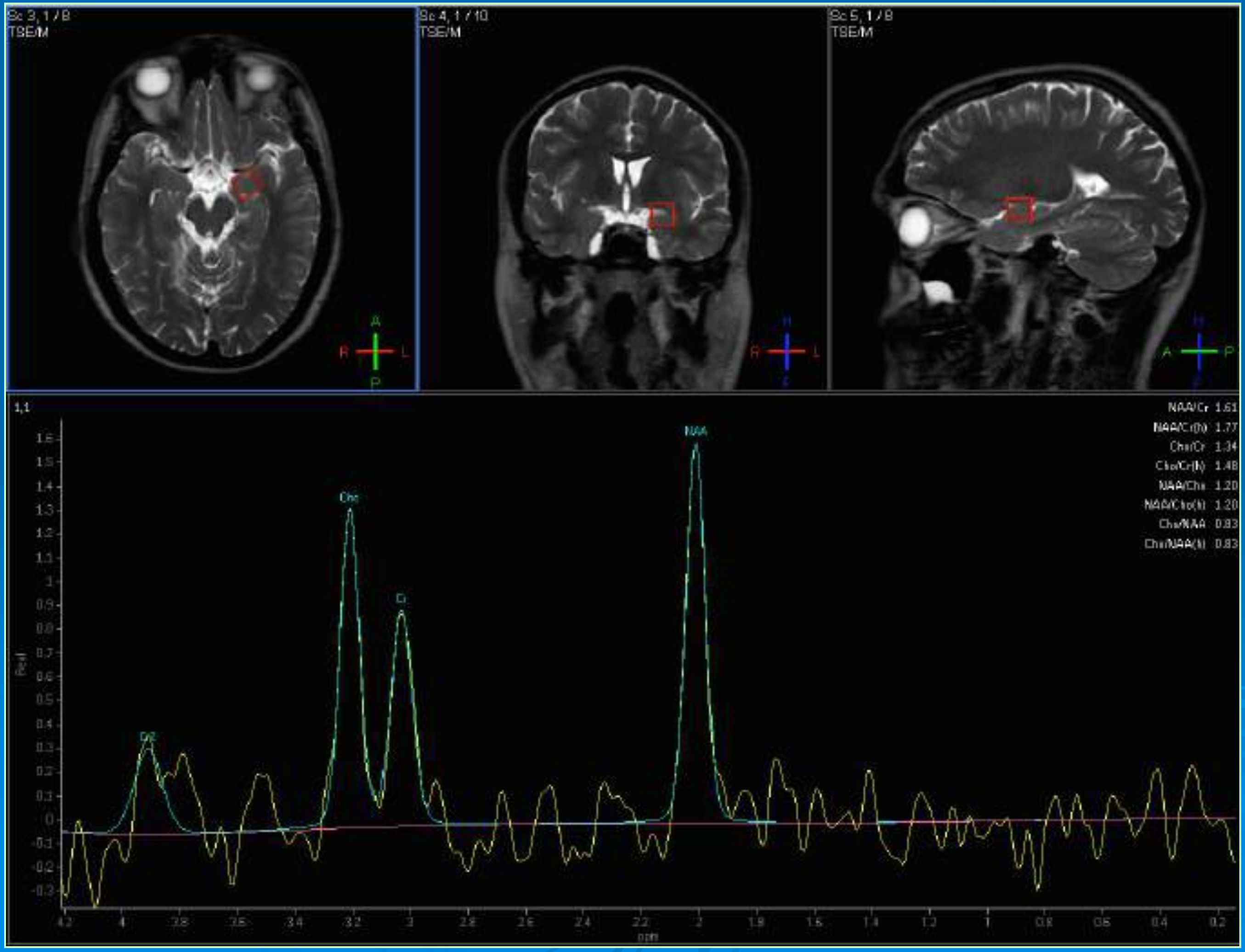


exercise



Signal localization

In *in vivo* MRS the signal localization