Center for Biomedical Imaging

AN INTRODUCTION TO MR NEUROIMAGING & SPECTROSCOPY

Lijing Xin

CIBM EPFL MRI

27.02.2025

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INTRODUCTION TO THE COURSE

TEACHERS

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Bernard Lanz

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Eleonora Fornari

Ileana Jelescu

Ruud van Heeswijk

Antoine Klauser

Antoine Kaiser

PROGRAM OF THE COURSE

Thursday 13:15-17:00

Session 1: Feb 27, 2025	Session 3: Mar 6, 2025	Session 5: Mar 20, 2025	Session 7: Apr 3, 2025 (Campus Biotech, Geneva)
08:15 – 09:00: Introduction to MRI and MRS (Xin) **09:15 – 10:00**: Introduction to MRI and MRS (Xin) **10:15 – 11:00**: Ethics for Human Study (Fornari) **11:15 – 12:00**: Ethics for Animal Study (Cudalbu)	**13:15 – 14:30**: Fast MR Imaging Methods (Zerbi) **14:45 – 15:45**: Functional Magnetic Resonance Imaging and Applications (Zerbi) **16:15 – 17:00**: MRI Sequences and Applications of Diffusion-Weighted Imaging (Jelescu)	**13:15 – 14:00**: RF Theory: Introduction and Demonstration (Wenz) **14:15 – 17:00**: Hands-On: RF Coil Construction and Characterization at the Bench (Wenz)	**13:15 – 17:00**:human MRI & MRS practical teaching (Xin, Kaiser)
Session 2: Feb 27, 2025	**Session 4: Mar 13, 2025**	**Session 6: Mar 27, 2025**	**Session 8: Apr 10, 2025**
13:15 – 14:00: Basics of Nuclear Magnetic Resonance I (Wenz) **14:15 – 15:00**: Basics of Nuclear Magnetic Resonance II (Lanz) **15:15 – 16:00**: Basics of MRI (Cudalbu) **16:15 – 17:00**: Basic MR Sequences (van Heeswijk)	**13:15 – 14:00**: RF Theory: Introduction and Demonstration (Wenz) **14:15 – 17:00**: Hands-On: RF Coil Construction and Characterization at the Bench (Wenz)	**13:15 – 14:00**: Introduction of MRS I (Xin) **14:15 – 15:00**: Introduction of MRS II (Xin) **15:15 – 16:00**: Basics of MRSI (Cudalbu) **16:15 – 17:00**: Basics of MRSI (Cudalbu)	**13:15 – 14:00**: X nuclei MRS (13C, 31P, 15N, 2H). (Xin) **14:15 – 15:00**: MRS Quantification (Cudalbu) **15:15 – 17:00**: Interpretation of dynamic X-nuclei experiments with metabolic modelling (Lanz)

PROGRAM OF THE COURSE

Thursday 13:15-17:00

Session 9: Apr 17, 2025	**Session 11: May 8, 2025**	**Session 13: May 22, 2025**	
13:15 – 16:00: - 1H MRS quantification(Cudalbu) **16:15-17:00** - Fast Magnetic Resonance Spectroscopic Imaging and reconstruction techniques (Klauser)	**13:15 – 17:00**:Lab for structure MRI processing (VBM and SBM) and fMRI (Bach Cuadra & Fornari)	**13:15 – 17:00**: Animal MRI & MRS practical teaching (Lanz, Cudalbu)	
Session 10: May 1, 2025	**Session 12: May 15, 2025**		
13:15 – 17:00: Theory of clinical MRI segmentation and registration. Introduction to surface and voxel based morphometry (VBM and SBM) and fMRI processing. (Bach Cuadra & Fornari)	**13:15 – 17:00**: Data processing using in-house developed tools for MRS and MRI (Cudalbu)		

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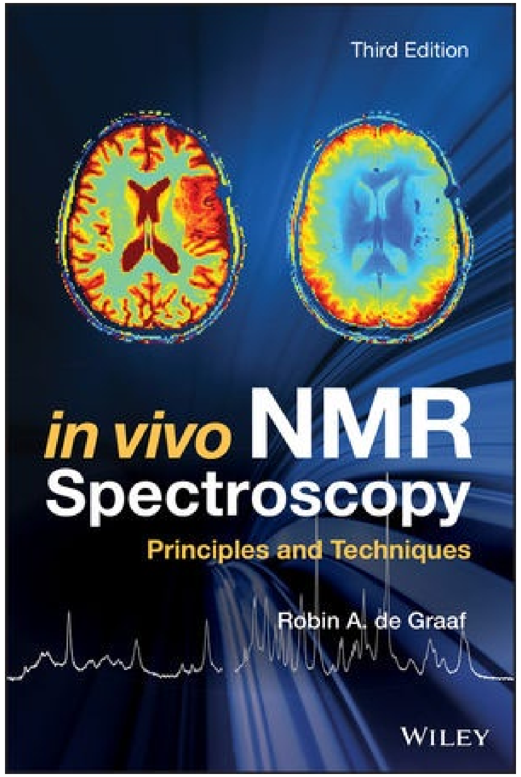
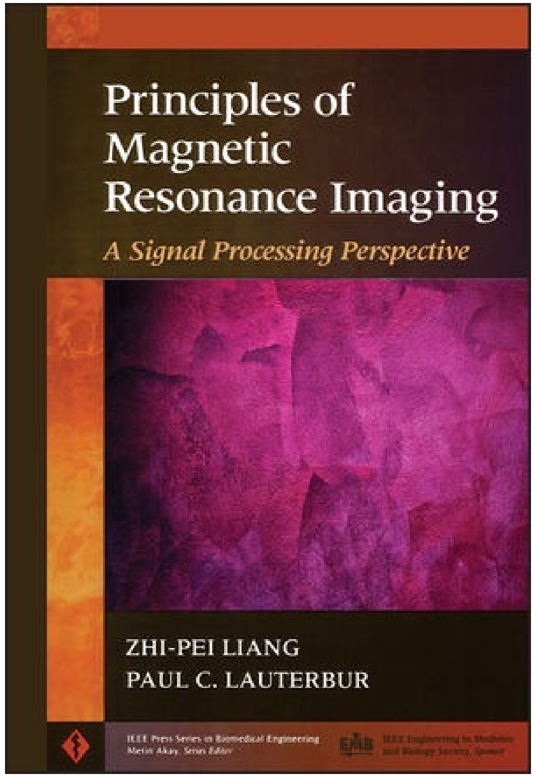
LEARNING OUTCOMES

- Know the essential elements in designing a translational neuroimaging study
- Understand the physical principles of MRI and MRS
- Know how to establish MRI and MRS acquisition protocols
- Know how to perform experiments independently on clinical and preclinical scanners, and analyze results for the research topic of interest.
- Know how to interpret results of neuroimaging and MRS data

STUDY RESOURCE





- https://www.youtube.com/playlist?list=PL471uBfQUs9qcODBkQGJTZkcbIIKrjKry

EXAM: MINI PROPOSAL

Submission deadline: June 15th

Topics: free-choice, including novel elements (methods or topics) beyond your current project

1. Project summary (max. 1 page)
2. Project plan (max. 5 pages)
   - background
   - hypothesis and aims
   - research approaches (study design, MR protocols, justification for methods of choice, data processing methods, statistical plan)
   - description of the potential impact of the research project
3. Bibliography

OUTLINE

- History: from NMR to MRI
- Introduction to MRI & MRS: structure, function, and metabolism
- Translational applications in psychiatric diseases
- MRI procedure & safety

HISTORY: FROM NMR TO MRI

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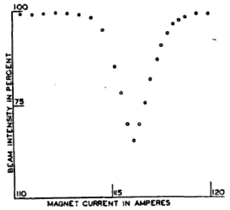
- (1924) By Pauli, nuclear particles have angular momentum (spin)
- (1937) By Rabi, measurement of magnetic moment of nucleus, "magnetic resonance"



- (1946) Edward Purcell, matter absorbs energy at a resonant frequency
- (1946) Felix Bloch, nuclear precession can be measured in detector coils

- (1959) Singer, measurement of blood flow using NMR (in mice)
- (1972) Damadian, patent idea for large NMR scanner to detect malignant tissue
- (1973) Paul Lauterbur, publish generating images using NMR gradients

- (1975) Ernst, develop 2D-Fourier transform for MR

- (1990) Ogawa and colleagues, obtain functional images using BOLD contrast
- (2005) UHF 7.0 T MRI developed by Harvard, NIH, Gachon, and Magdeburg

- 1991: Richard Ernst Chemistry (High-resolution pulsed FT-NMR)

Magnetic **R**esonance **I**maging

1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020

- (1944) Rabi, award Nobel Prize in Physics

- (1952) Purcell and Bloch, share Nobel Prize in Physics

- (1973) Peter Mansfield, published gradient approach to MR
- (1980s) 1.5 T and 2.0 T superconducting MRI developed by Goldstar, GE, and Siemens
- (2003) Lauterbur and Mansfield, share Nobel Prize in Physiology and Medicine

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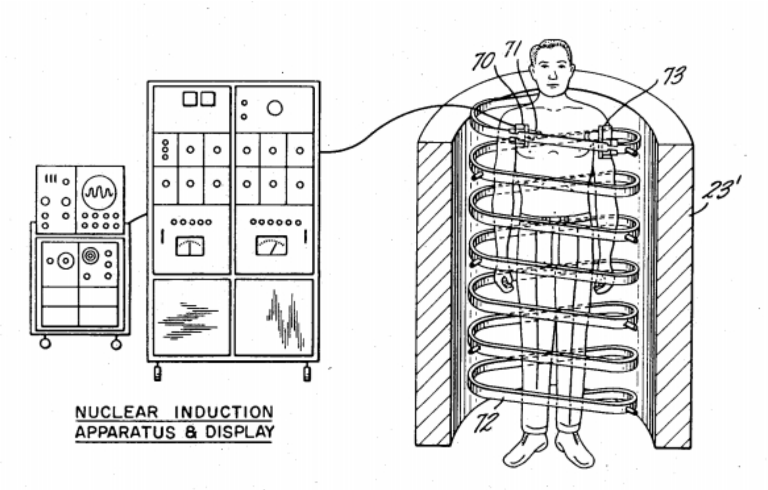
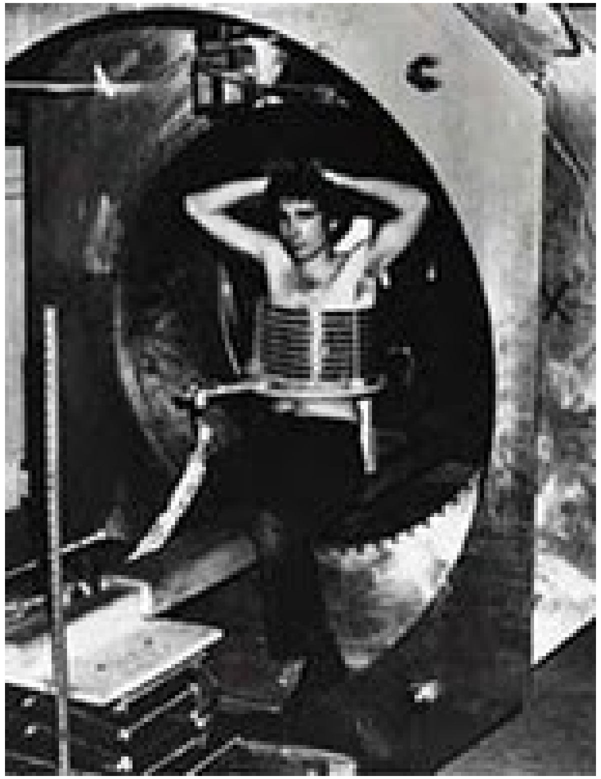
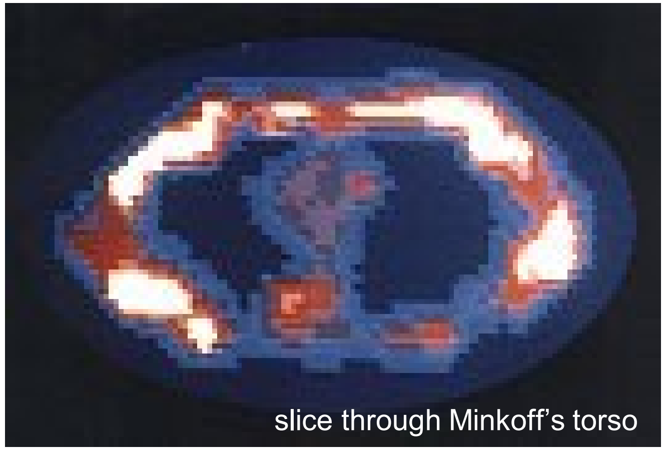
FIRST HUMAN MRI (1977)

Damadian’s grad student, Larry Minkoff, in “Indomitable”, the first MRI scanner



Damadian's 1972 patent application





4 hours to get one slice

https://www.smithsonianmag.com/science-nature/the-indomitable-mri-29126670/

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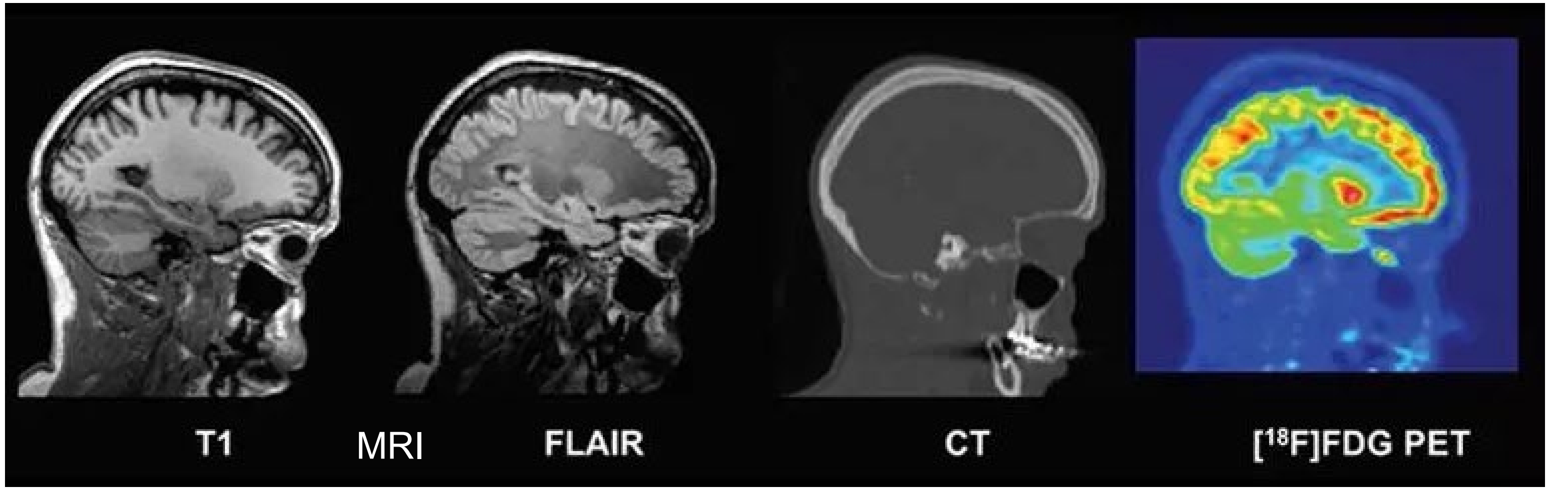
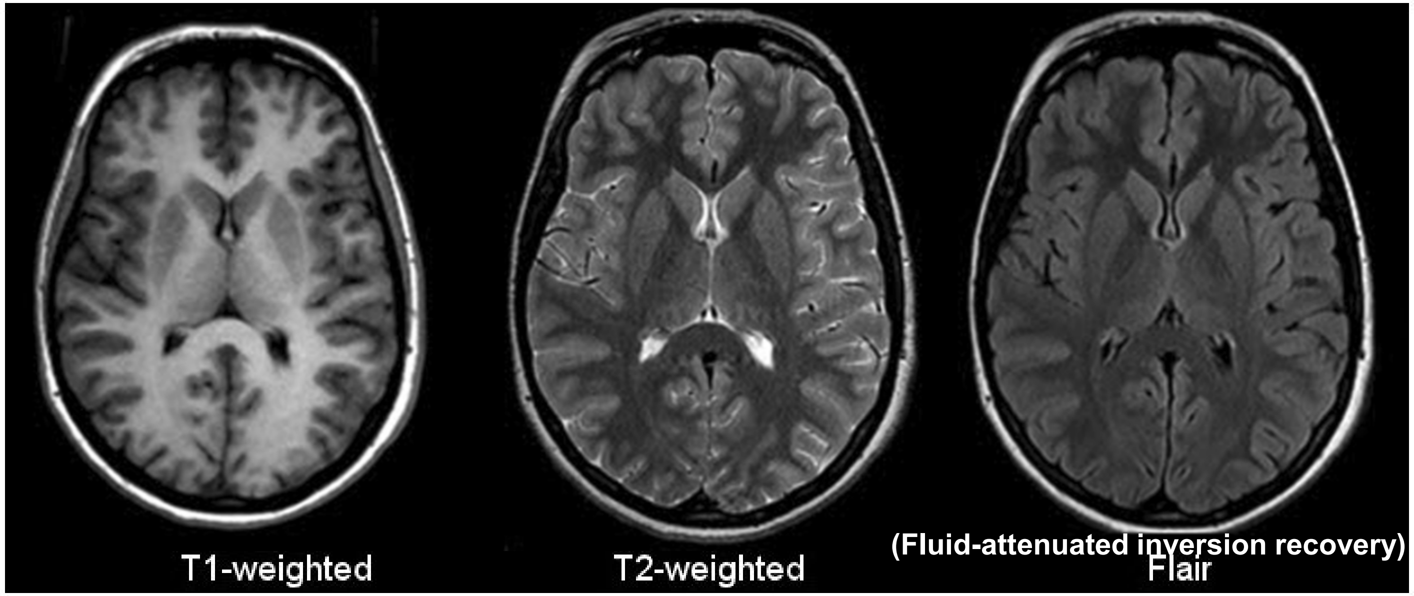
MRI: STRUCTURE, FUNCTION, METABOLISM



