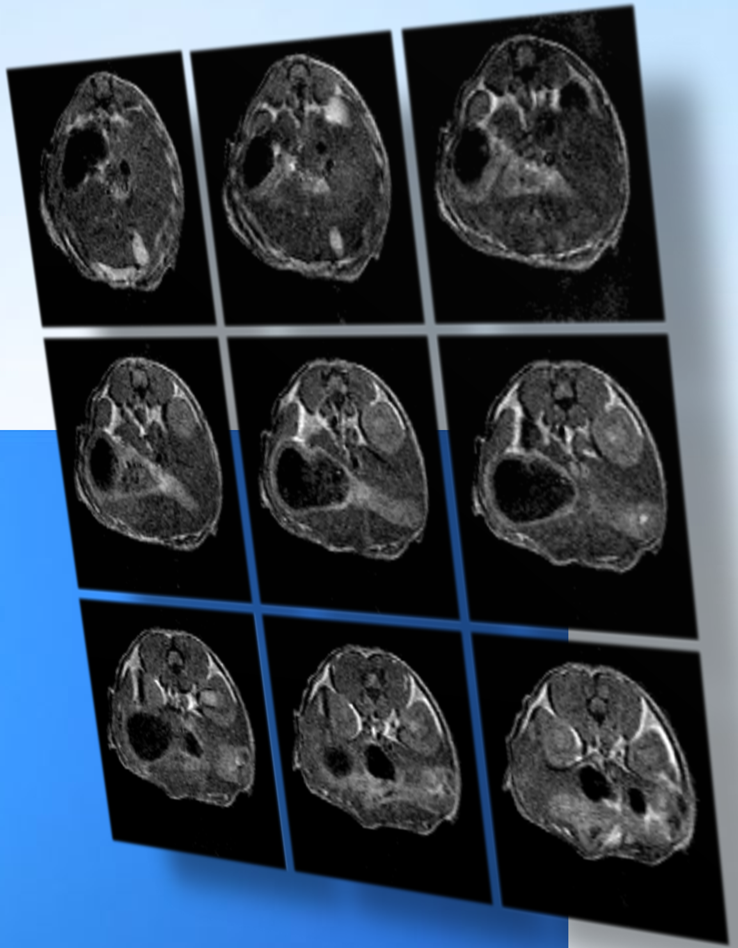
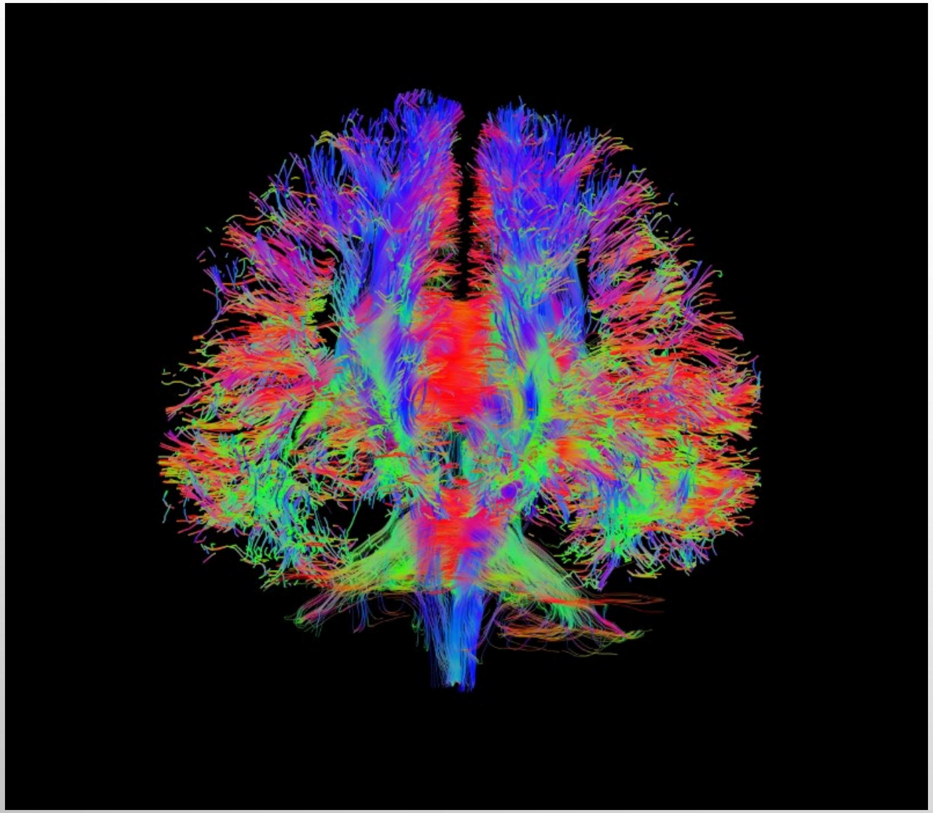
INSTITUTE OF BIOMEDICAL SCIENCES
生醫所
中央研究院