is mandatory



Signal localization

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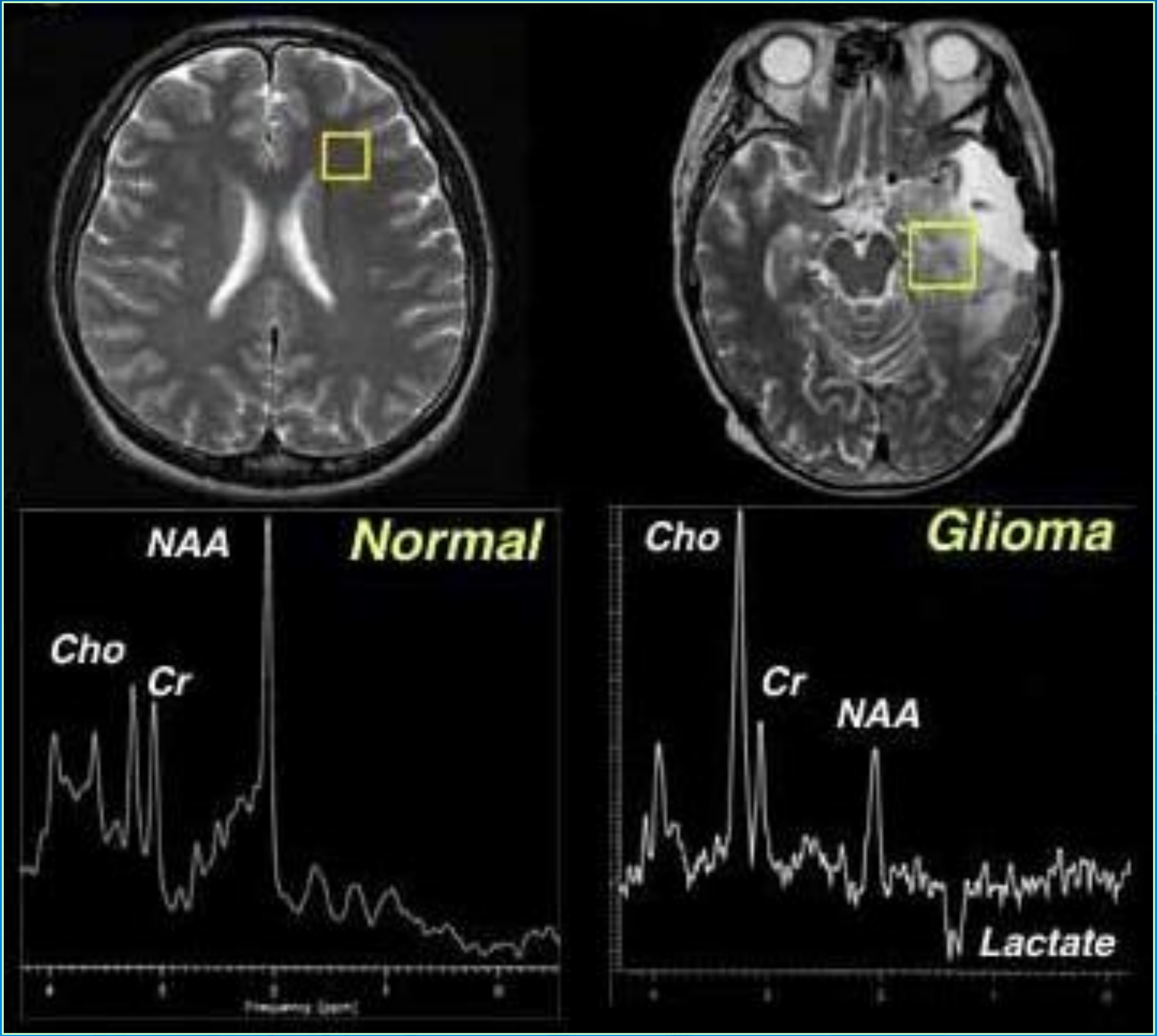