STRUCTURAL MRI: TISSUE CONTRAST

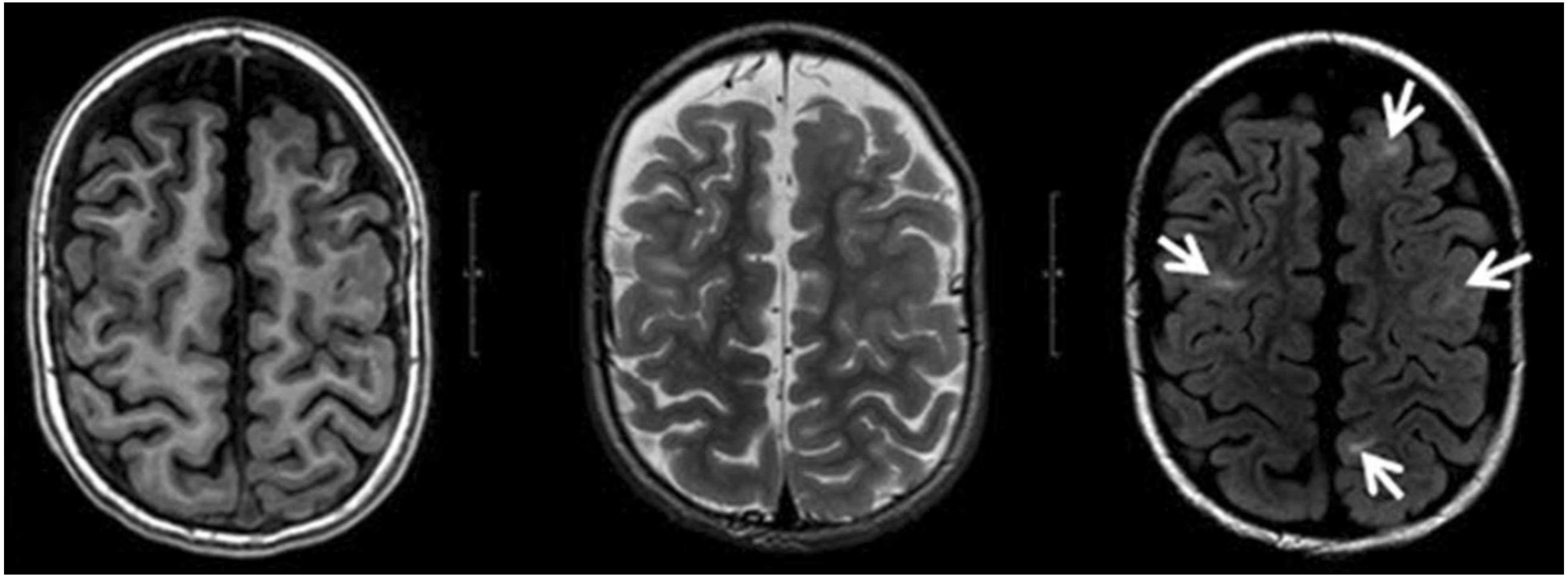


Tissue	T1-Weighted	T2-Weighted	Flair
CSF	Dark	Bright	Dark
White Matter	Light	Dark Gray	Dark Gray
Cortex	Gray	Light Gray	Light Gray
Fat (within bone marrow)	Bright	Light	Light
Inflammation (infection, demyelination)	Dark	Bright	Bright

https://case.edu/med/neurology/NR/MRI%20Basics.htm

Various tissue contrasts :
for different purposes

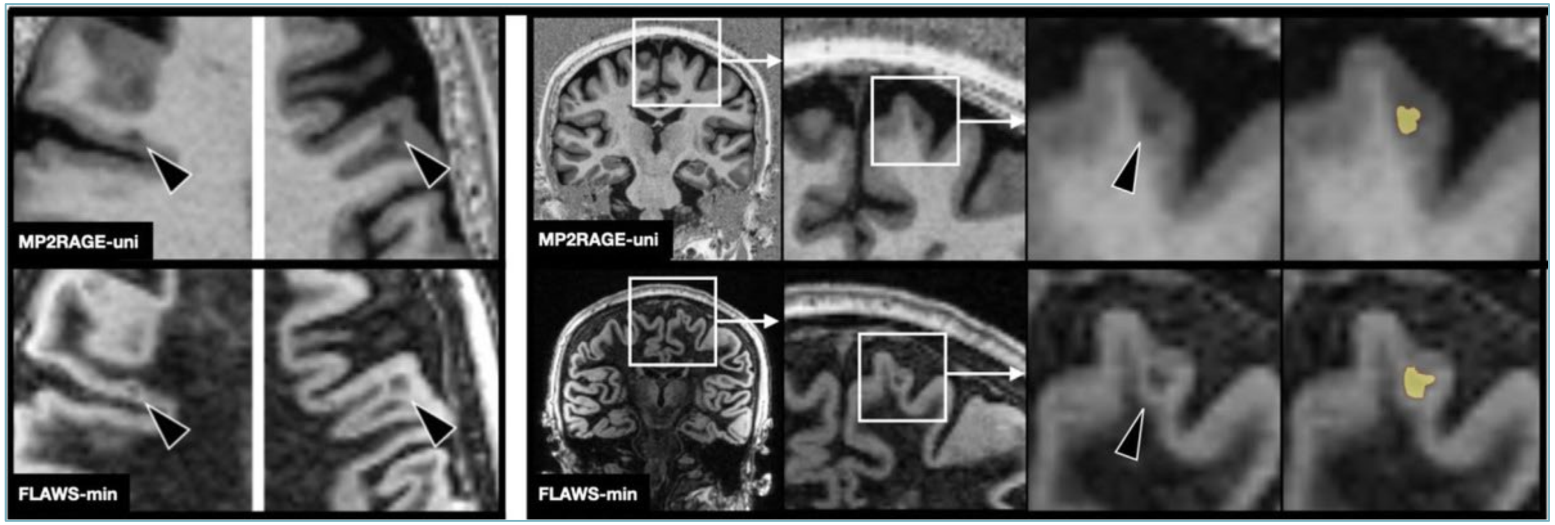
MRI IN TUBEROUS SCLEROSIS



T1-weighted T1-weighted T2-FLAIR

CORTICAL LESION DETECTION IN MULTIPLE SCLEROSIS

MP2RAGE: T1 weighted



FLAWS: T1 weighted + fluid and white matter suppression

TABLE 1 - Magnetic Resonance Imaging Sequence Parameters

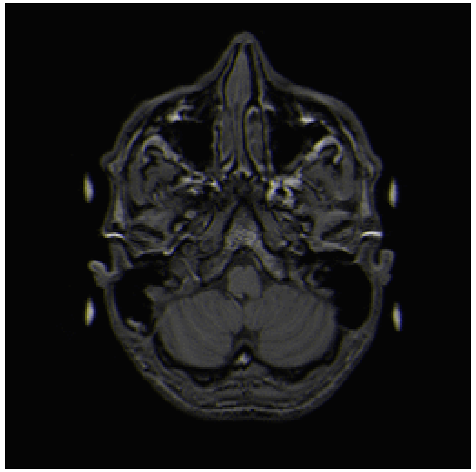
	MP2RAGE	FLAWS
Resolution, voxel size, mm^3	1.0 × 1.0 × 1.0	1.0 × 1.0 × 1.0
Orientation	Sagittal	Sagittal
Phase encoding	Anteroposterior	Anteroposterior
FoV, mm^3	256 × 240 × 176	256 × 240 × 192
TR/TE, ms	5000/2.98	5000/2.19
TI 1, ms	700	449
TI 2, ms	2500	1270
Flip angle 1, degrees	4	5
Flip angle 2, degrees	5	6

FLAWS, fluid and white matter suppression; FoV, field of view; MP2RAGE, magnetization prepared 2 rapid acquisition gradient echo; TE, echo time; TI, 1 inversion time 1; TI, 2 inversion time 2; TR, repetition time.

Müller et al., Investigative Radiology, 2022.

STRUCTURAL MRI MEASURES

- Total brain volume: atrophy, ventricular enlargement (e.g. in Alzheimer's disease)



Fehlbaum et al., Developmental Cognitive Neuroscience, (2022)

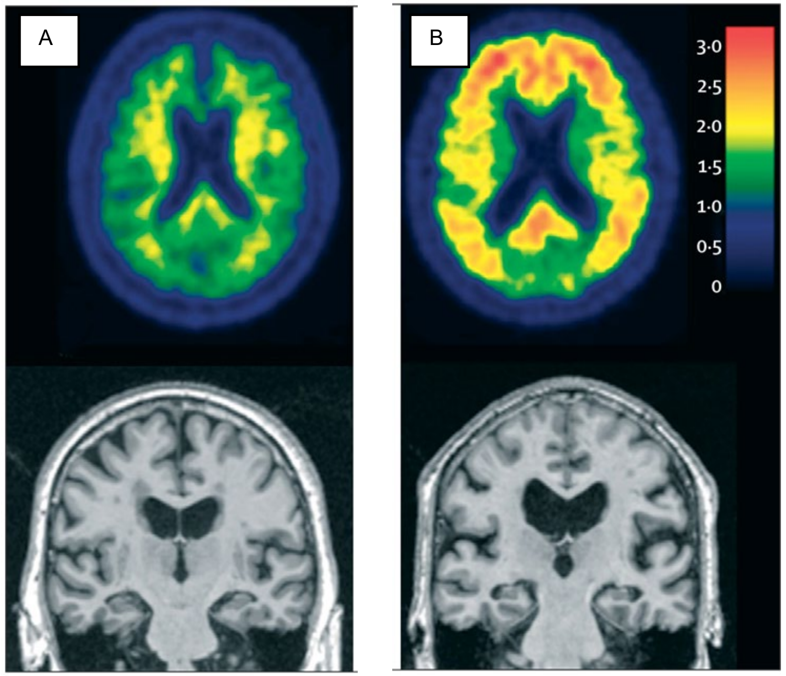
MRI IN ALZHEIMER'S DISEASE

PET Amyloid-Beta(Aβ) Imaging

Brain Aβ-plaque deposition

MRI

Neurodegeneration



A. A cognitively normal individual with no evidence of Aβ on PET amyloid imaging and no evidence of atrophy on MRI.

B. An individual who has dementia and a clinical diagnosis of Alzheimer's disease, a positive PET amyloid imaging study, and neurodegenerative atrophy on MRI.

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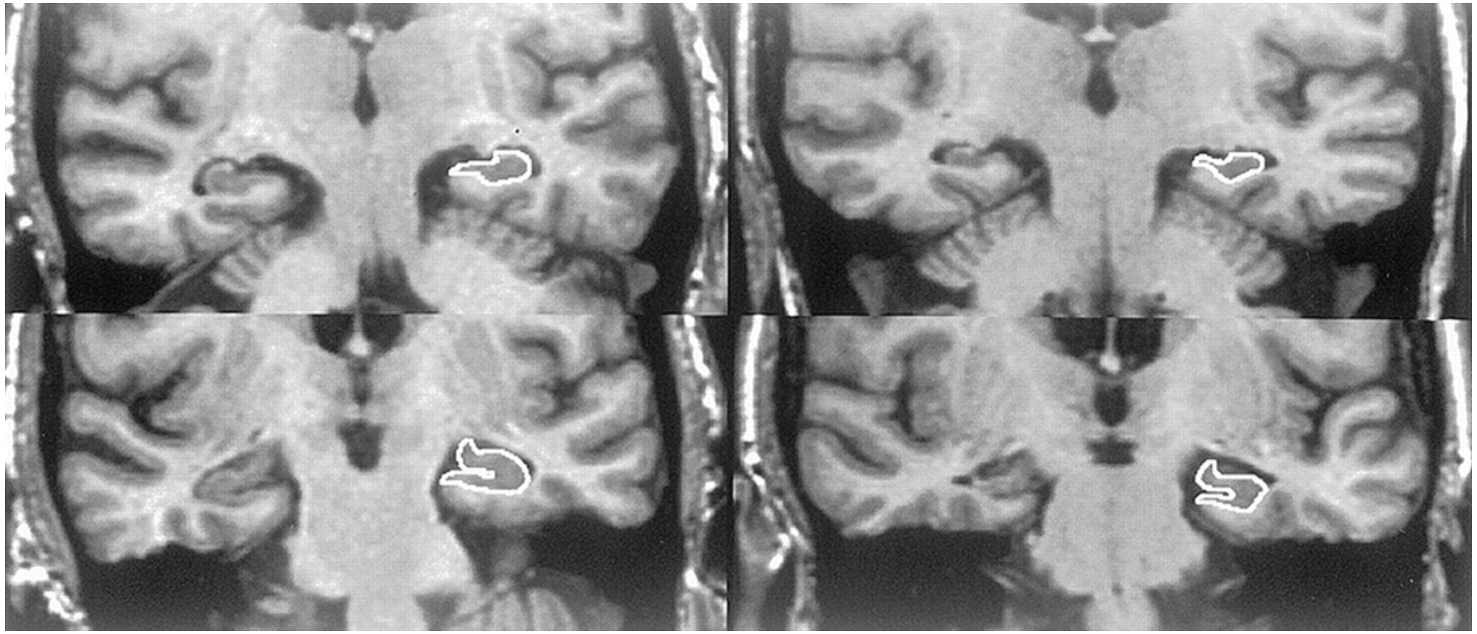
STRUCTURAL MRI MEASURES

- Total brain volume: atrophy, ventricular enlargement (e.g. in Alzheimer's disease)
- Volume of specific brain structure (e.g Hippocampus: reduction in dementia)

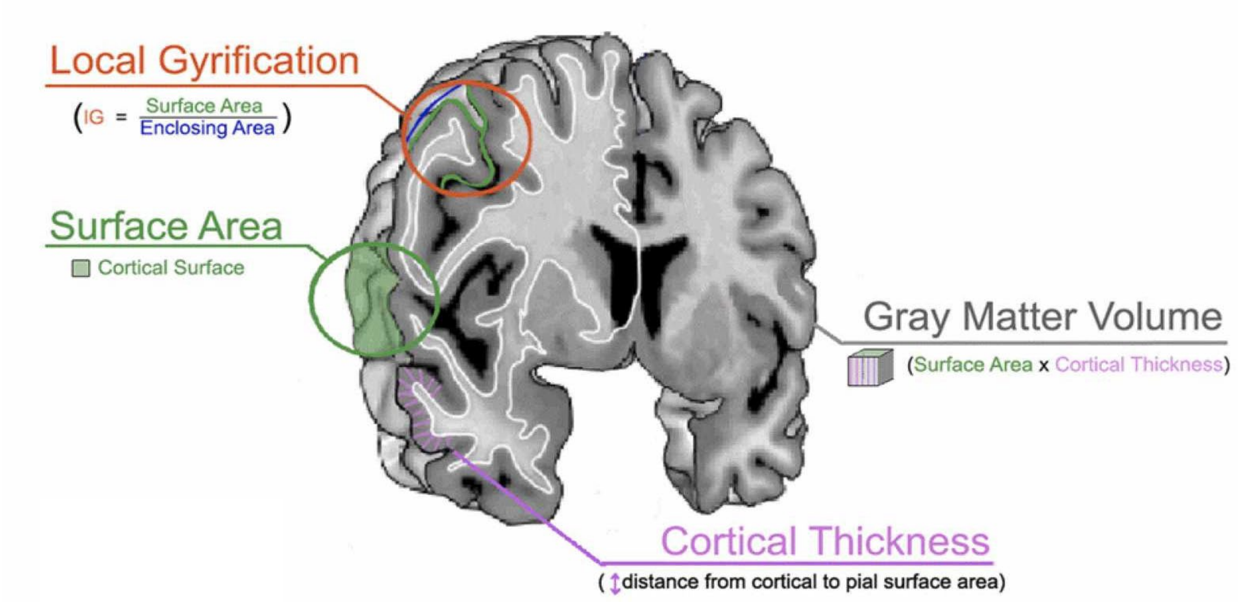
Patient (mild cognitive impairment) Patient (AD)



Jack et al., Neurology, (2009)

STRUCTURAL MRI MEASURES

- Total brain volume: atrophy, ventricular enlargement (e.g. in Alzheimer's disease)
- Volume of specific brain structure (e.g Hippocampus: reduction in dementia)
- Cortical volume, surface area, thickness, gyrification



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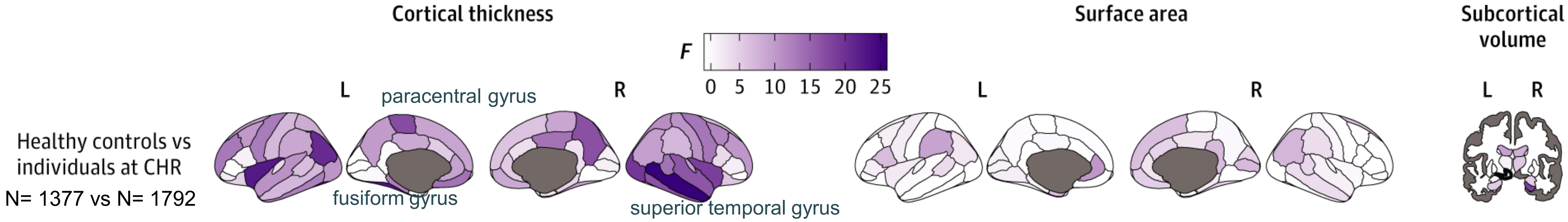
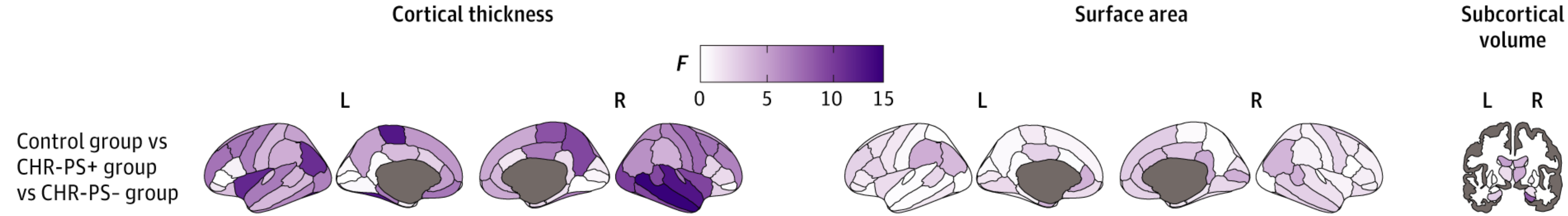
Fehlbaum et al., Developmental Cognitive Neuroscience, (2022)