Magnetic Resonance in Biomedicine



黃聖言 Dennis W. Hwang




AcroViz Technology 上頂醫學影像科技

立即登入 瞭解更多

腦神經年齡檢測報告書

編號：MHF31
姓名：
性別：男
出生日期：1974/07/29
檢查時間：2022/11/15

研究使用，僅供參考

量測結果

腦神經年齡			
44.6歲 您的腦神經年齡	48.3歲 您的身分證年齡	3.7歲 較年輕	A 腦健康評分

綜合評估

您的全腦神經束為44.6歲，與您的身分證年齡差不多，表示您的大腦在健康範圍內。建議您至少 3 年後回來追蹤檢查。

腦神經年齡

- 人類年齡可用身分證年齡及生物年齡表示，常見的生物年齡有骨齡、膚齡，而腦神經年齡也是屬於生物年齡。
- 藉由磁振造影 (MRI) 拍攝大腦影像，評估不同面向的大腦生理指標，以反映大腦的健康程度。
- 頭部創傷、神經精神疾病、心血管疾病會較容易有較老的腦神經年齡。

腦健康評分

- 評分是根據上頂的健康人資料庫與您的腦神經年齡結果評比所得出。
- 評分等級從健康至警訊分別為：A⁺, A, B, C，一般健康人等級為 A。
- 腦神經年齡較年輕以綠色表示；較老化以紅色表示。

3大主要面向 8大認知功能 評分總覽

記憶網絡				高階認知功能		接收反應功能	
事件記憶-情緒	語意記憶	內隱記憶	工作記憶	注意力	語言	感覺運動	視覺
A	A⁺	A	A	A	A	A	A
正常	健康	正常	正常	正常	正常	正常	正常
+0.3歲	-14.2歲	-4.9歲	+4.0歲	-0.0歲	-3.4歲	-3.9歲	+3.9歲

綜合評估 恭喜您！您的八項認知功能網絡皆屬健康或正常。建議您可依報告後方的建議內容，從生活開始改變，優雅老化，享受生活。

什麼是主要認知功能網絡年齡？

- 上頂依據 WHO 及 DSM-V，選出與失智症最相關的 8 項認知功能網絡，進行分析，得出其年齡。分別為：事件記憶、情緒、語意記憶、內隱記憶、工作記憶、注意力、語言、感覺運動、視覺網絡。
- 上頂於報告第 4 頁有針對個人較老化的網絡提出改善建議，您可以與您的醫師、營養師討論，打造專屬您的增進腦健康方案。

PAGE 1/8

OUTLINE

THE CONCEPT OF MRI

- 何謂光譜 WHAT IS SPECTROSCOPY?
- MRI的訊號從哪裡來? WHERE DOES MRI SIGNAL COME FROM?