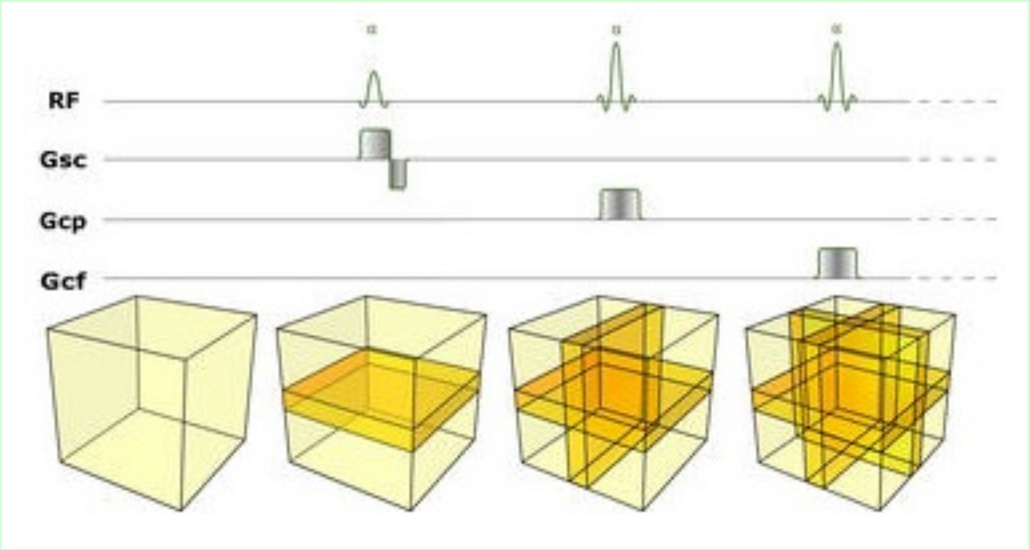
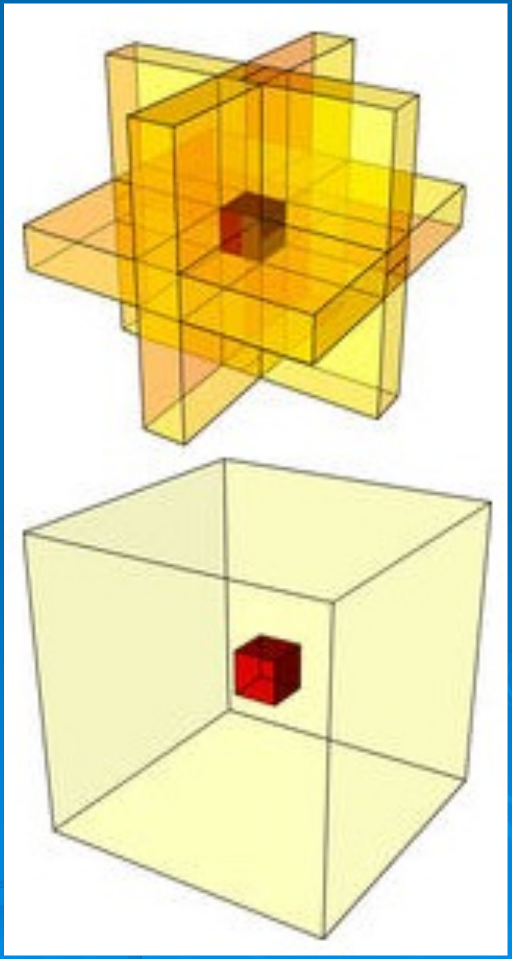
^{1}H MRS