STRUCTURAL MRI MEASURES IN INDIVIDUALS AT CLINICAL HIGH RISK FOR DEVELOPING PSYCHOSIS



Low cortical thickness in individuals at clinical high risk (CHR)

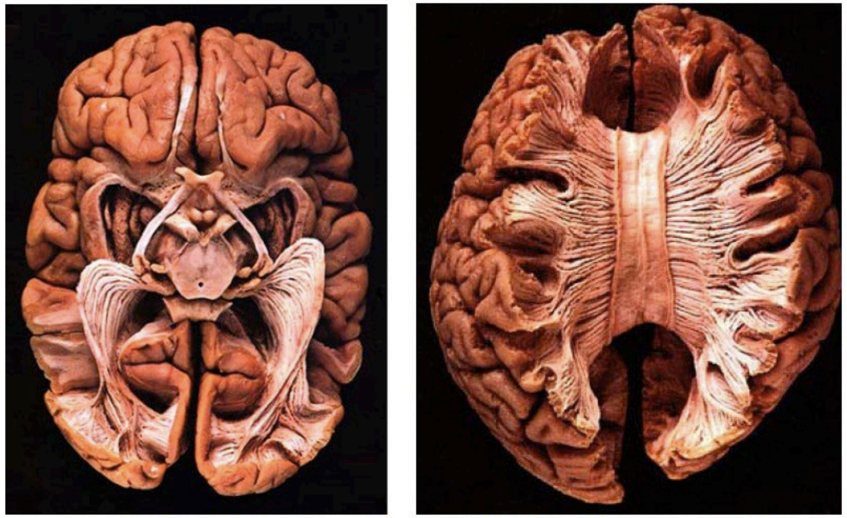


Transition to psychosis was robustly associated with lower cortical thickness

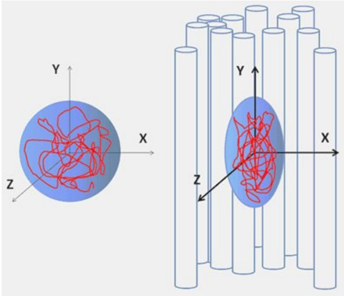
ENIGMA Clinical High Risk for Psychosis Working Group, JAMA (2021)

DIFFUSION MRI

white matter tracts in dissected brain

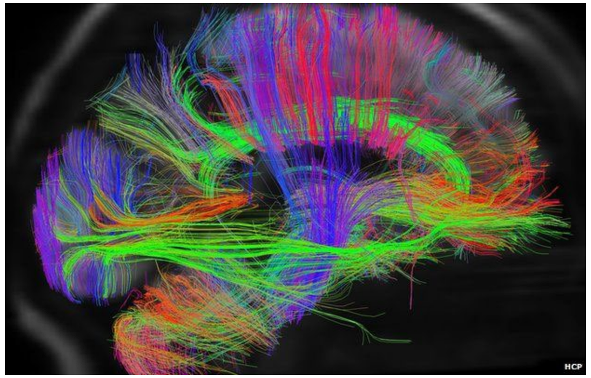


From: The Virtual Hospital (www.vh.org); TH Williams, N Gluhbegovic, JY Jew



Brownian motion of water

white matter tracts in the living brain



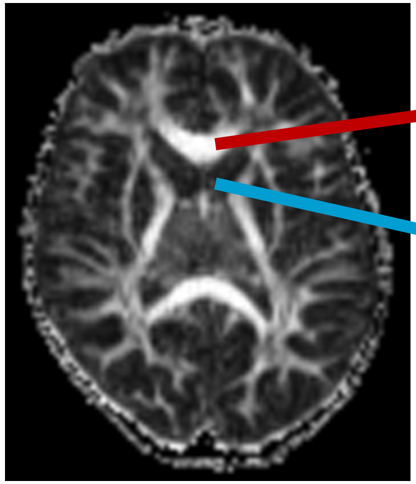
Diffusion MRI

- red = left-right
- green = anterior-posterior
- blue = superior-inferior

http://www.humanconnectomeproject.org

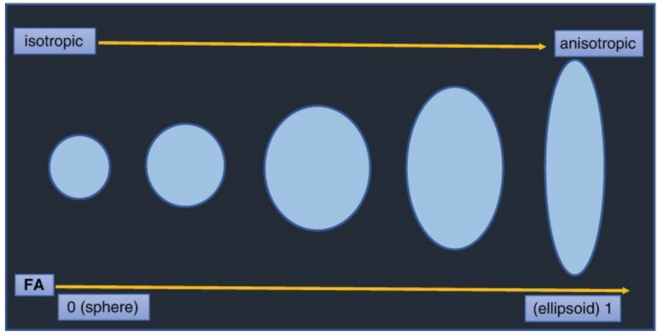
DIFFUSION TENSOR IMAGING (DTI) MEASURES

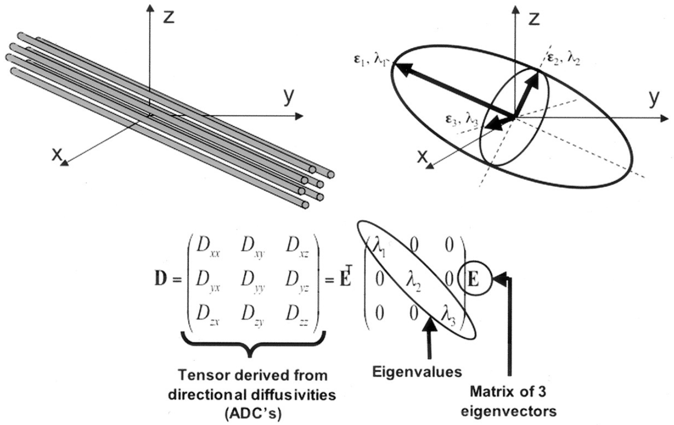
Fractional Anisotropy (FA) mapping



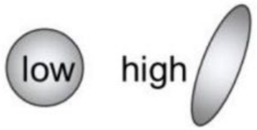
High FA, anisotropic, high WM integrity

Low FA, isotropic, low WM integrity



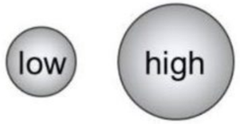


- **Fractional Anisotropy (FA)** $\sqrt{\frac{(\lambda_1-\lambda_2)^2+(\lambda_2-\lambda_3)^2+(\lambda_3-\lambda_1)^2}{2(\lambda_1^2+\lambda_2^2+\lambda_3^2)}}$



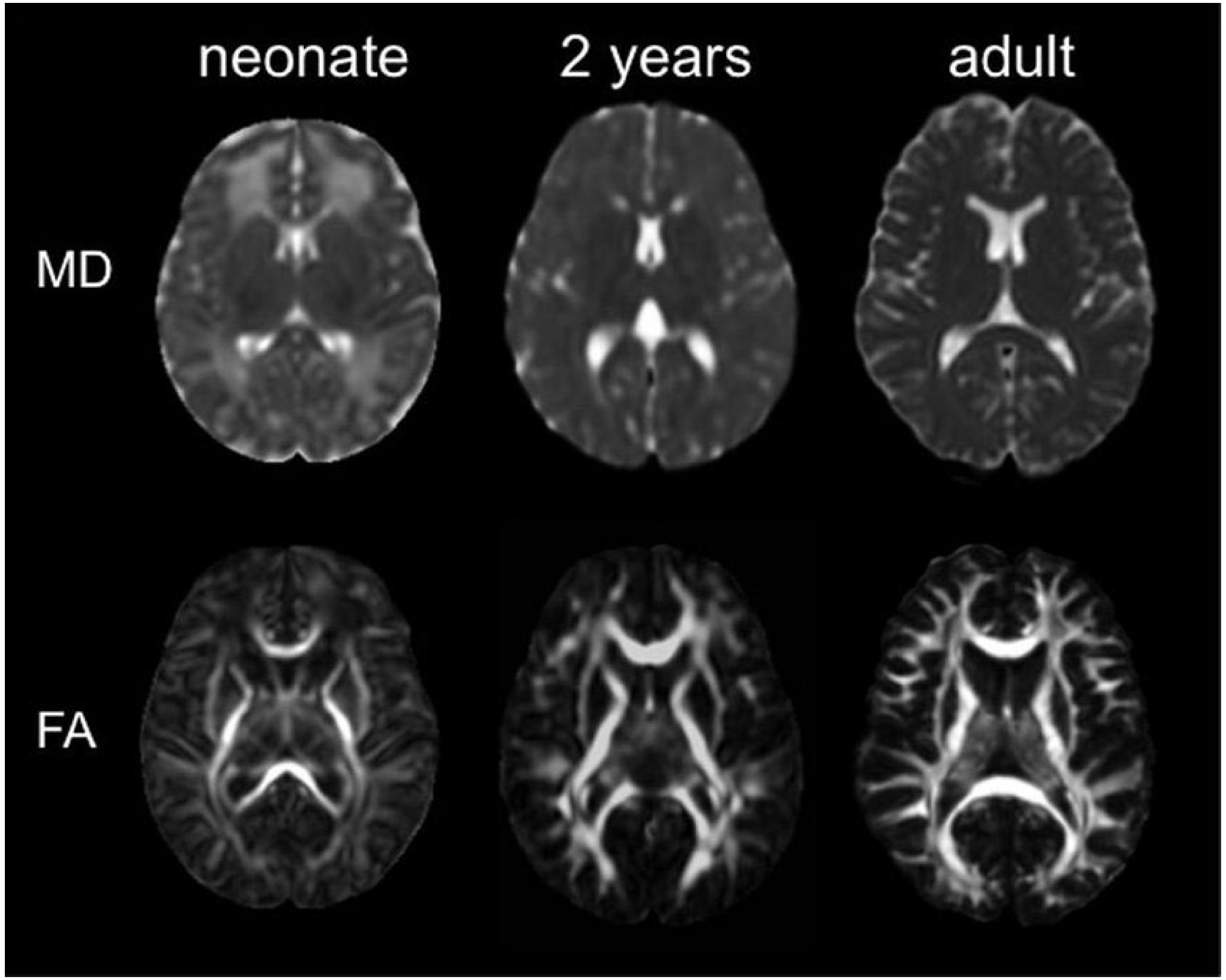
  - the directionality of water diffusion in brain tissue
  - integrity and organization of white matter tracts

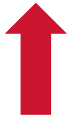
- **Mean Diffusivity (MD)** $\frac{\lambda_1+\lambda_2+\lambda_3}{3}$



  - average water diffusion in one voxel
  - cellularity of white matter tracts

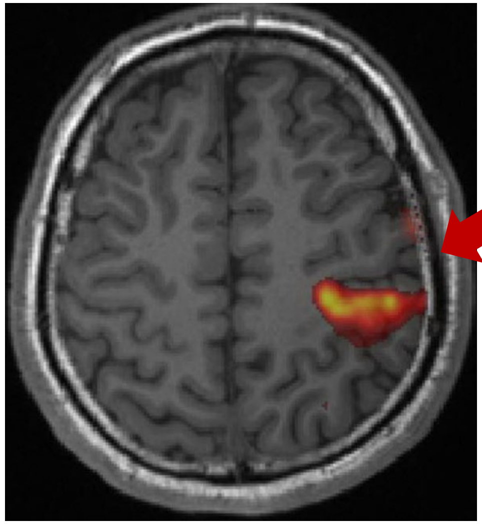
DIFFUSION TENSOR IMAGING (DTI) MEASURES





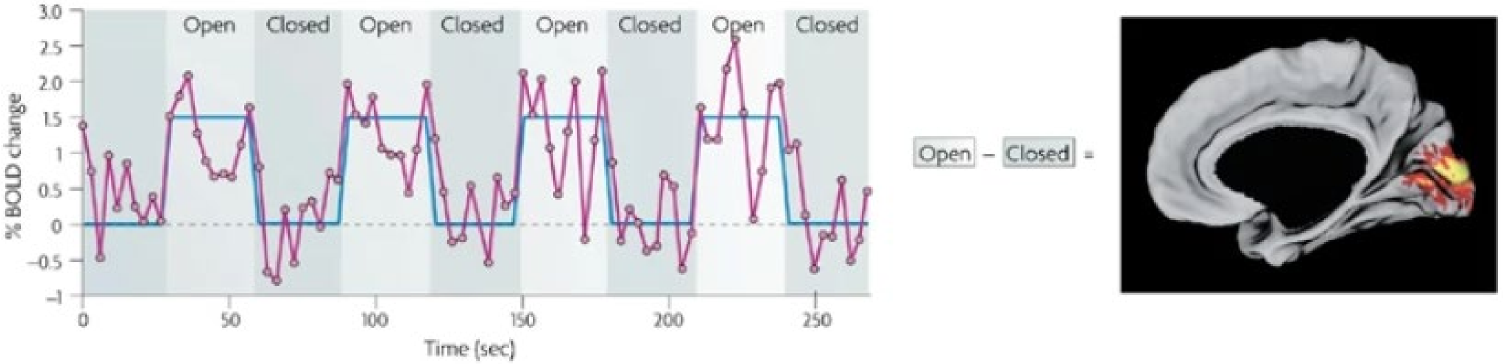
Deshpande et al., Front. Neuroanat. , 2015

FUNCTIONAL MRI (FMRI)



brain activation

open and close eyes

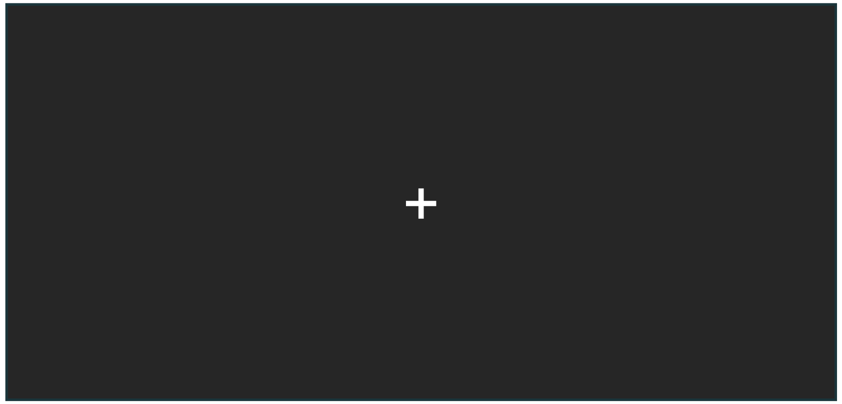


Blood **O**xygen **L**evel **D**ependent signal (**BOLD**)

↑neural activity ➔ ↑ blood flow ➔ ↑ oxyhemoglobin ➔ ↑ T2* ➔ ↑ MR signal

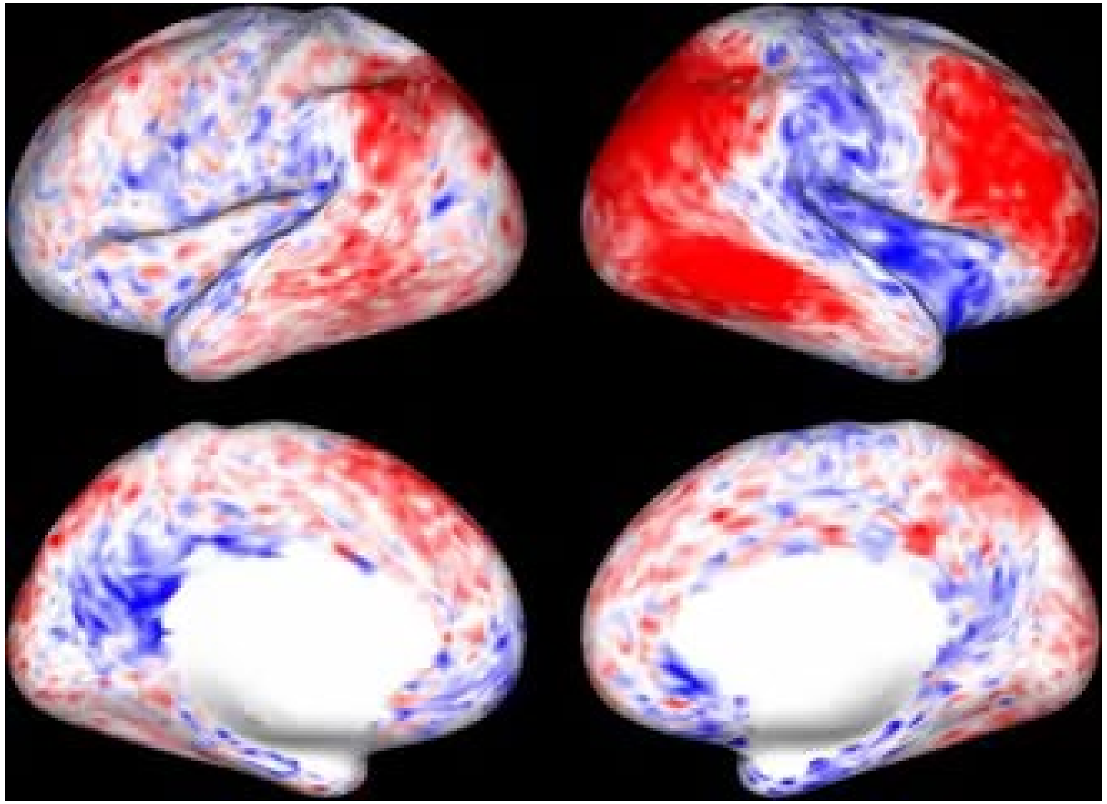
Fox & Raichle, 2007, Nat Rev Neurosci

RESTING STATE FMRI



"Please look at the white cross in the middle of the screen, try not to fall asleep, and let your mind wonder."