APPLICATIONS

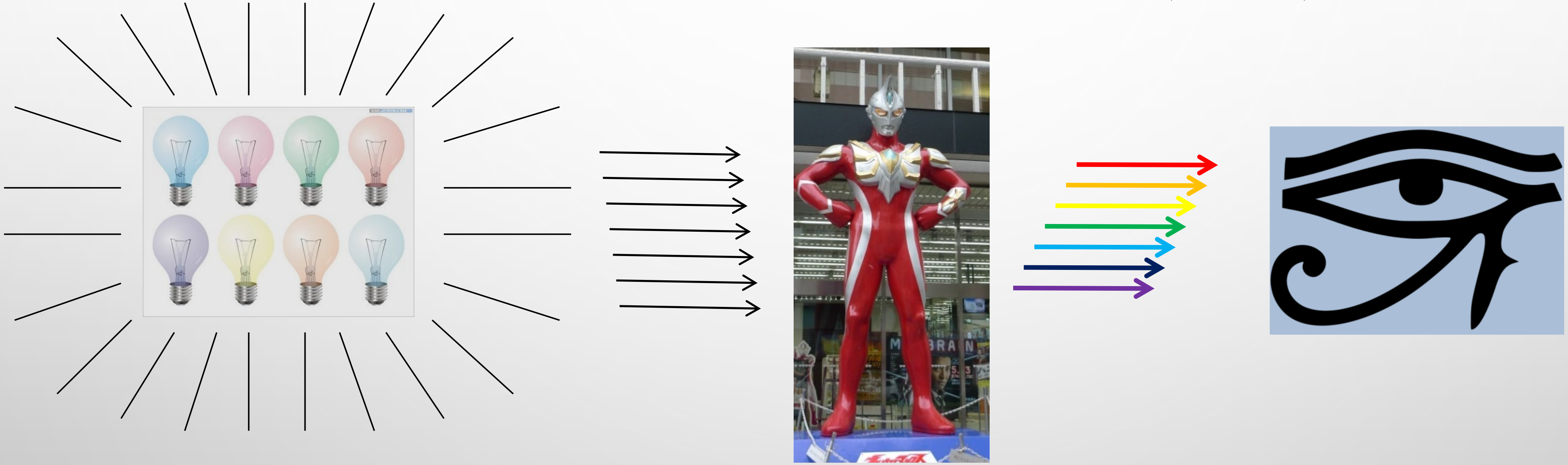
- 弛豫影像 RELAXATION BASED IMAGING
- 擴散影像 DIFFUSION BASED IMAGING
- 化學交換飽和轉移影像 CHEMICAL EXCHANGE SATURATION TRANSFER (CEST) IMAGING
- 核磁共振血管造影 MR ANGIOGRAPHY
- 功能性磁振造影 FUNCTIONAL MRI

先來了解何謂光譜?
WHAT IS SPECTROSCOPY?

WHAT IS SPECTROSCOPY?

HUMAN'S EYE

WHY COLORED?



Think about the spectrometer you used before !!!

WHAT IS SPECTROSCOPY?

How about normal life?

灑水
Water

What is information you get when the color of flame changes?

WHAT IS SPECTROSCOPY?