Volume selection

✓The localization of the MRS signal is essential for in vivo application
✓Gradients are used localized spectroscopy
✓The simplest localization technique is the use of the surface coil

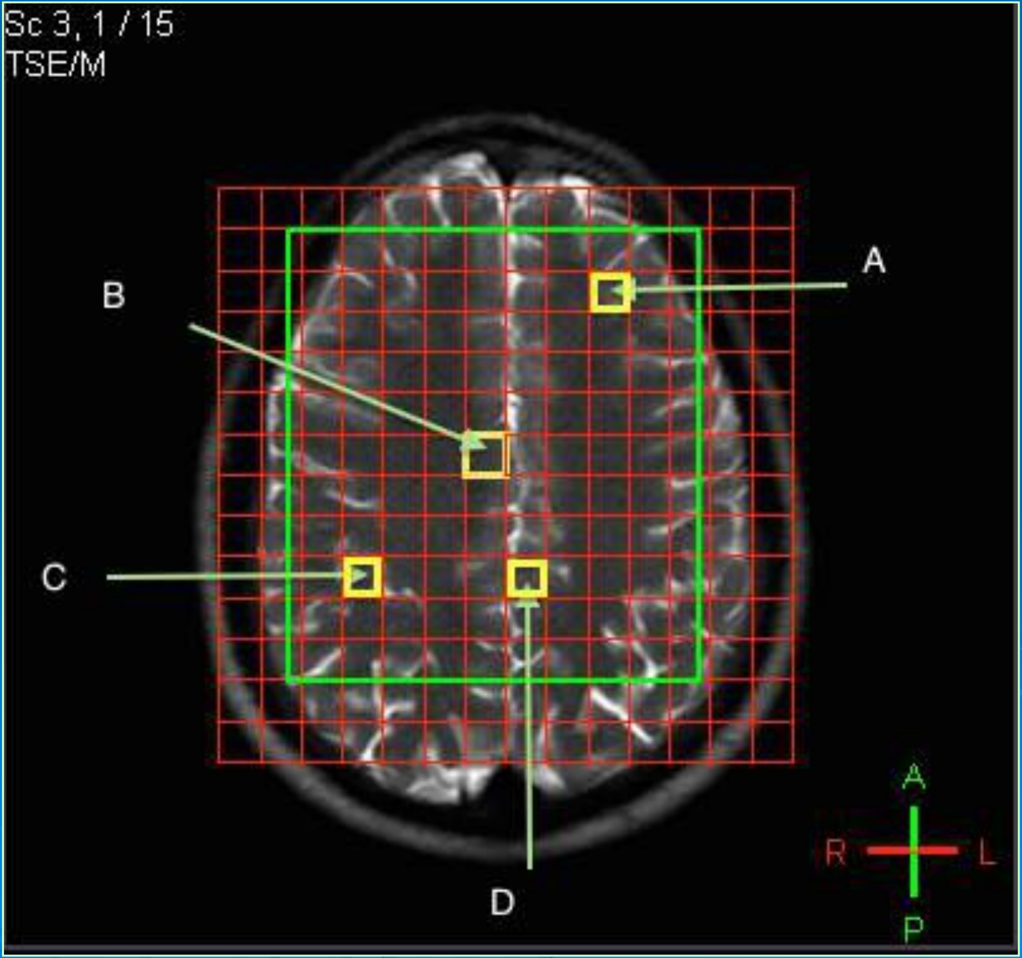




www.imaios.com/en/e-Courses/e-MRI/Magnetic-Resonance-Spectroscopy-MRS/single-voxel-spectroscopy

Spectroscopic imaging (Chemical shift imaging CSI)

- ✓CSI is an acquisition sequence that allows the acquisition of a spectrum per each voxel
- ✓The acquisition time is large (> 10 minutes)



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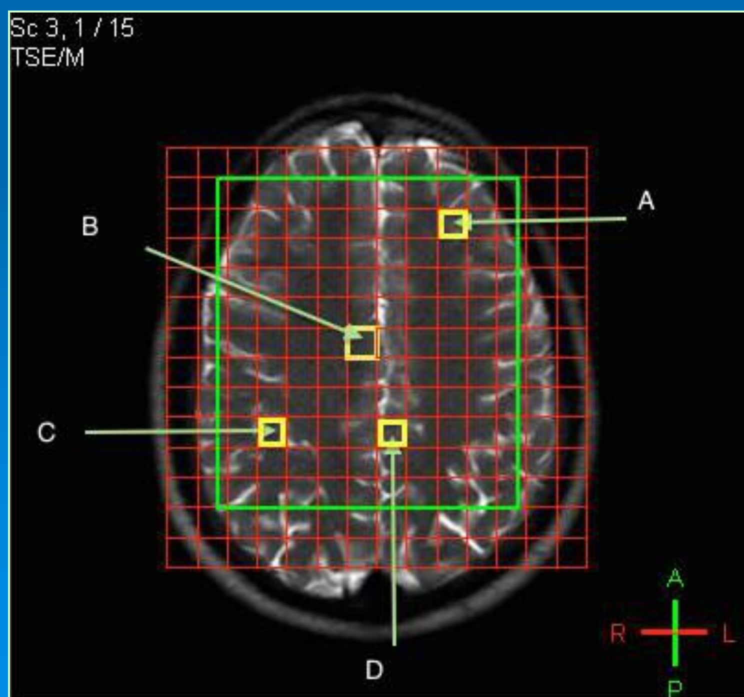