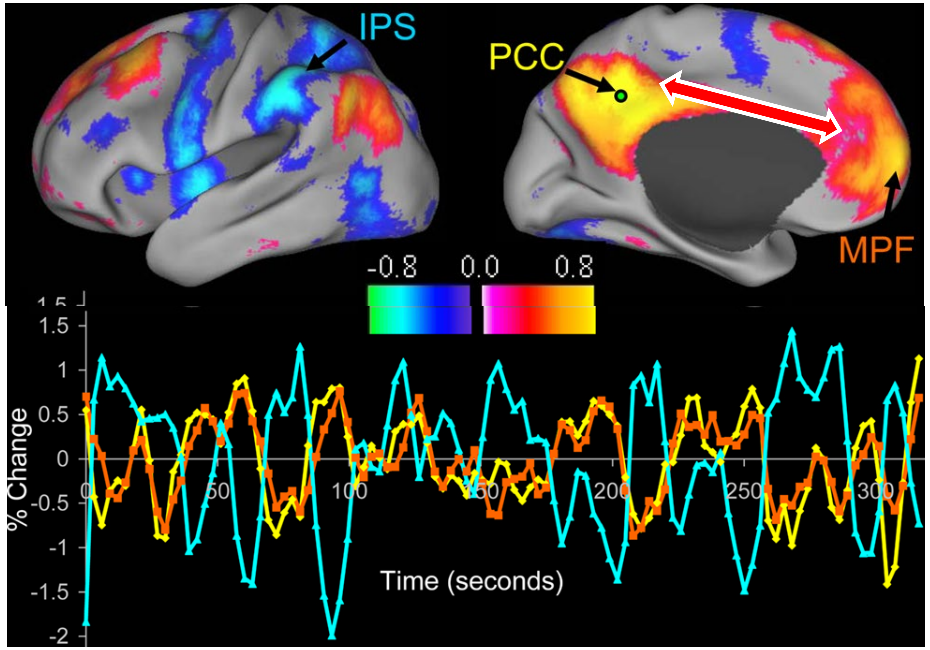
Activity Fluctuations During Rest

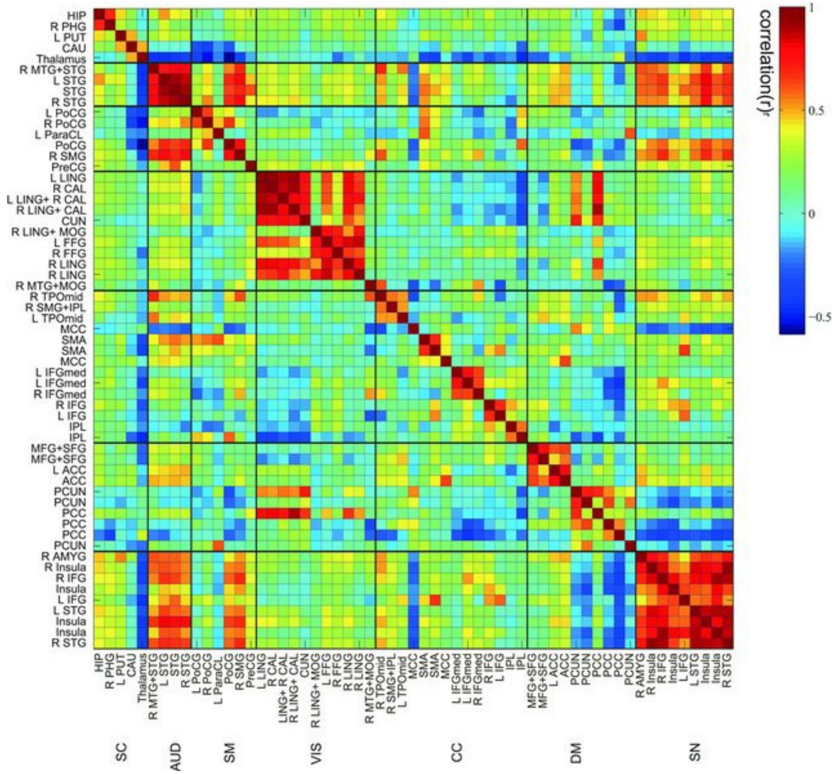


https://en.wikipedia.org/wiki/File:Temporal-Non-Local-Means-Filtering-Reveals-Real-Time-Whole-Brain-Cortical-Interactions-in-Resting-pone.0158504.s002.ogv

FUNCTIONAL CONNECTIVITY

- Temporal correlation between spontaneous BOLD signal





Inferior parietal cortex **(IPS)**
Posterior cingulate cortex **(PCC)**
Medial prefrontal cortex **(MPFC)**

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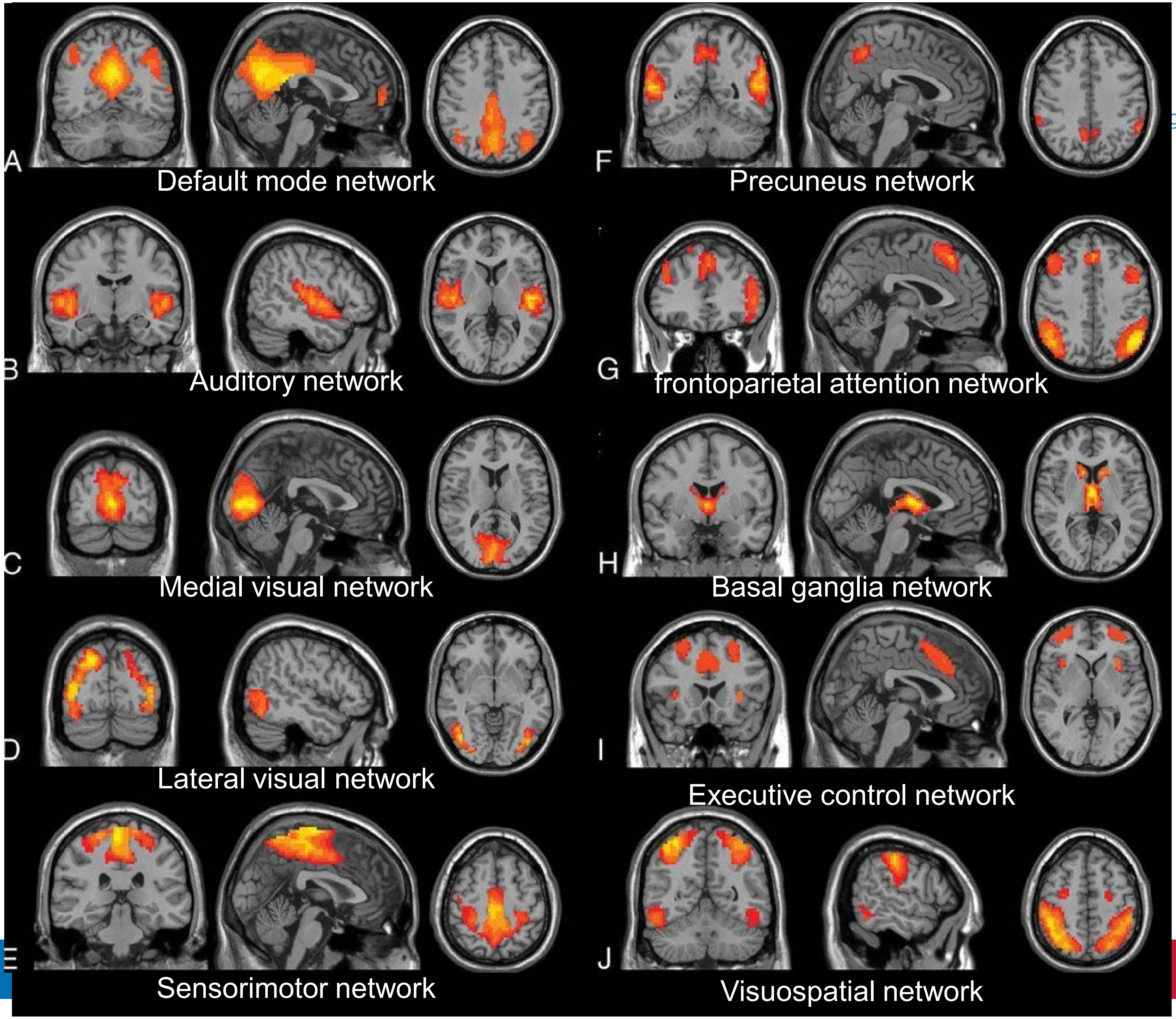
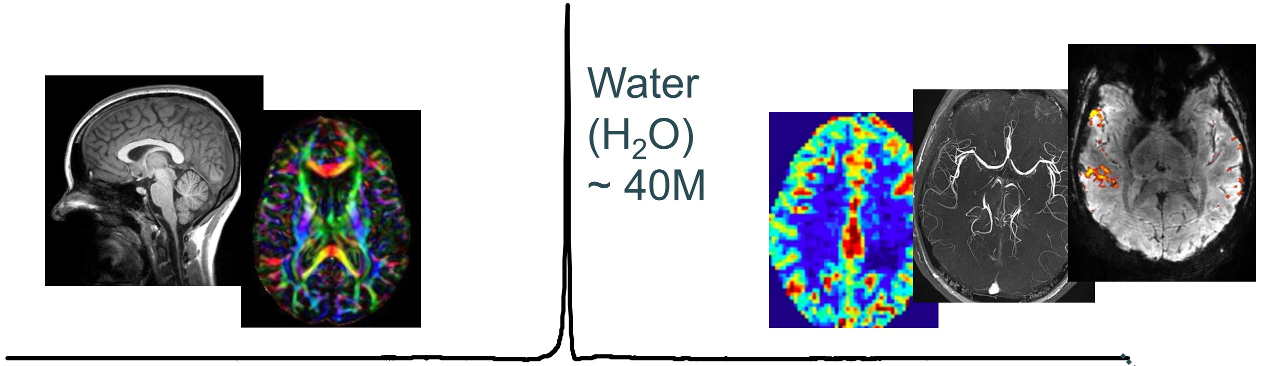
Fox & Raichle, 2007, Nat Rev Neurosci

TYPICAL NETWORKS



BREAK

METABOLISM: MR SPECTROSCOPY (MRS)

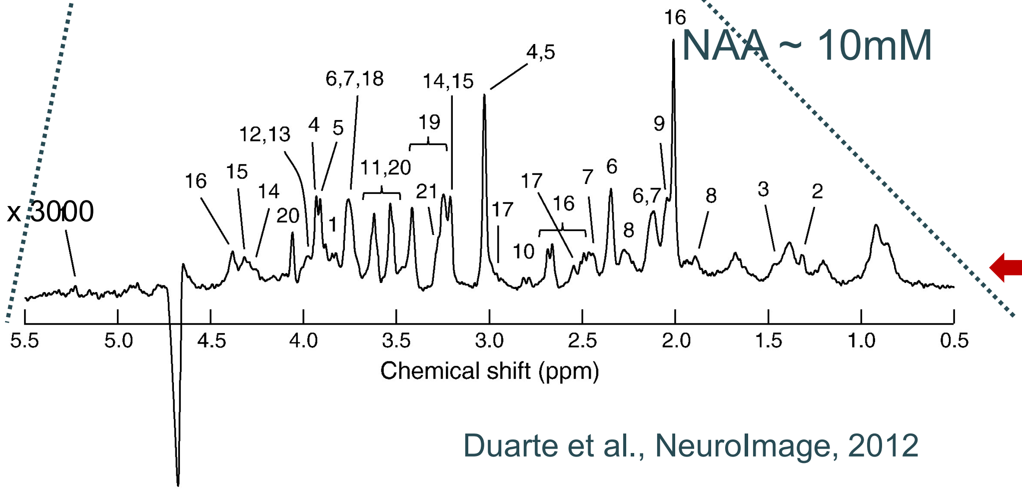


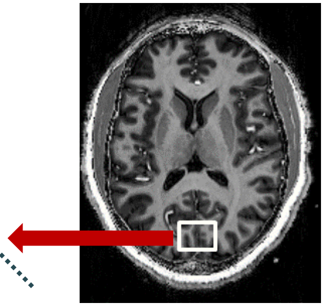
Energy metabolism:
1. Glucose
2. Lactate
3. Alanine
4. Phosphocreatine
5. Creatine

Myelination and membrane metabolism:
13. Phosphorylethanolamine
14. Phosphrylcholine
15. Glycerylphosphorylcholine
16. *N*-acetylaspartate

Neurotransmitters:
6. Glutamate
7. Glutamine
8. GABA
9. *N*-acetylaspartylglutamate
10. Aspartate
11. Glycine
12. Serine

Antioxidants and osmolytes:
17. Glutathione
18. Ascorbate
19. Taurine
20. *myo*-inositol
21. *scyllo*-inositol





Duarte et al., NeuroImage, 2012

ROLE OF MAJOR BRAIN METABOLITES

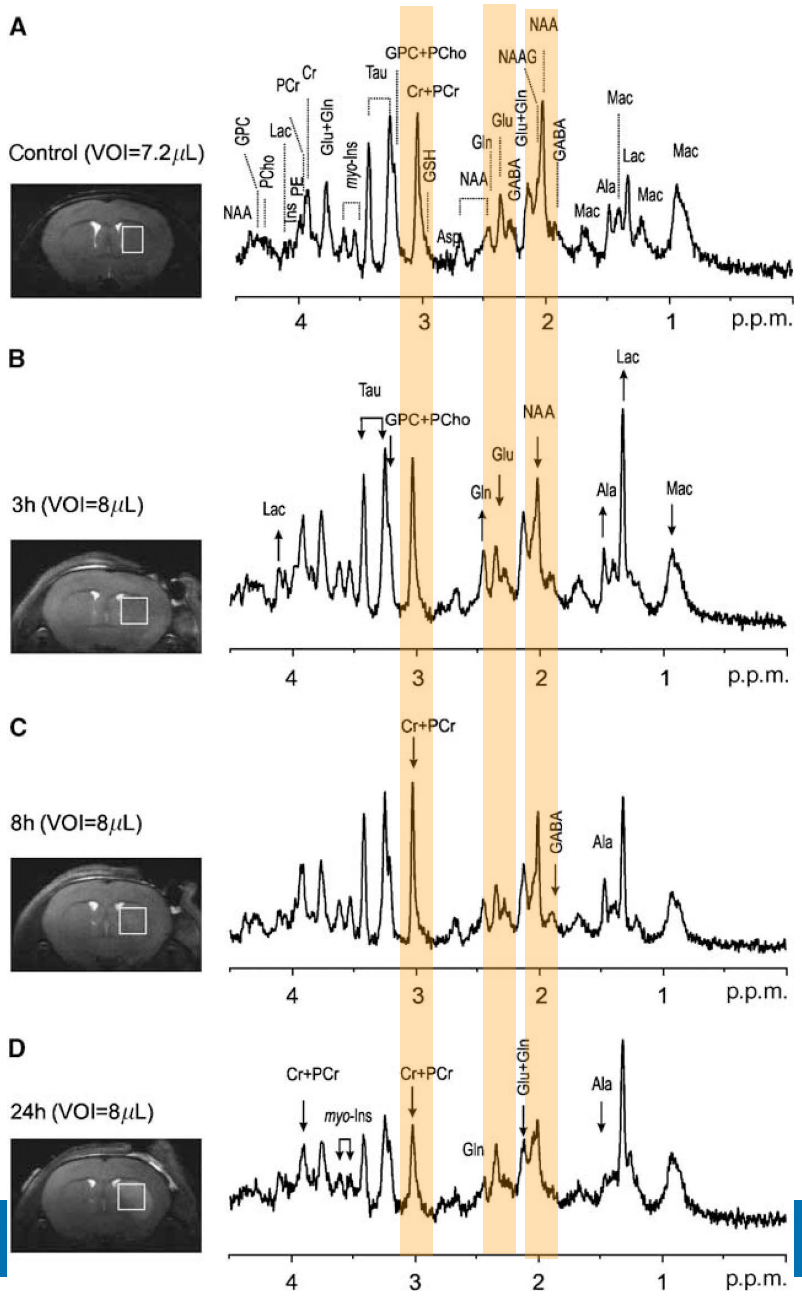
^{1}H MRS	
Single metabolites	
Lactate (Lac)	End product of anaerobic glycolysis Marker of inflammation in the subacute phase
Creatine (Cr), phosphocreatine (PCr)	Energy metabolism, PCr is a reserve of high-energy phosphates
N-acetylaspartate (NAA)	No complete understanding of its function, but reduced levels with brain injury Possibly a marker of neuronal viability, density, and mitochondrial function Also present in oligodendroglia progenitors Precursor of *N*-acetylaspartylglutamate
Myoinositol	Osmolyte, marker of glial cell proliferation
Choline (Cho)	Marker of cell membrane synthesis and breakdown, precursor for acetylcholine
Lipids	Marker of membrane degradation
Glutamate	Excitatory neurotransmitter, high concentrations in neurons
Glutamine	Derivative of glutamate, de novo synthesis exclusively in astrocytes
GABA	Neurotransmitter with excitatory properties in the immature brain (inhibitory in the adult brain)
Aspartate	Excitatory neurotransmitter
Taurine	Osmolyte, antioxidative properties, inhibitory neurotransmitter
Glutathione	Antioxidant

Berger et al., Dev neurosci,(2017)