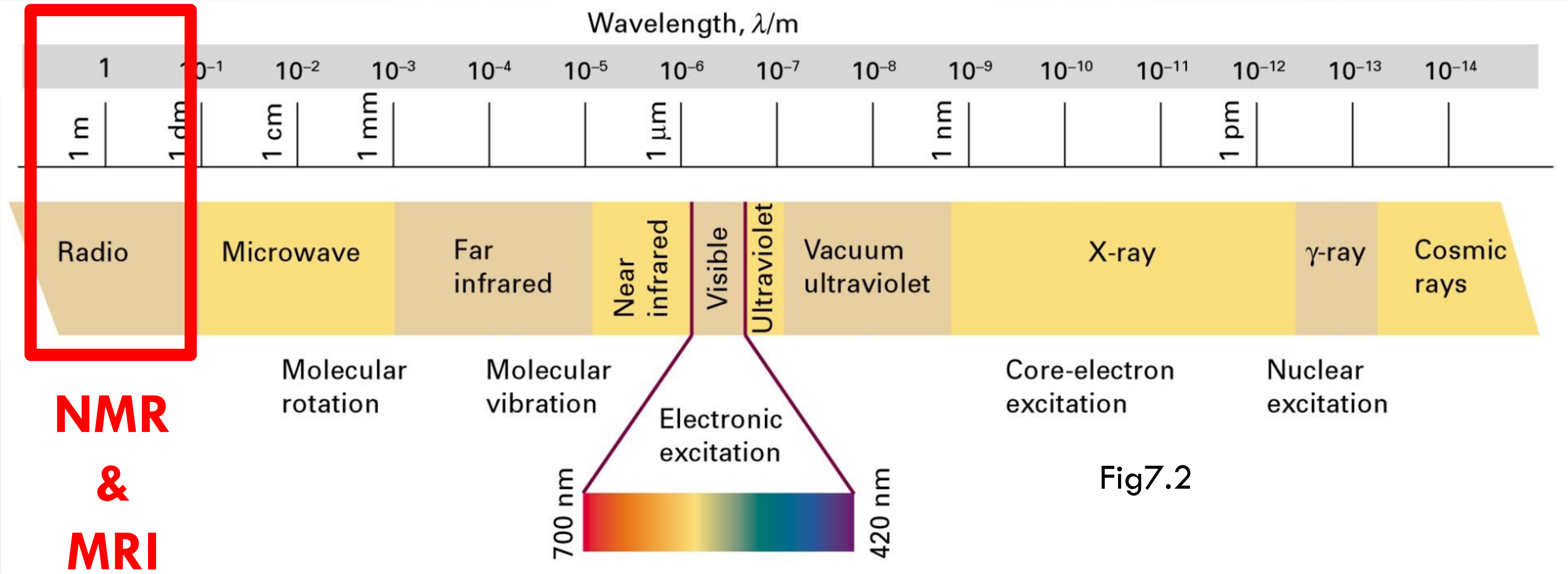
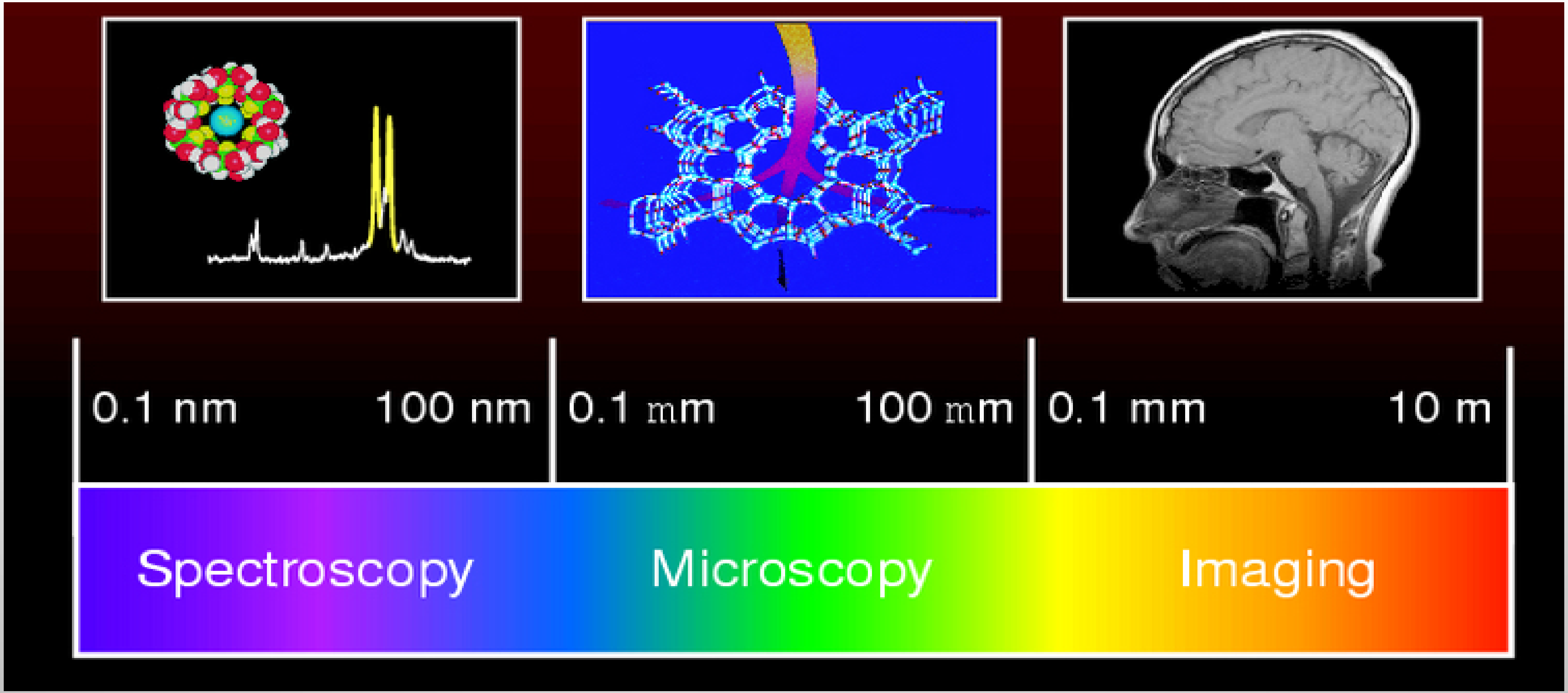