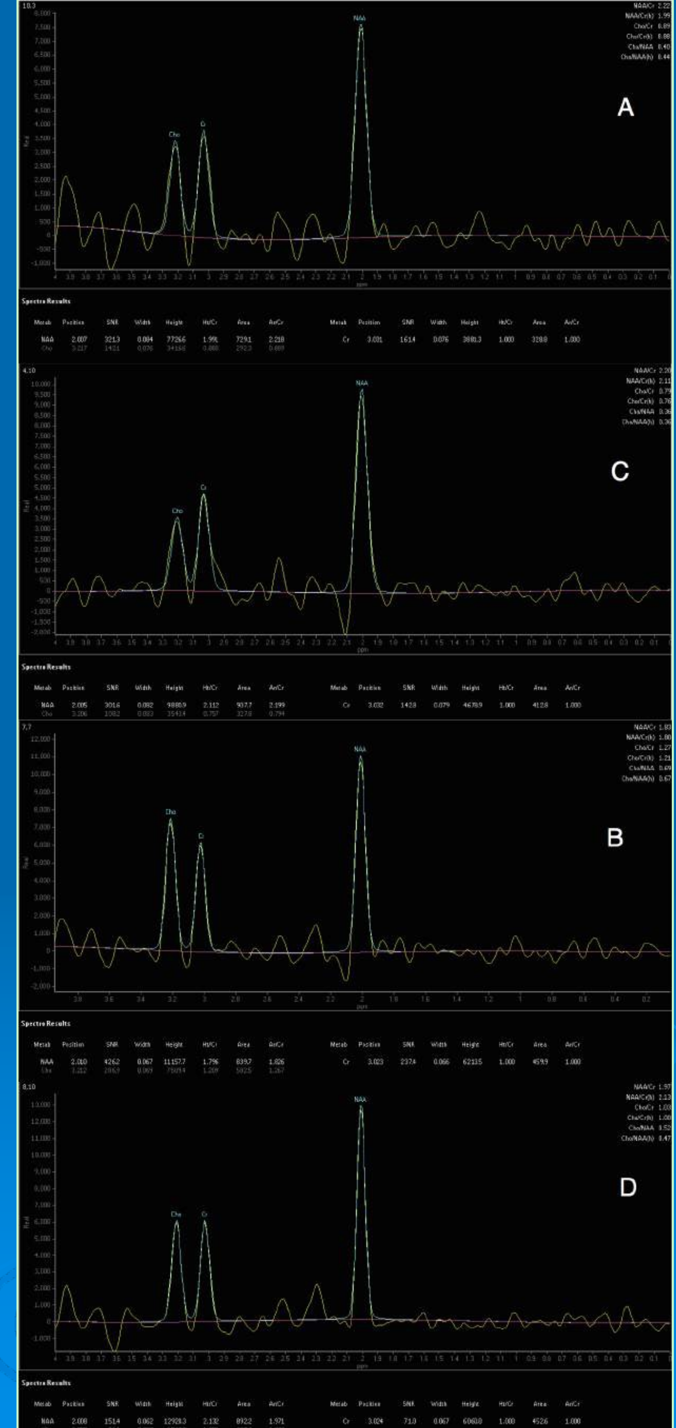

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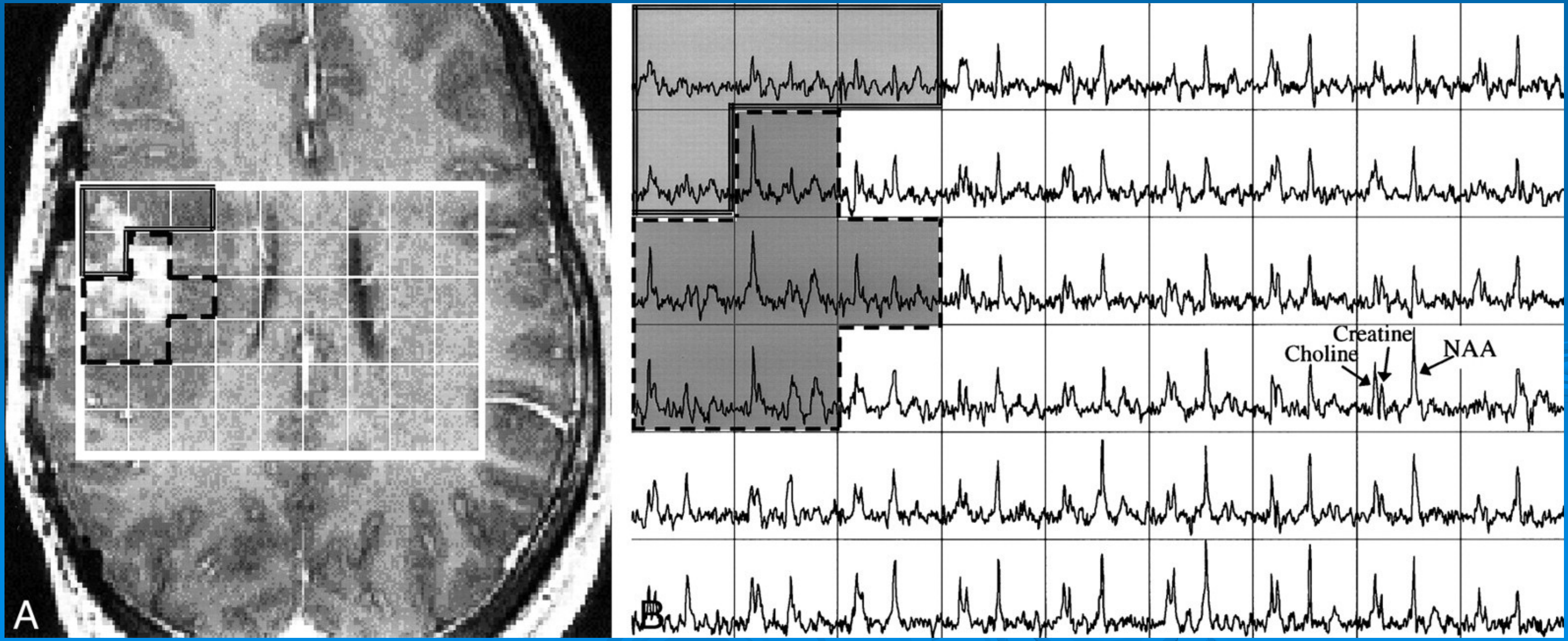