APPLICATION OF ^{1}H MRS

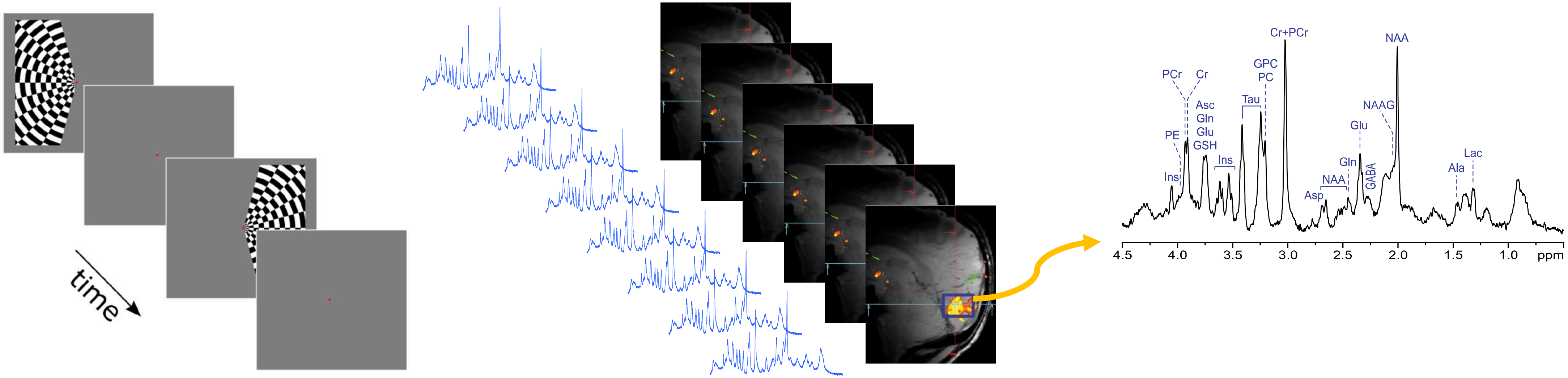
Evolution of the neurochemical profile after ischemia (30 mins of middle cerebral artery occlusion)

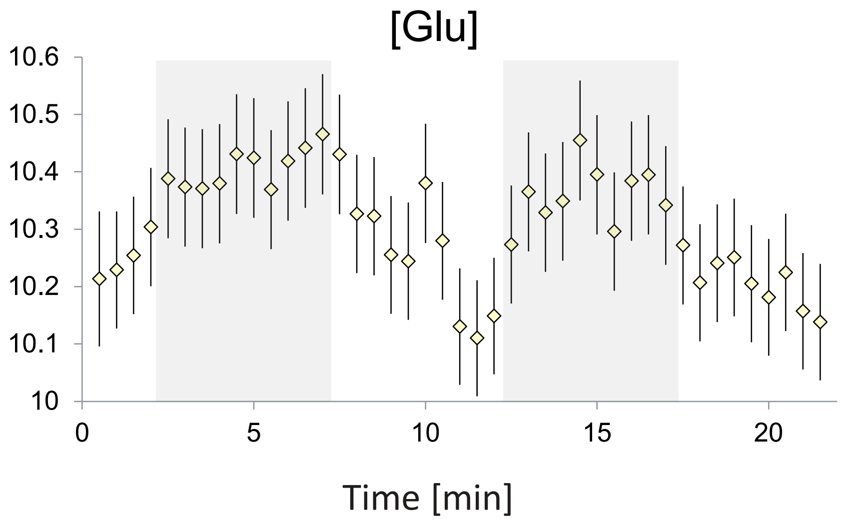
- energy metabolism
- glutamate excitotoxicity
- neuronal viability

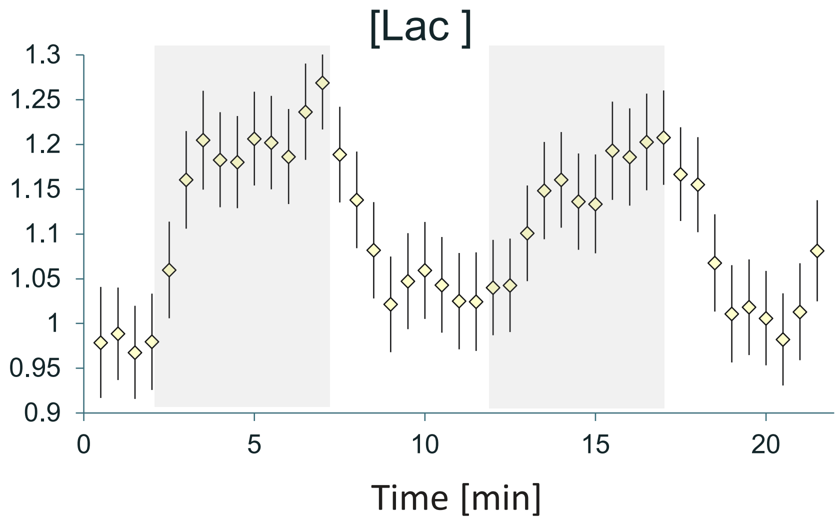


Lei et al., JCBFM, 2009.

FUNCTIONAL MRS







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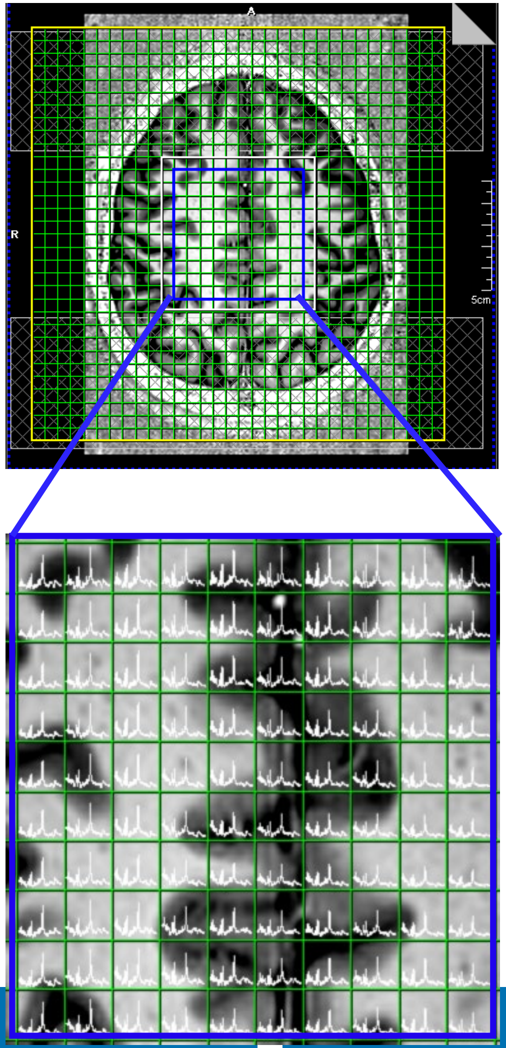
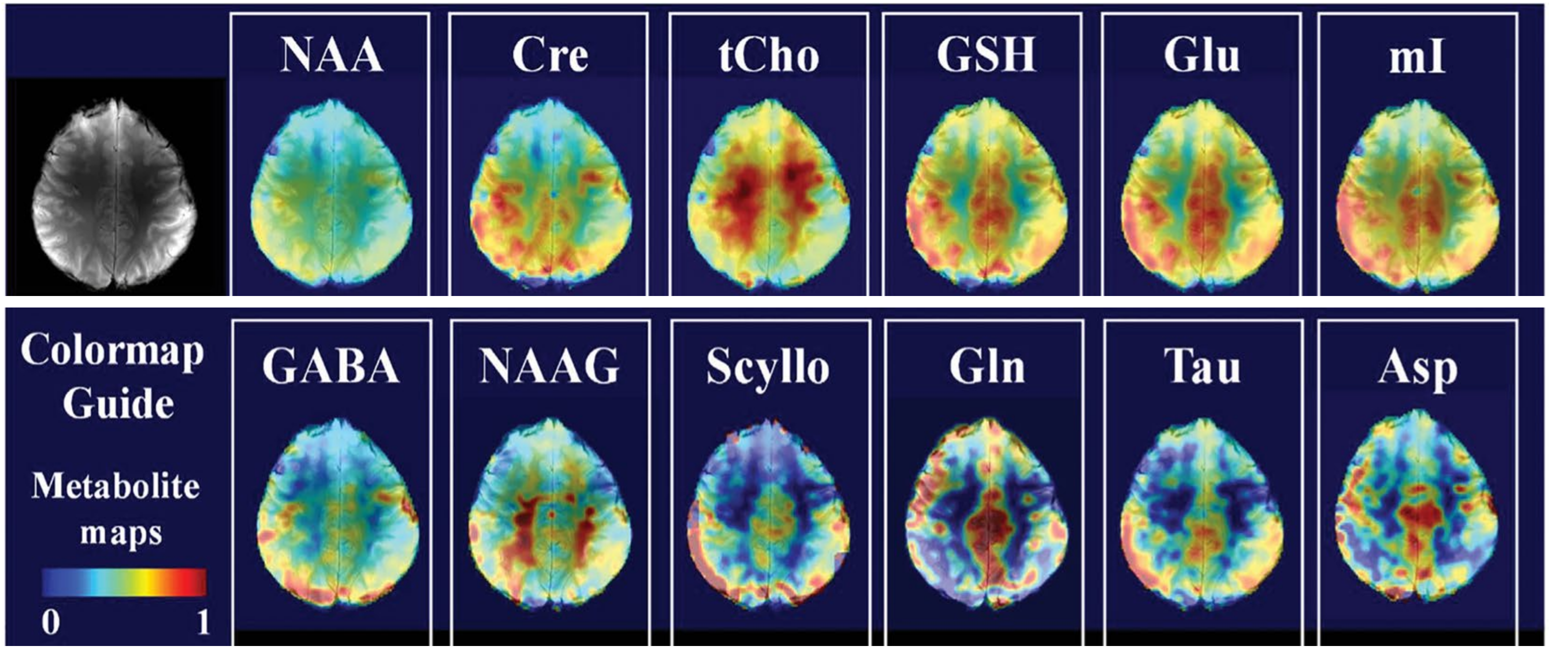
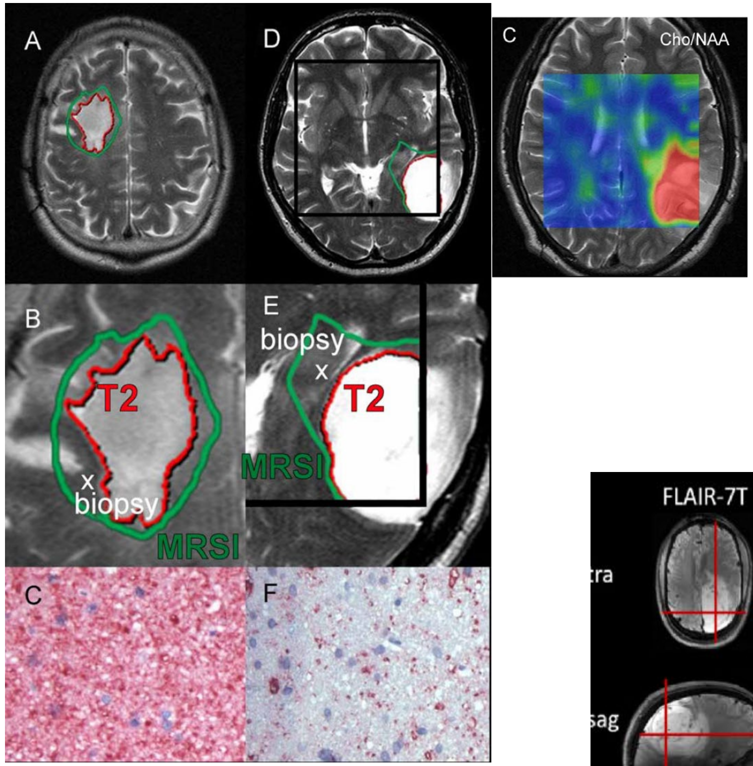
^{1}H MR SPECTROSCOPIC IMAGING (MRSI)





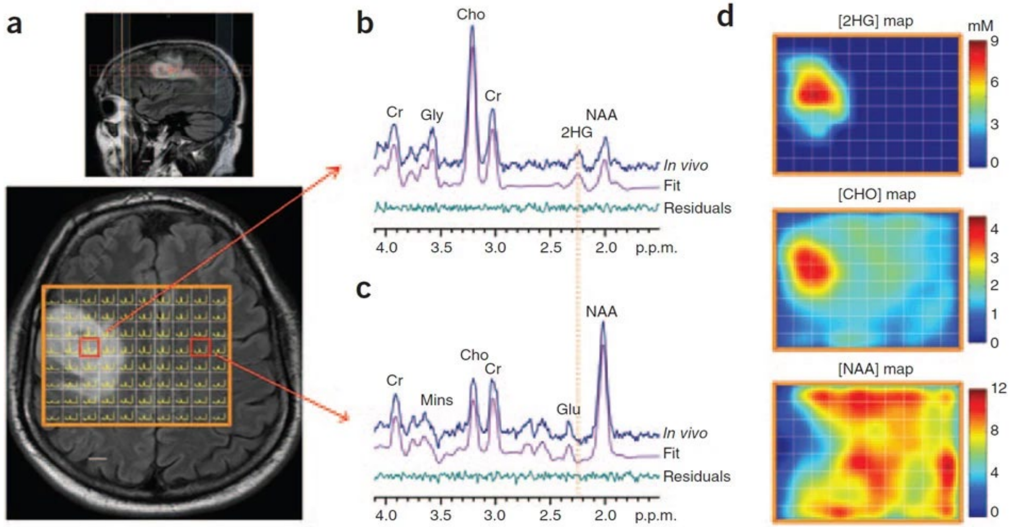
Nassirpour et al., NeuroImage (2018).

^{1}H MRSI IN BRAIN TUMORS

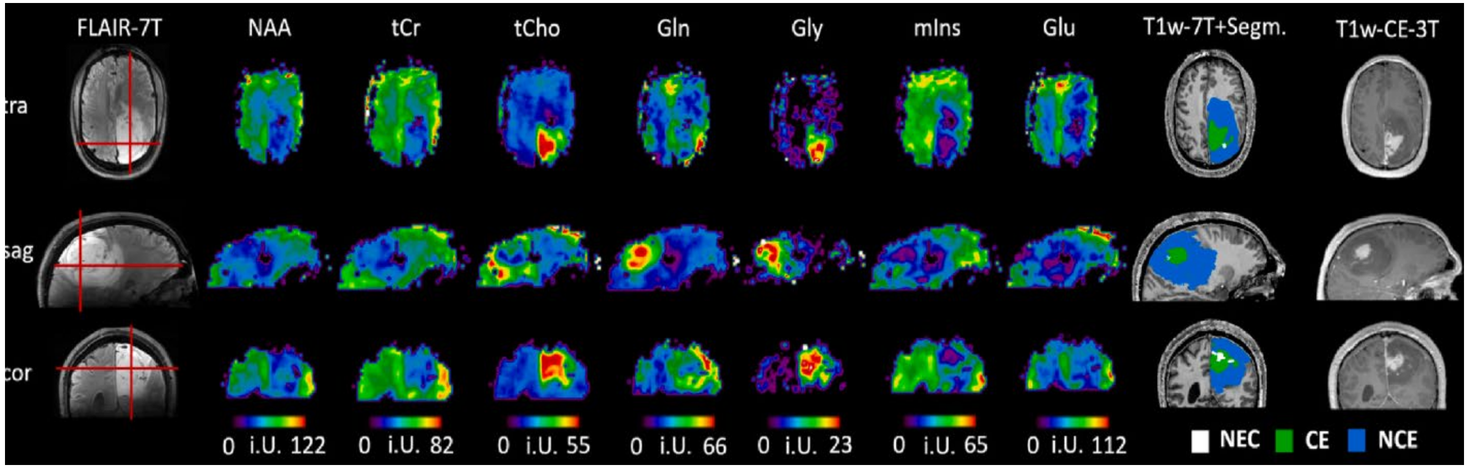


Stadlbauer et al., NeuroImage (2004)

2-Hydroxyglutarate mapping



Choi et al., Nature Medicine (2012)



Hangel et al., NeuroImage: Clinical (2020)

X-NUCLEI (BEYOND ^{1}H)

Isotope	Natural abundance	γ $(10^6 rad \cdot s^{-1} T^{-1})$
^{1}H	0.99985	267.522
^{2}H	0.00015	41.066
^{12}C	0.989	–
^{13}C	0.01108	67.283
^{14}N	0.9963	19.338
^{15}N	0.0037	-27.126
^{16}O	0.99963	–
^{17}O	0.00037	-36.279
^{23}Na	1	70.801
^{31}P	1	108.394