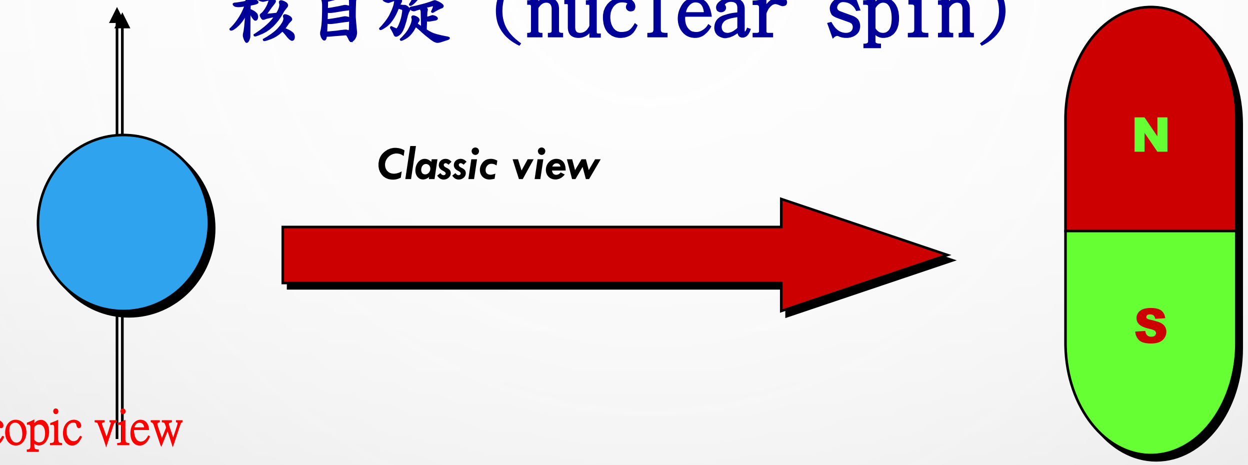
Fig7.2

NMR: From Nanometer to Meter: Molecules to Man



WHAT IS MAGNETIC RESONANCE?

核自旋 (nuclear spin)



Microscopic view

氫原子核 (proton)