AJNR 22, 4 (2007)

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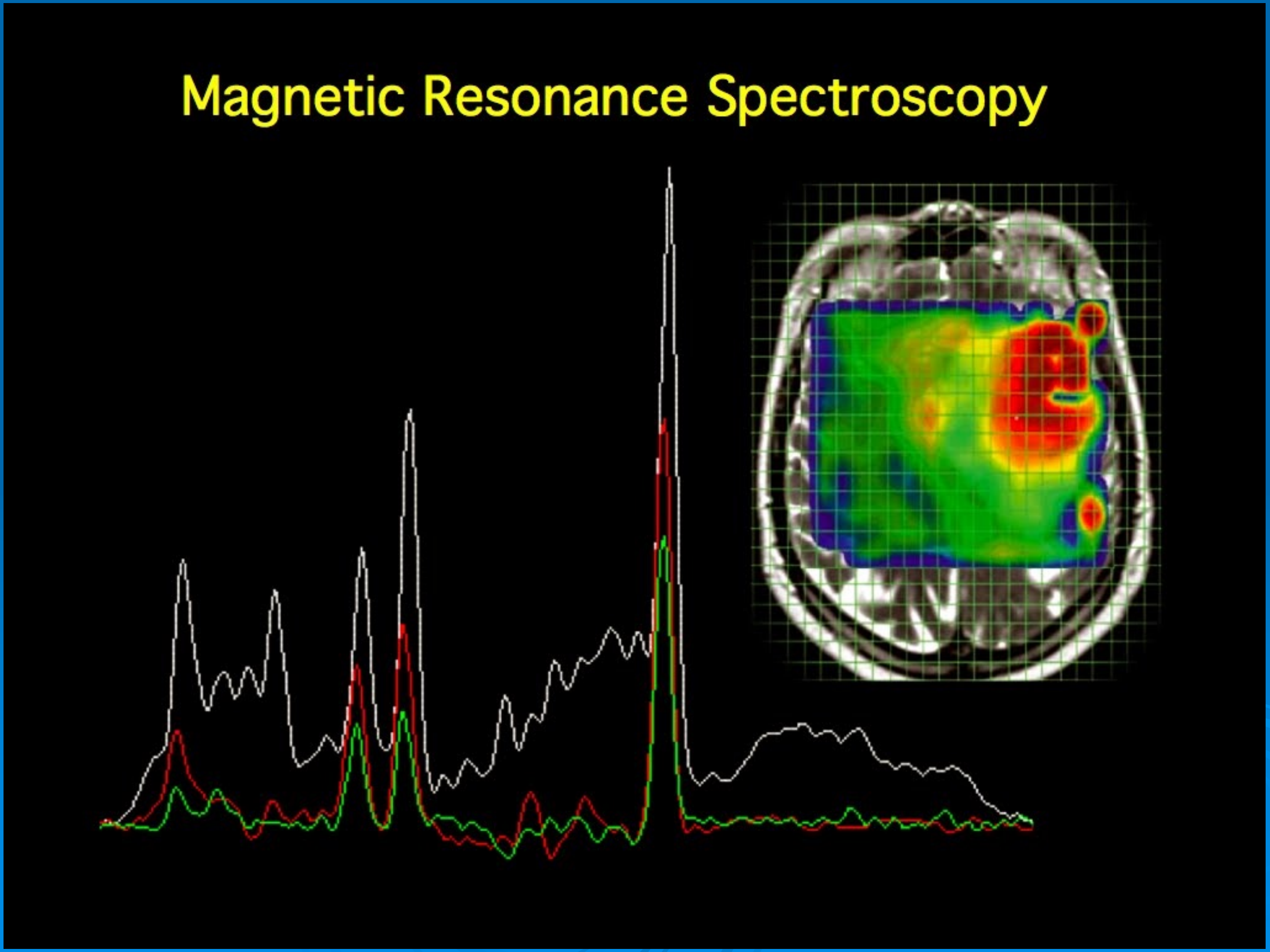