Highest sensitivity, Mostly used in MRI and MRS

Low natural abundance

low sensitivity

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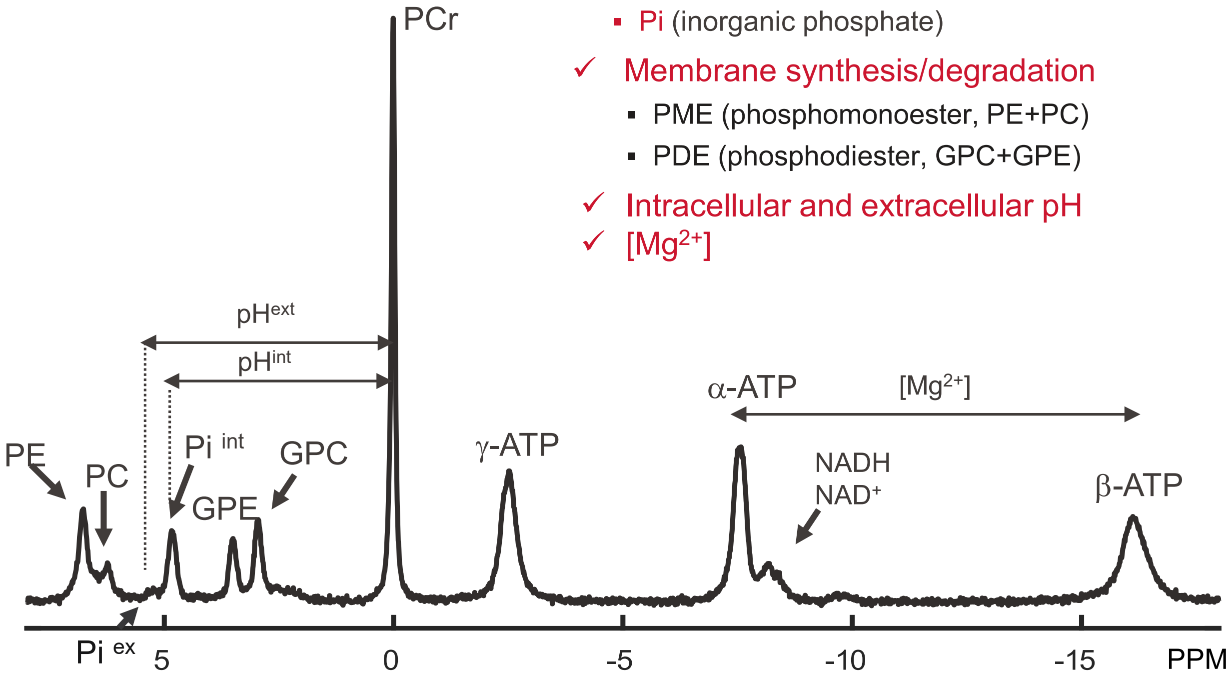
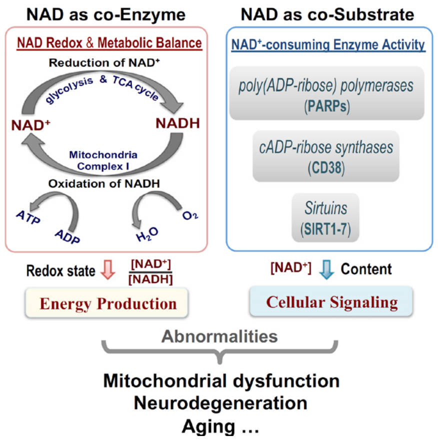
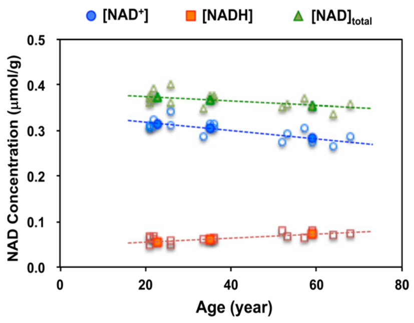
^{31}P MRS

- ✓ Energy metabolites
  - ATP (adenosine triphosphate)
  - PCr (phosphocreatine)
  - Pi (inorganic phosphate)
- ✓ Membrane synthesis/degradation
  - PME (phosphomonoester, PE+PC)
  - PDE (phosphodiester, GPC+GPE)
- ✓ Intracellular and extracellular pH
- ✓ $[Mg^{2+}]$



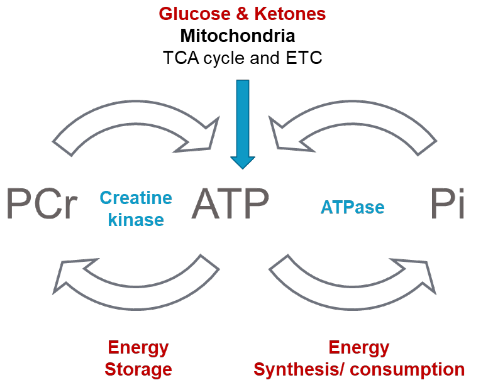
- ✓ Nicotinamide adenine dinucleotide (NAD^+/NADH)





Zhu et al., PNAS, (2015)

- ✓ ATP metabolism



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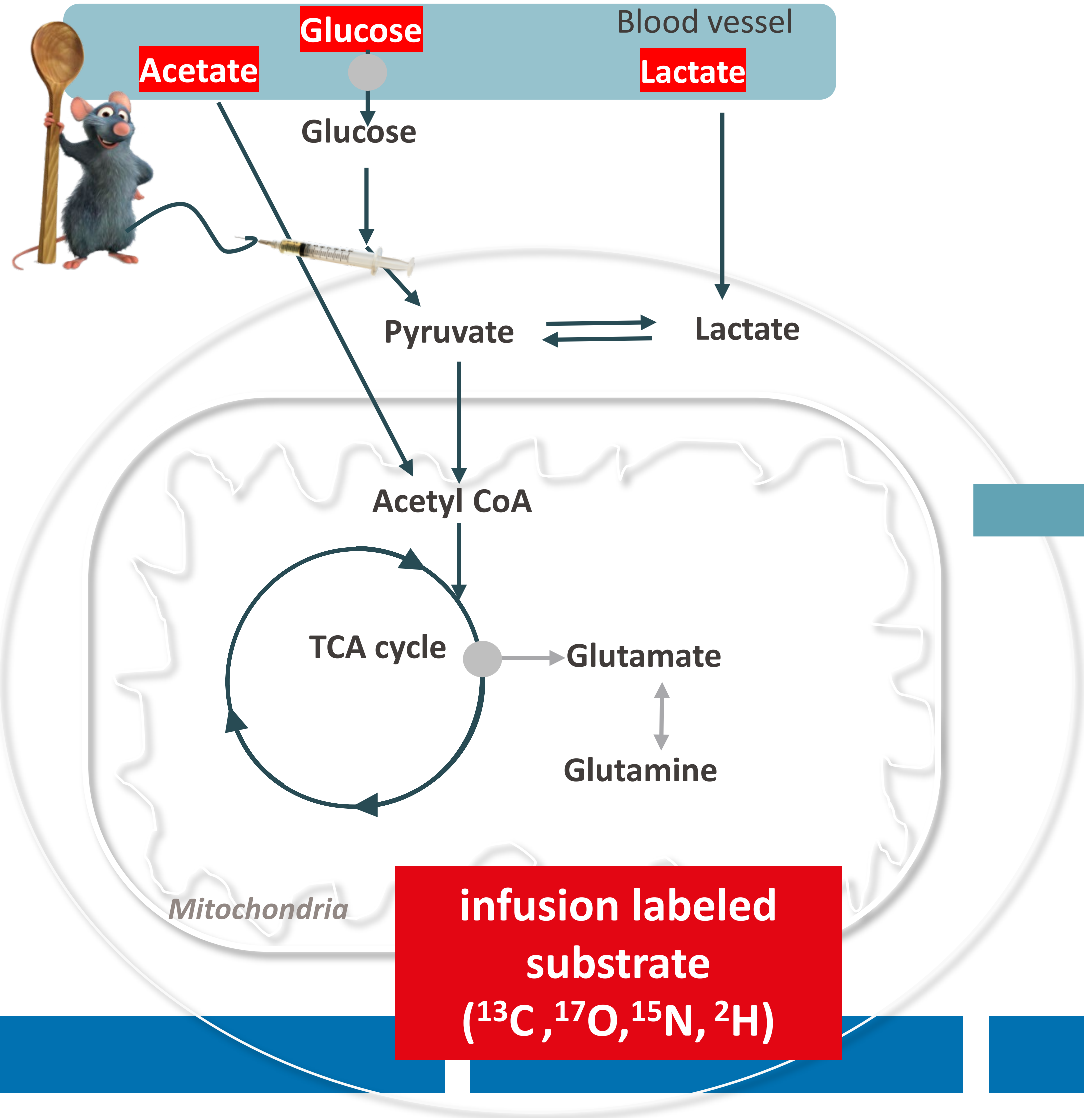
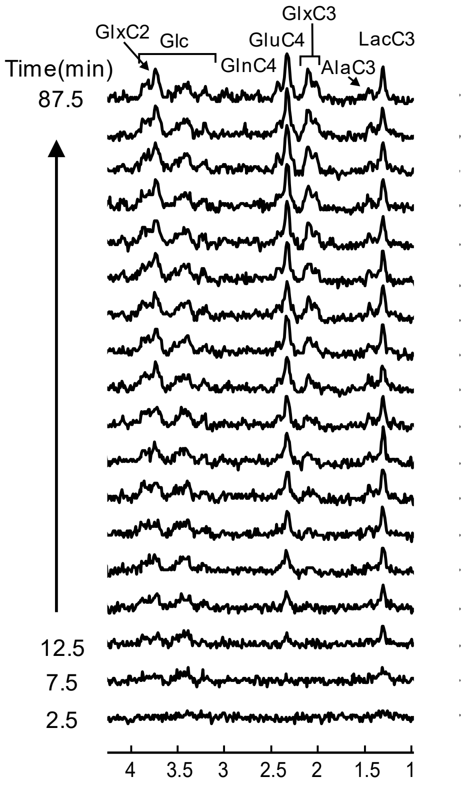
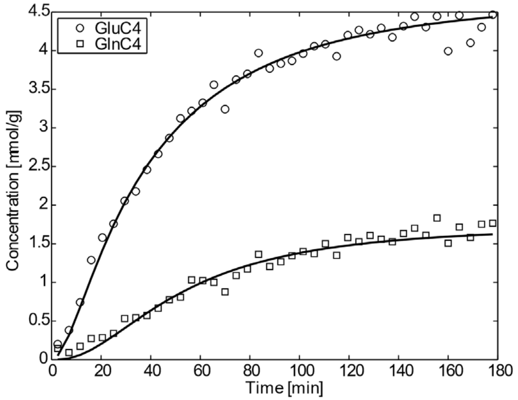
DYNAMIC X-NUCLEI MRS: METABOLIC FLUX



infusion labeled substrate (^{13}C, ^{17}O, ^{15}N, ^{2}H)



probe labeling time course



$$\frac{d[P^*]}{dt} = \frac{[S^*]}{[S]} V_1 - \frac{[P^*]}{[P]} V_2$$

neuron TCA flux (V_{TCAn})
glial TCA flux (V_{TCAg})
Glu-Gln cycling flux (V_{NT})

mathematic modeling (metabolic fluxes)

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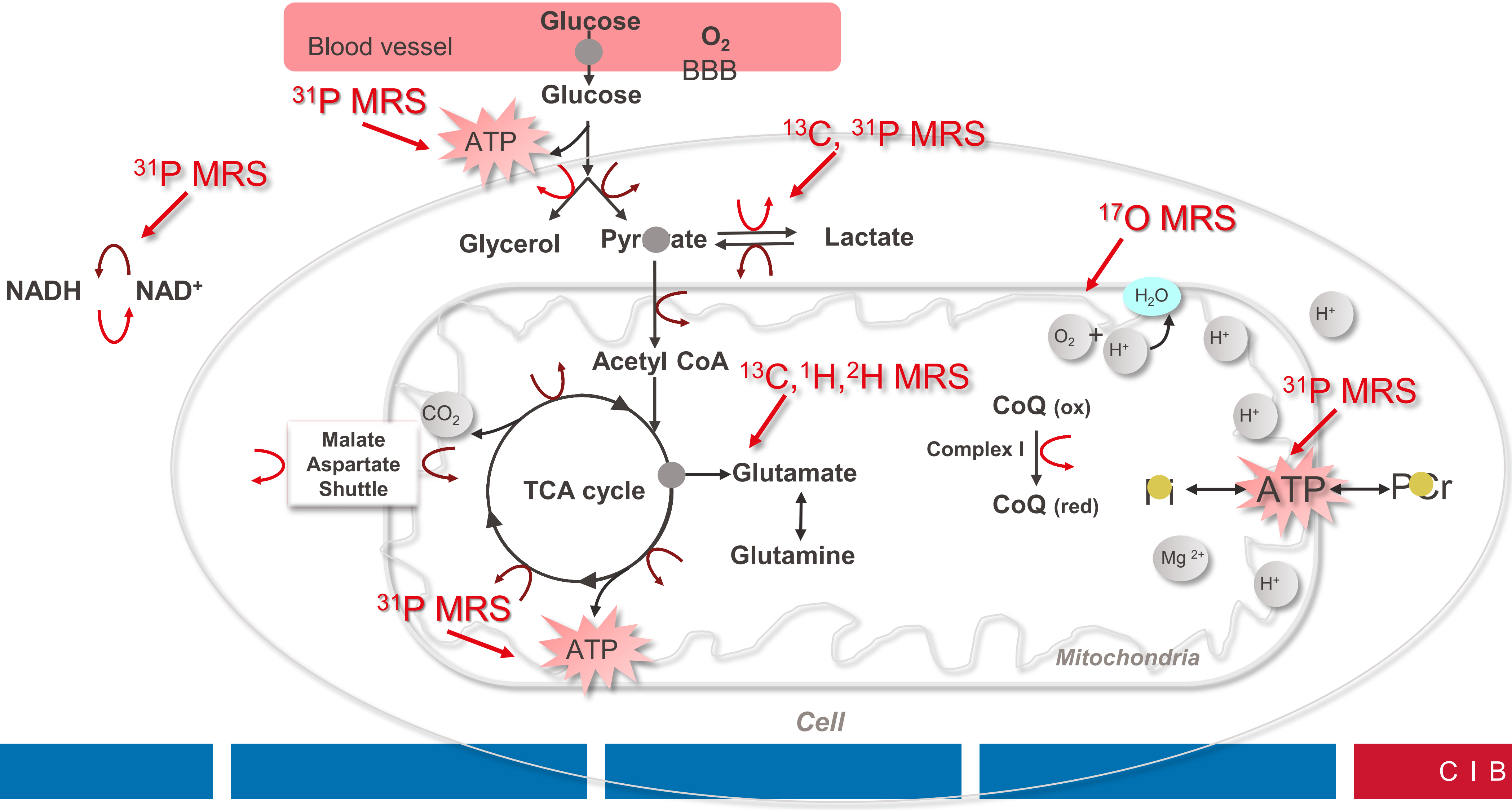
X-NUCLEI MRS FOR BRAIN METABOLISM



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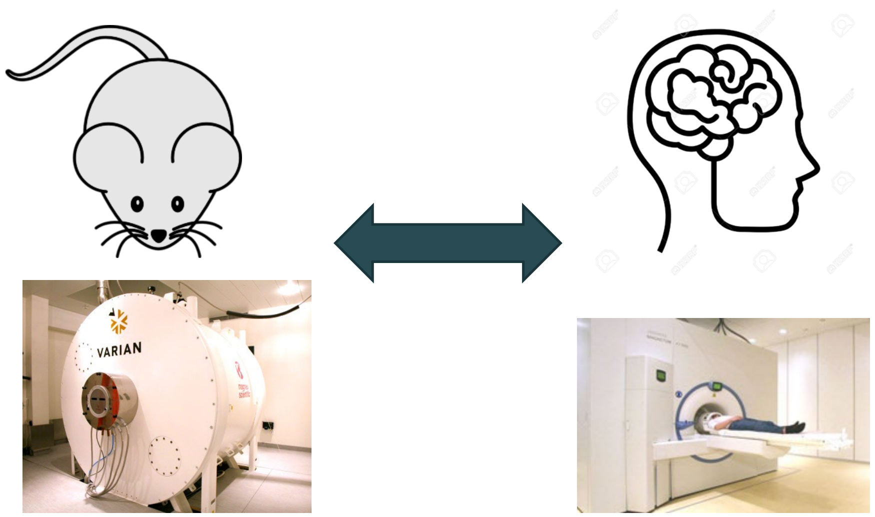
TRANSLATIONAL APPLICATION IN PSYCHIATRIC DISORDERS



Clinical characteristics of schizophrenia

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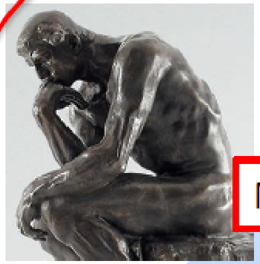


Most invalidating

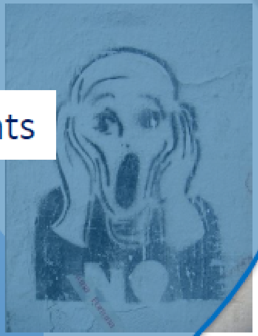
Cognitive deficits:

Working memory
attention, abstraction
executives functions

Disorganization

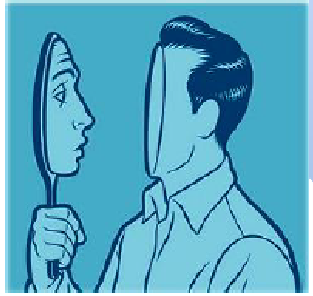
in behavior
and/or thinking

Current treatments



Positive symptoms :
Hallucination,
delusion…

Schizophrenia



Basic Symptoms :
Abnormal
- self perception
- sensory-motor perception

Negative Symptoms :
Blunted affect, social withdrawal , poverty of speech, loss of motivation, anhedonia…

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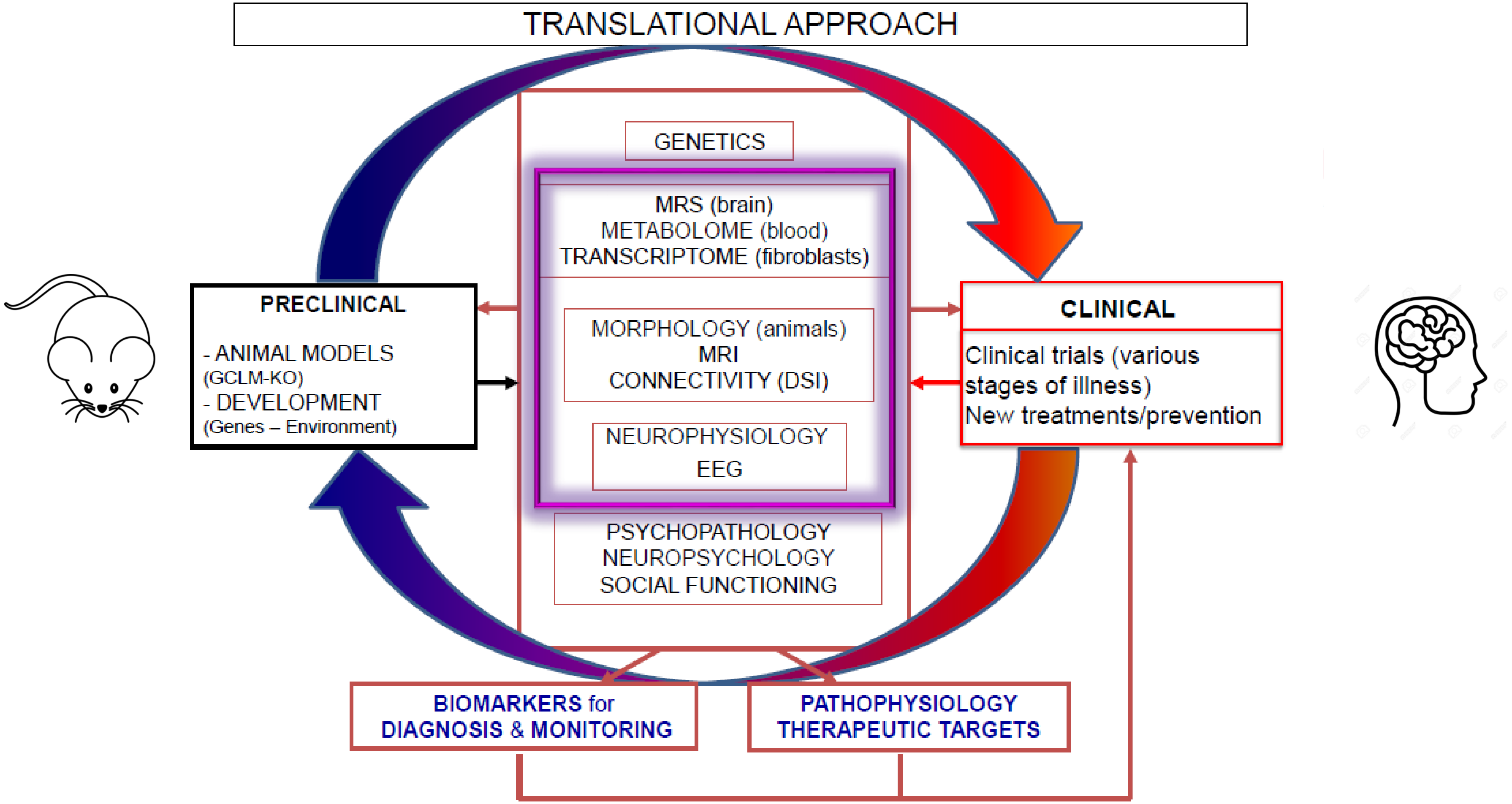
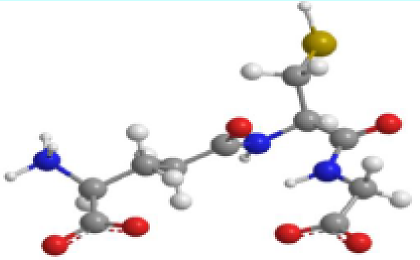
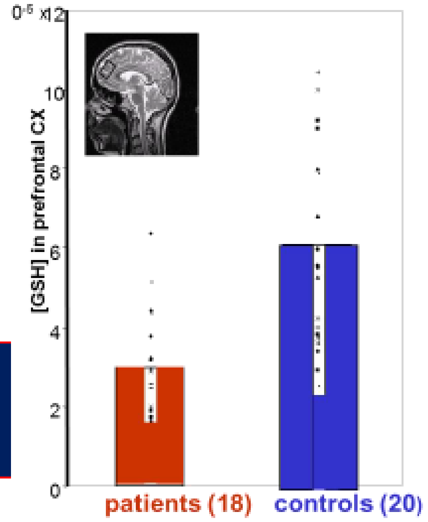
2008 – 2022: NCCR-SYNAPSY (CHUV, UNIL, EPFL, CIBM)



Schizophrenia vulnerability factor: Redox dysregulation / glutathione synthesis deficit



Tripeptide: γGlutamyl-Cysteinyl-Glycine



Decreased prefrontal GSH in SZ patients Double quantum coherence 1H-MRS

Glutathione (GSH): endogenous redox regulator and antioxidant
- protect cells from damage by reactive oxygen species (ROS)

GSH ↓ prefrontal cortex & cerebrospinal fluid	***Do&al. Eur J Neurosci 2000***
GSH ↓ in post-mortem brain	*Gawryluk&al.2011; Yao &Keshavan, 2011, Flatow&al, 2013*
GSH synthesis **genes associated** with SZ	*Gysin &al…Do PNAS 2007; Tosic &al…Do J. Am. Hum. Gen., 2006*
High-Risk GCLC genotypes → synthesis ↓ : **GSH ↓** levels in fibroblasts and brain	*Gysin &al…Do PNAS 2007; 2011 L.Xin &al, 2014*

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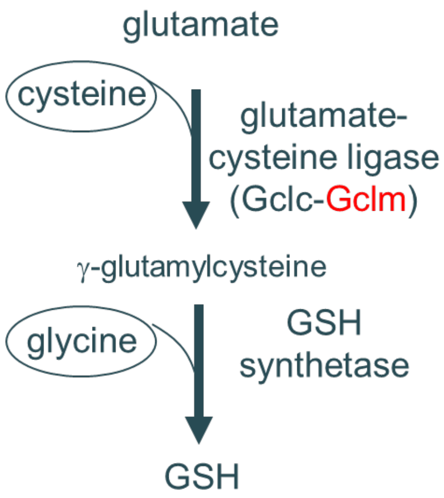
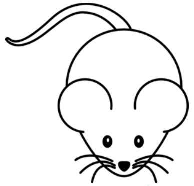
GCLC “HIGH-RISK” GENOTYPES → GSH ↓

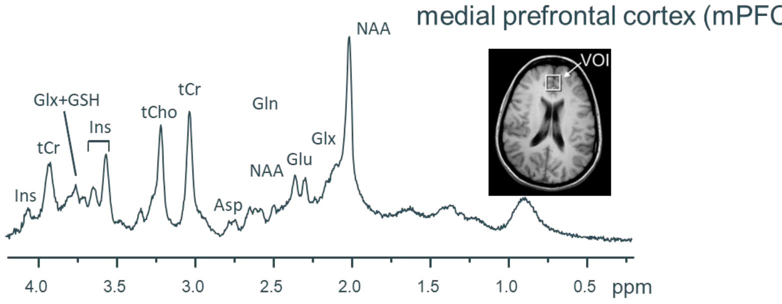


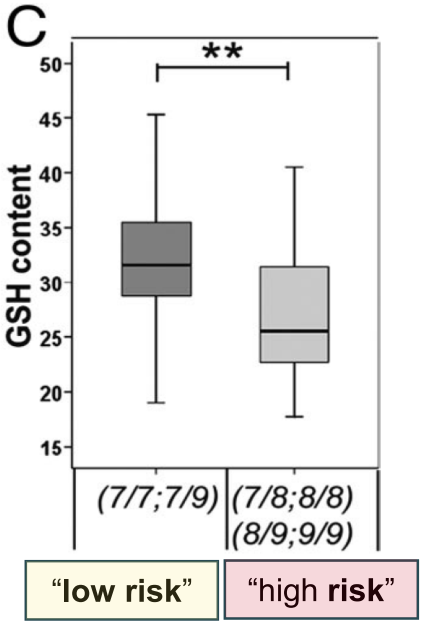
GAG trinucleotide repeat (TNR) polymorphisms in the gene coding for the catalytic (**GCLC**) subunit of GCL associated with schizophrenia

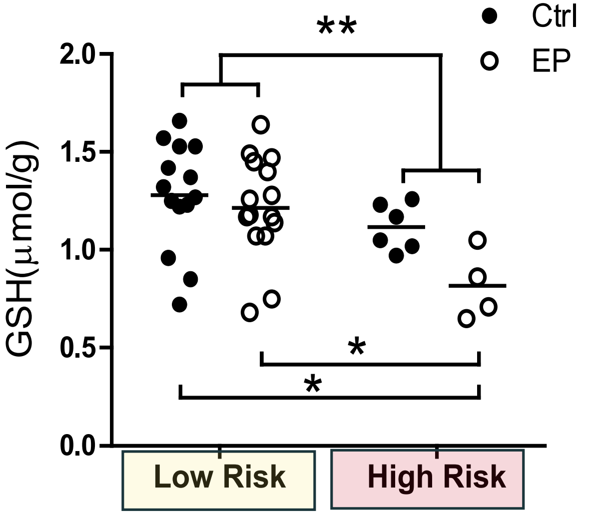


Gclm-KO mice

- low brain GSH levels (- 80-90%)
- resembles characteristic features of schizophrenia: impaired GABAergic parvalbumin-positive interneurons (PVI) in numerous brain regions, abnormal myelination, behavioral anomalies



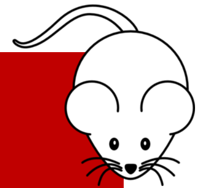




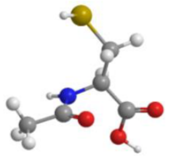
Gysin et al., Proc Natl Acad Sci USA, (2007). Xin et al., Schizophrenia Bulletin, (2016).

Animal model 14T MRS allows:

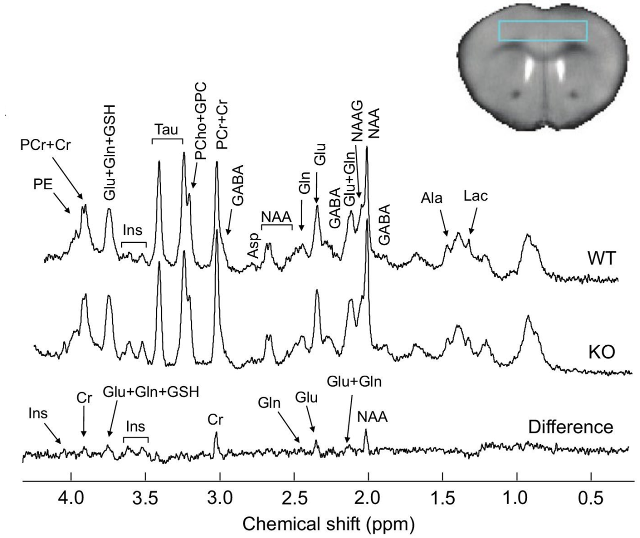
- ➢High resolution neurochemical profile along **neurodevelopment**
- ➢Predict potential sensitive period of vulnerability: glutamate/glutamine anomalies at **peripuberty**
- ➢➢Prevention potentiality: N-Acetylcysteine normalizes neurochemical changes in the glutathione-deficient schizophrenia mouse model during development

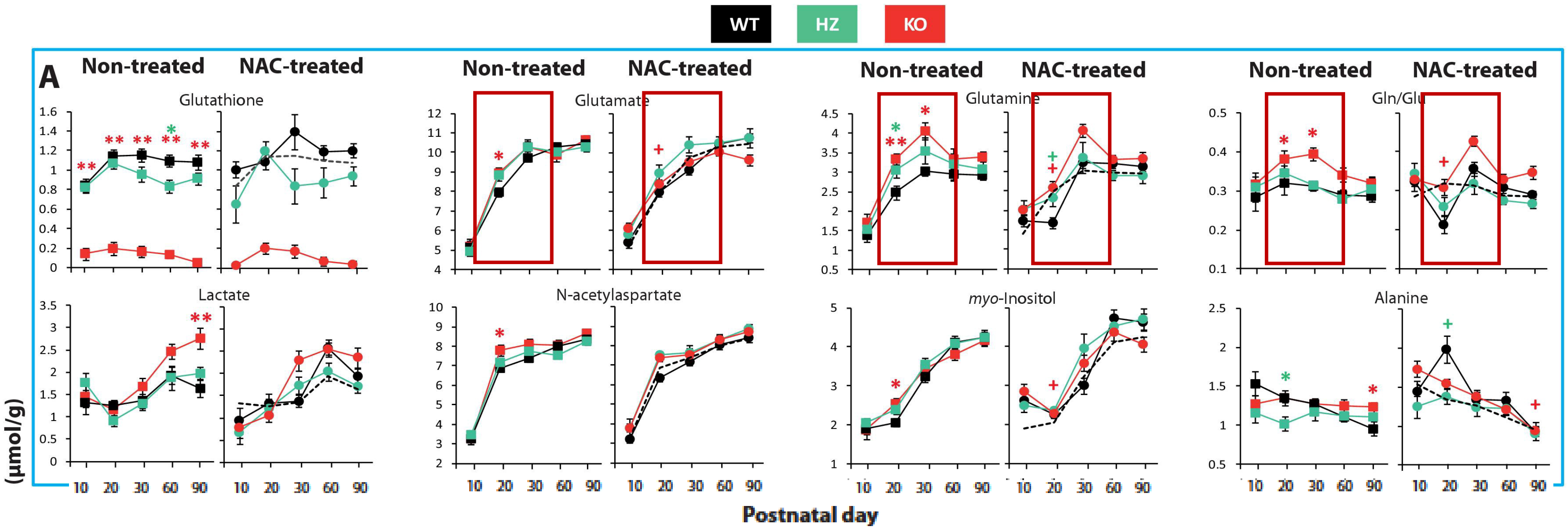


N-Acetyl-Cysteine (NAC): a safe antidote for cysteine/glutathione deficiency



- •antioxidant
- • reduces disulfide bonds
- • anti-inflammatory

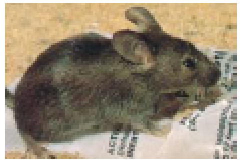


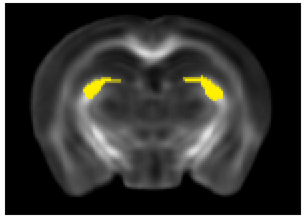


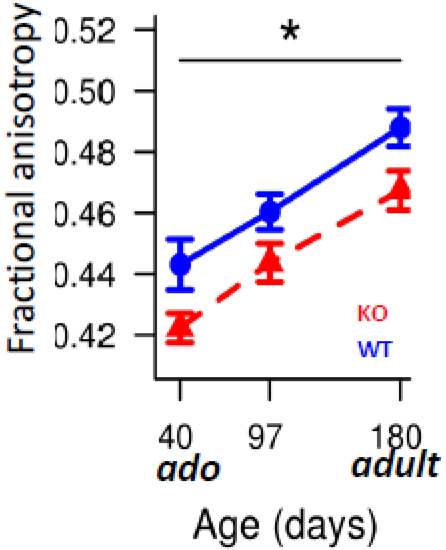
Duarte et al., Biological Psychiatry (2012)

Longitudinal DTI in GCLM-KO: Reduced WM integrity in the fornix (hippocampus) already present at peripuberty, associated with decreased conduction velocity

14T DTI of *Gclm* KO during development: decreased fornix integrity







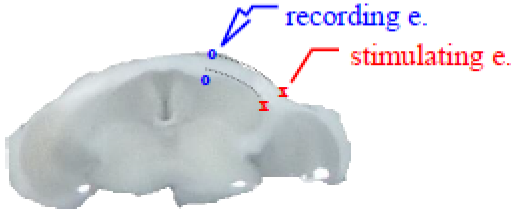
Y Van de Looij

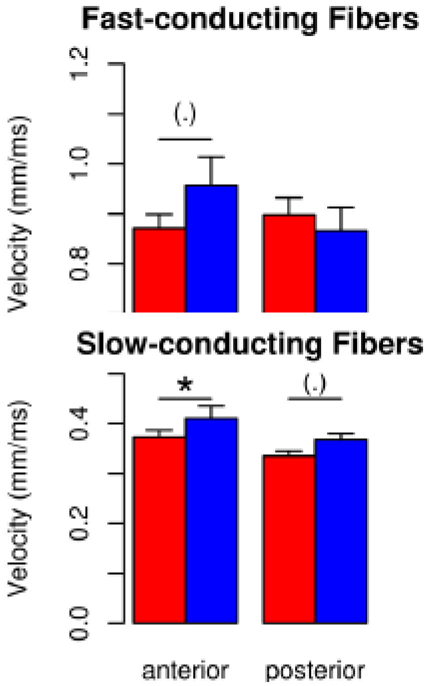
A. Corcoba

Corcoba, &al…Do IJNPP.,2015

Fornix, a white matter bundle, output tract of the hippocampus, and play a key role in cognition

Electrophysiological recording: fornix fibers conducting slower





P. Steullet

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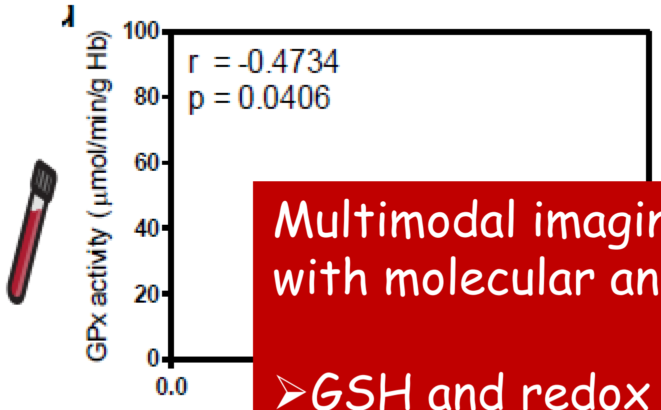
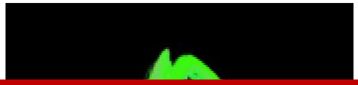
Slide courtesy of Kim Do

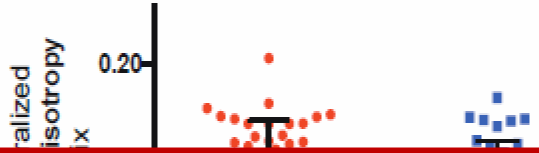
Translation from model to patient:
Abnormal fornix integrity in early psychosis patients predicted by the model
high peripheral oxidation is associated with low brain GSH levels and low hippocampal volume



Fornix gFA: DSI in early psychosis



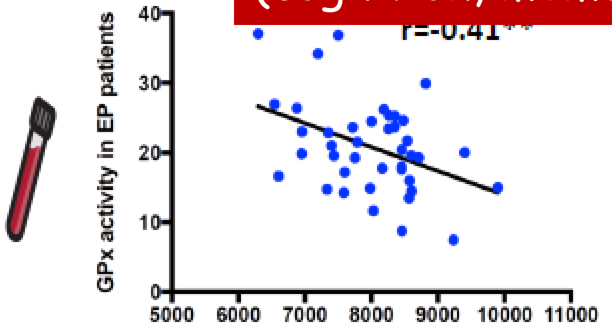
Fornix: decreased integrity



Multimodal imaging both in model and early psychosis patients, combined with molecular and cellular analysis in model demonstrate:

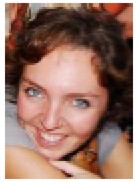
- ➢GSH and redox regulation play a critical role in the maturation of nerve fibers (rodent and human)
- ➢WM integrity of limbic system connectivity, cingulum and fornix, (cognition, memory): potential early markers?

oxidati



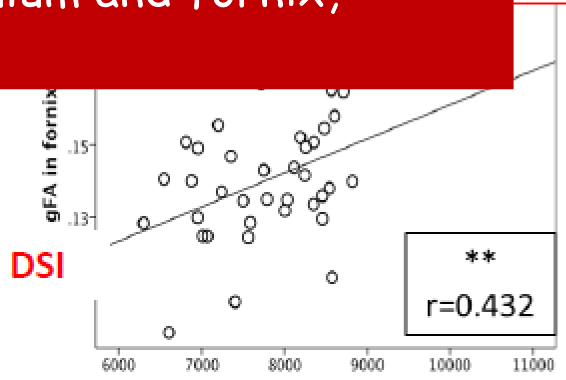
Hippocampus volume MRI

‹P.Baumann
A.Griffa ›
J-P.Thiran
P.Hagmann



Baumann &al, Transl. Psy. 2016

npe ↓



Hippocampus volume MRI

Slide courtesy of Kim Do

TRANSLATION TO PATIENTS: CLINICAL TRIALS

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Patients

- In **chronic** patients, «proof of concept»: NAC treatment improves negative symptoms & MNN and local synchronization Berk 2008 Biol.Psy; Lavoie 2008 Neuropsychopharm, Carmeli 2012 PlosOne
- In **early psychosis**, 6 months clinical trial with **NAC** leading to biomarker guided treatment :

Animal models

Deficits prevented by antioxidants
GCLM-KO: Cabungcal 2013 Biological Psy.
Developmental NVHL: Cabungcal 2014 Neuron (neonatal ventral hippocampal lesion)
Convergence of various models: Steullet 2017 Mo.Psy.