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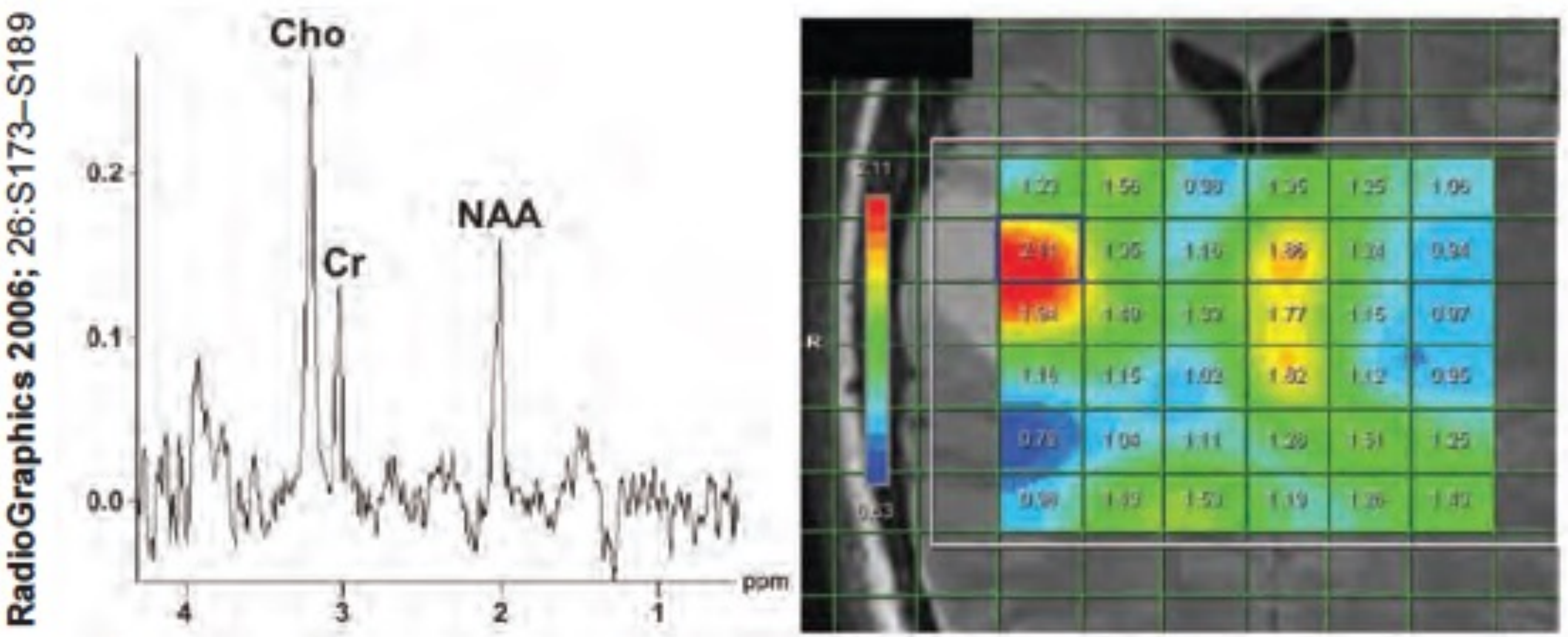
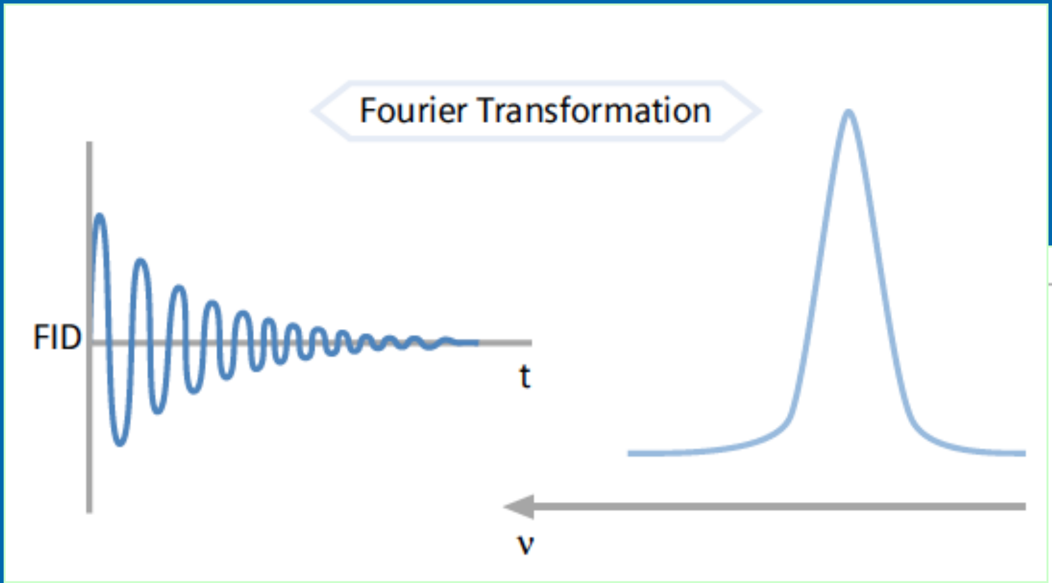
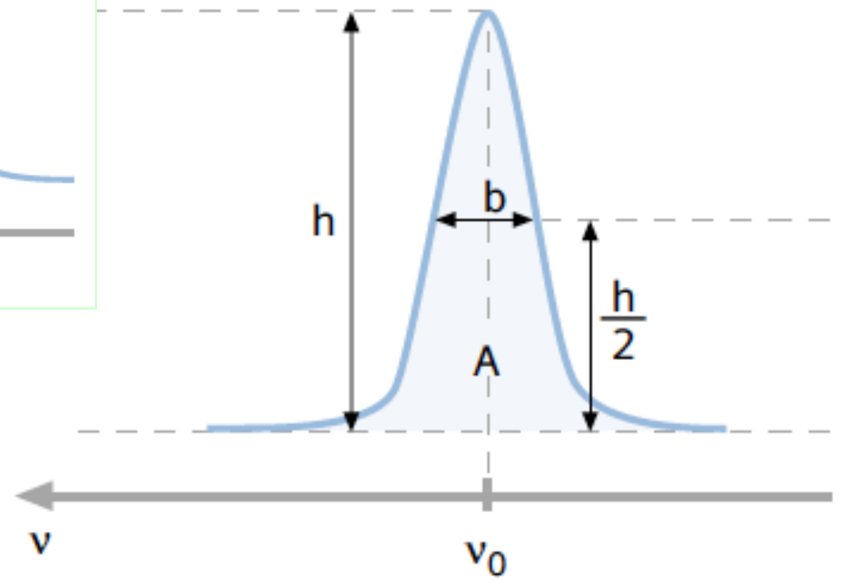


MR Spectrum from anaplastic oligoastrocytoma Choline / Creatine ratio map

Quantitative data analysis





- Resonance frequency: ν_0
- Height of peak: h
- Full Width at Half Maximum, FWHM: b
- Integral: A

Applications

frontiers in Psychiatry

REVIEW
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Functional Magnetic Resonance Spectroscopy: The "New" MRS for Cognitive Neuroscience and Psychiatry Research

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Preliminary evidence of the ability of ^{1}H fMRS to detect changes in <u>glutamate</u> during various perceptual, motor, and cognitive tasks.

Applications

Magnetic resonance spectroscopy assessment of brain injury after moderate hypothermia in neonatal encephalopathy: a prospective multicentre cohort study

Peter J Lally et al for the MARBLE consortium

Lancet Neurol 2019; 18: 35–45

Summary

Thalamic proton MRS measures acquired soon after birth in neonatal encephalopathy had the highest accuracy to predict neurodevelopment 2 years later.

Applications

Magnetic resonance spectroscopy assessment of brain injury after moderate hypothermia in neonatal encephalopathy: a prospective multicentre cohort study

Lancet Neurol 2019; 18: 35–45

Methods

- ✓ 3.0 Tesla scanner
- ✓ single 15 × 15 × 15 mm^3 voxel centred on the left thalamus
- ✓ ^1H MRS metabolite peak area ratios (7 min)
- ✓ 1H MRS metabolite absolute concentrations (25 min)
- ✓ diffusion weighted MRI (DW MRI; 7 min)