***N-Acetylcysteine* (*NAC*),**
a precursor of intracellular cysteine and *GSH*

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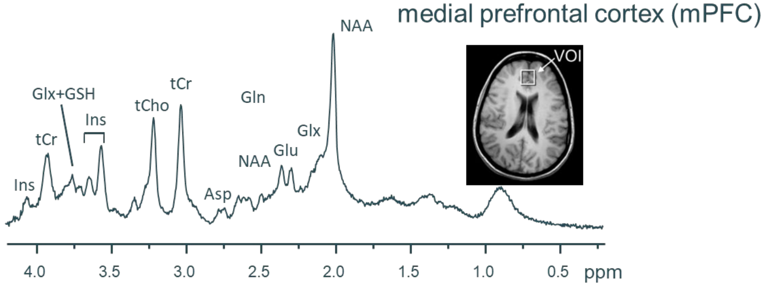
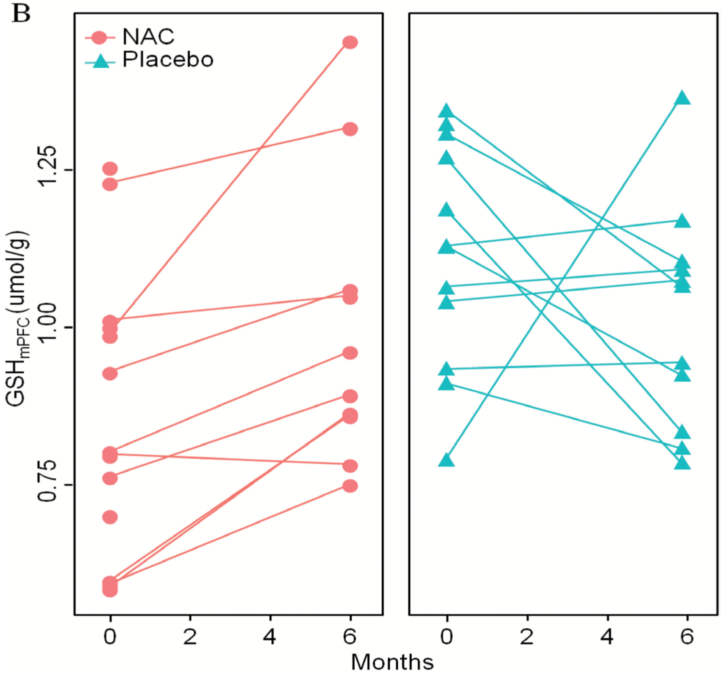
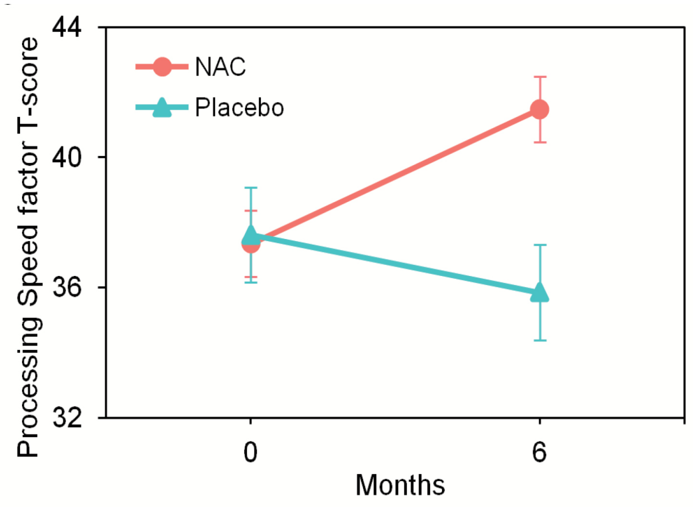
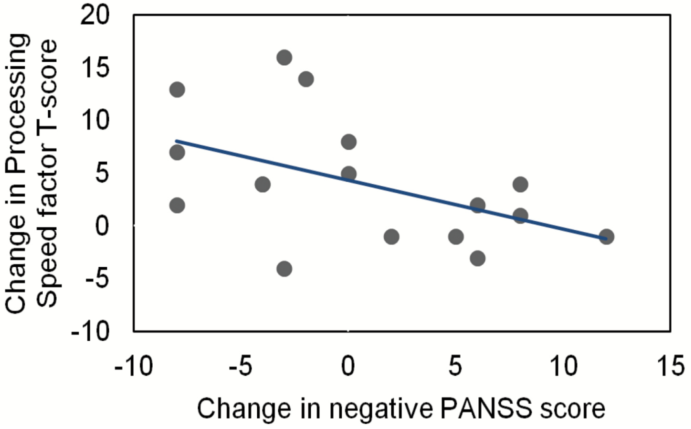
Target engagement: NAC increases prefrontal GSH levels





NAC improved neuro-cognition in association with negative symptoms





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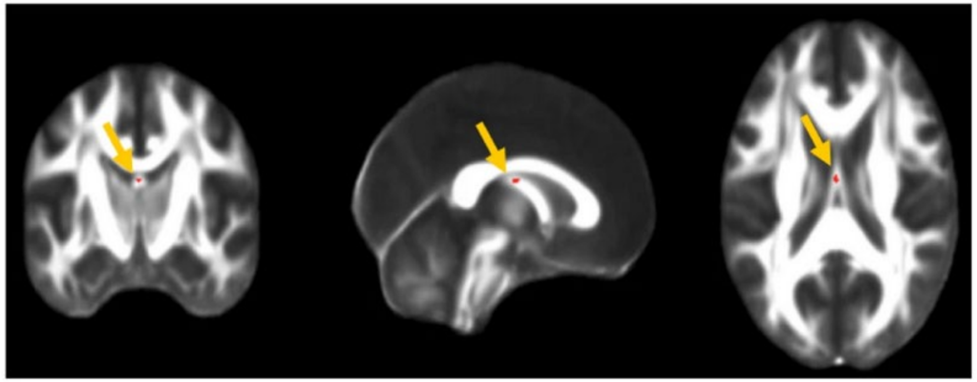
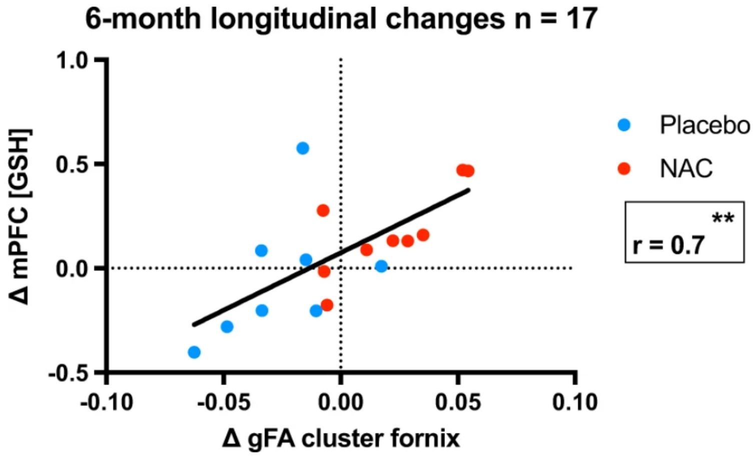
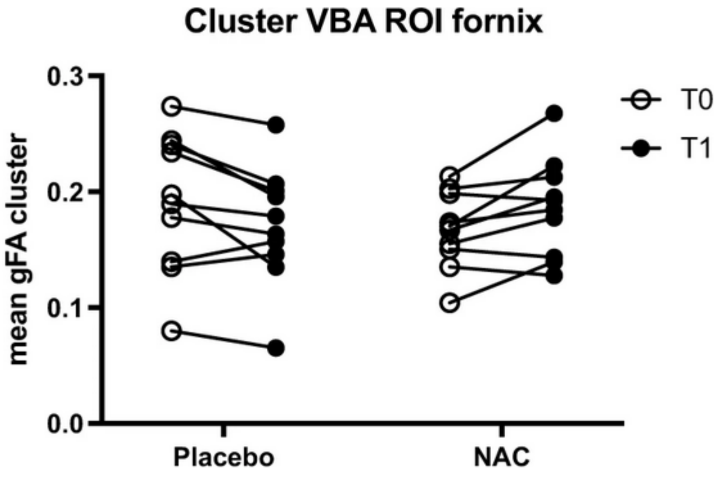
Conus et al., Schizophr Bull (2018)

NAC IMPROVED FORNIX INTEGRITY

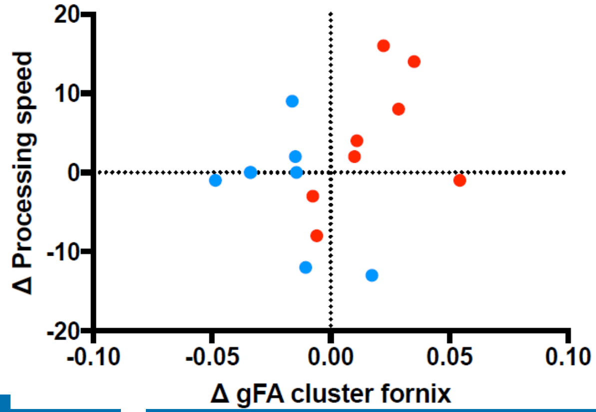
↑ GSH → Fornix FA ↑







↑ Fornix FA → cognition ↑



NAC → Fornix FA ↑

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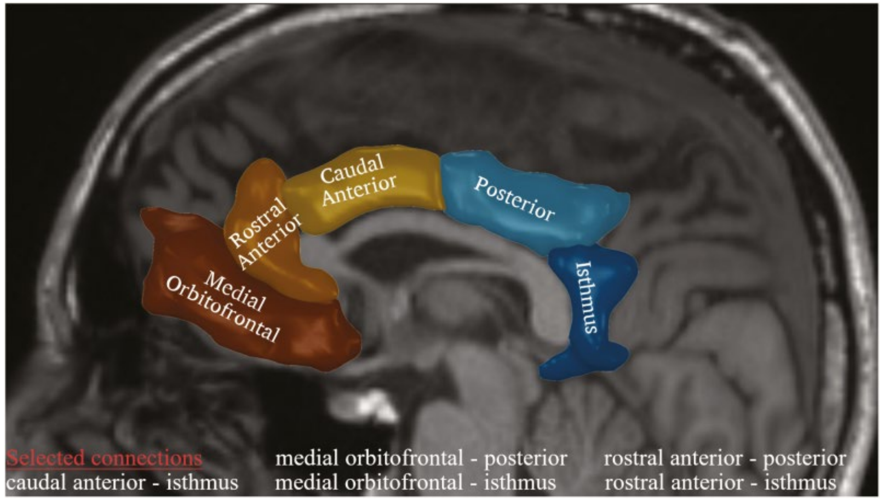
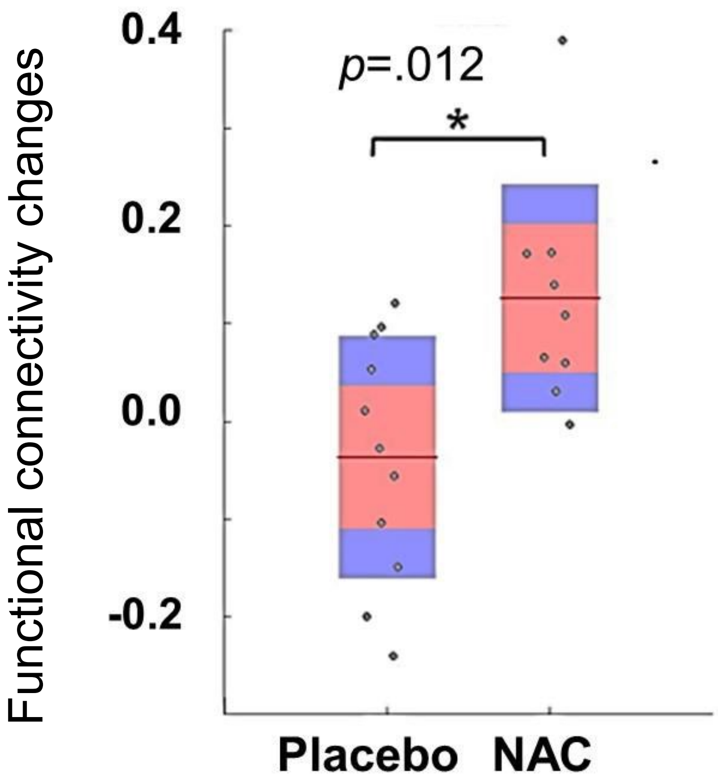
Klauser et al., Transl Psychiatry (2018)

NAC IMPROVES FUNCTIONAL CONNECTIVITY





NAC → functional connectivity between **anterior** and **posterior cingulate** ↑

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Mullier, et al. , Int.J.Neuropsychopharmacology, 2019

EFFECTS OF NAC TREATMENT IN PSYCHOSIS

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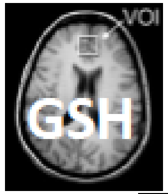
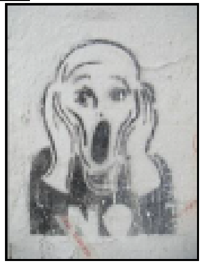
➢ NAC



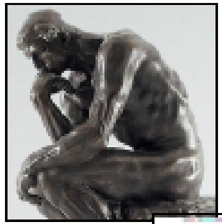
- elevates the brain glutathione

Conus &al., 2018 Schizo.Bull.

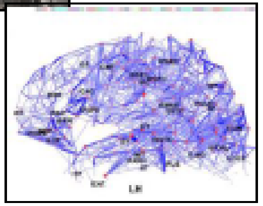


- improves positive symptoms (patients with blood marker of high oxidative status)

Conus &al., 2018 Schizo.Bull.



- improves the cognition *Conus &al., 2018 Schizo.Bull.*



- improves the connectivity of nerve fibers (macrocircuits) *Klauser &al 2018; Mullier &al 2019*

MRI PROCEDURE & SAFETY

CONTRAINDICATIONS TO MRI

- Metal implants (pacemakers, cochlear implants, aneurysm clips, metal plates or screws) can interfere with MRI and harm the patient.
- Pregnancy: unknown effects on the fetus.
- Claustrophobia
- Severe kidney disease may prevent the patient from tolerating the contrast dye used in some MRI exams.
- Weight limits that prevent larger patients from undergoing the procedure.
- Allergic reactions or kidney disease: no contrast agents

MRI PRE-EXPERIMENTAL PROCEDURE

- Ask your participants/patients: empty pockets & remove all metallic objects
- Fill in MRI safety form
- Explain the experimental procedure and consent form
- Check once more: every metallic objects are removed

MRI ACCIDENTS

http://www.mrisafety.com

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IMPORTANT BUTTONS

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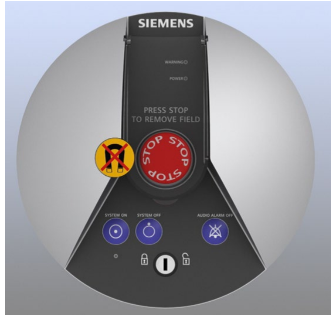
Center for Biomedical Imaging

- **Quench button**: use it only if there is an **<u>immediate risk to life</u>**



- **Emergency electricity button:** only be used in emergency situations
  - Power failure
  - Fire
  - Patient emergency

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MAGNET SAFETY

- Magnets are always « **ON** » even during a power failure
- In case of quenching, open the doors, there is a risk of low oxygen level
- Don't touch the cold pipes
- Report to the responsable staff ASAP, there are some procedures to follow

Emergency call: 115

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THANK YOU FOR YOUR ATTENTION