From water

Most abundant in the nature

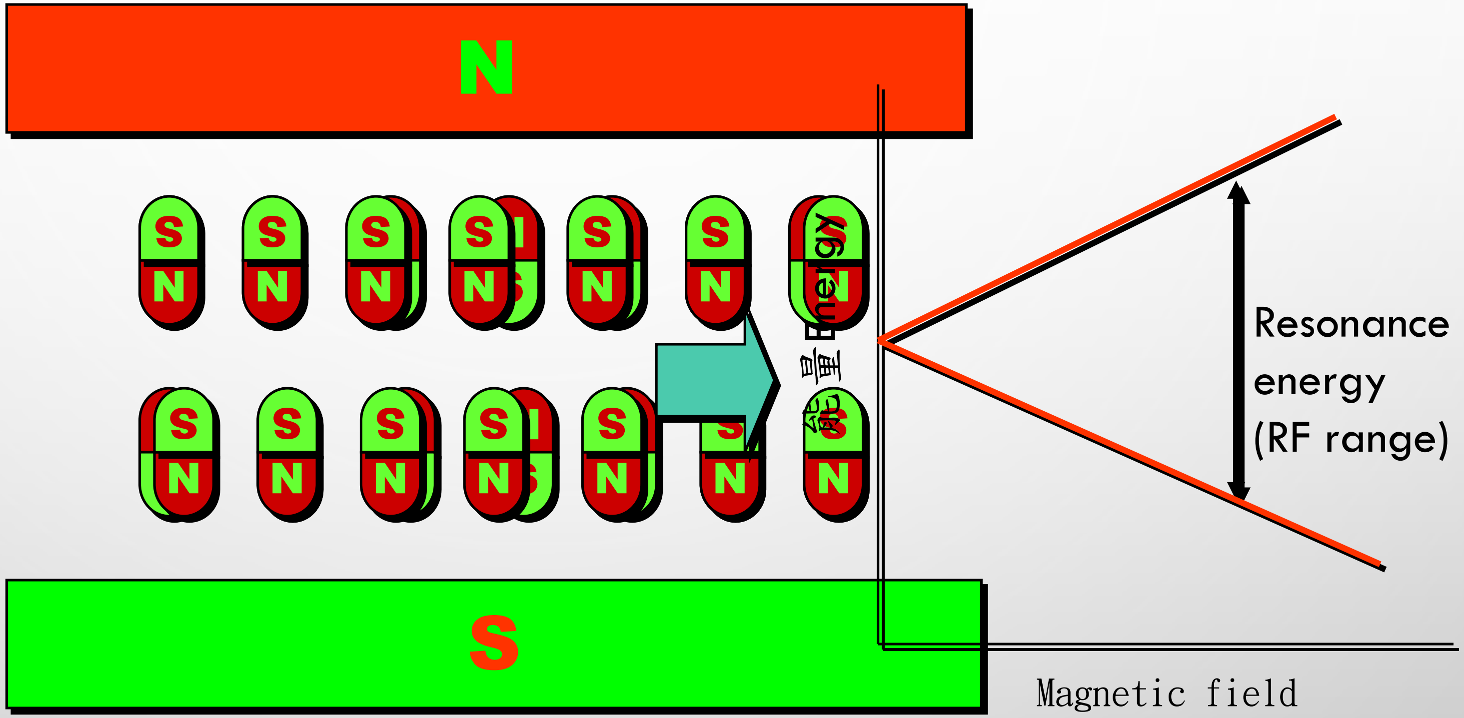
Macroscopic view

磁偶極 (Magnetic dipole)

The ensemble of proton nucleus as a small magnet (magnetization)

WHAT IS MAGNETIC RESONANCE?

ZEEMAN EFFECT



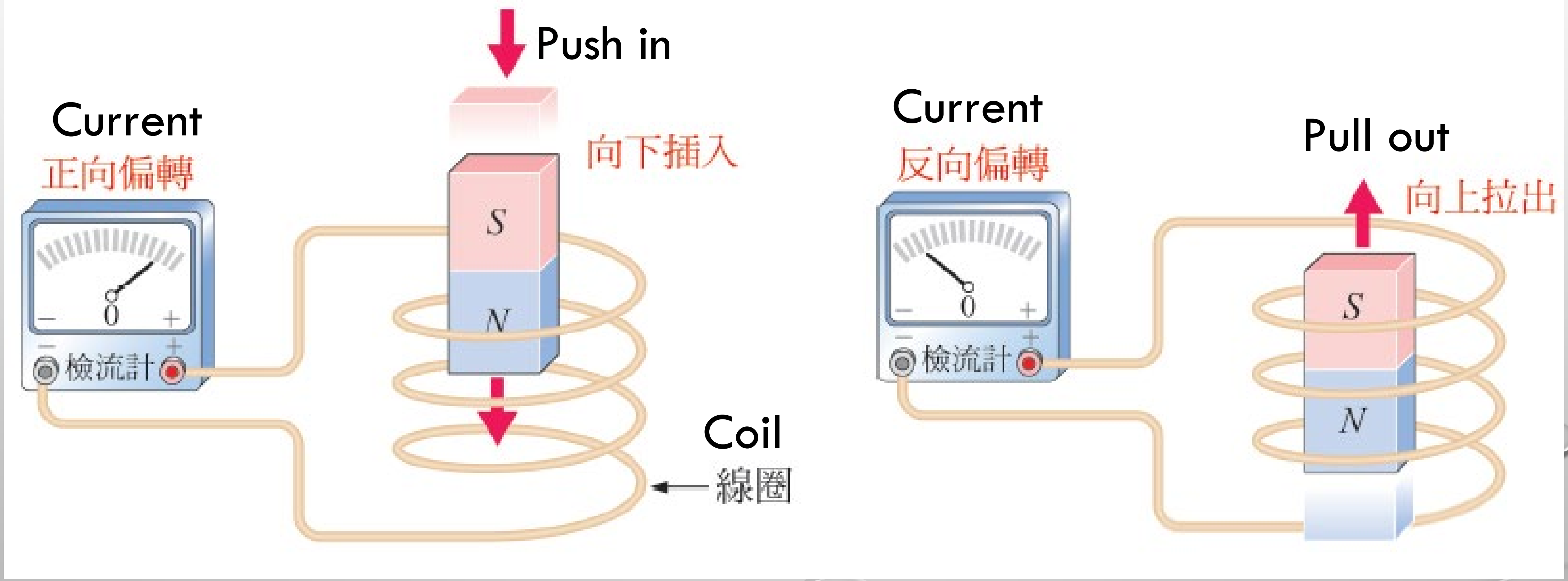
Higher magnetic field, larger energy gap

The resonance frequency of proton nucleus at 7 Tesla= 300 MHz

(Earth field=0.5 Gauss ， 1 Tesla=10000 Gauss)

FARADAY'S LAW

Lenz's law: the induced current in a loop is in the direction that creates a magnetic field that opposes the change in magnetic flux through the area enclosed by the loop.
The induced current tends to keep the original magnetic flux through the circuit from changing.



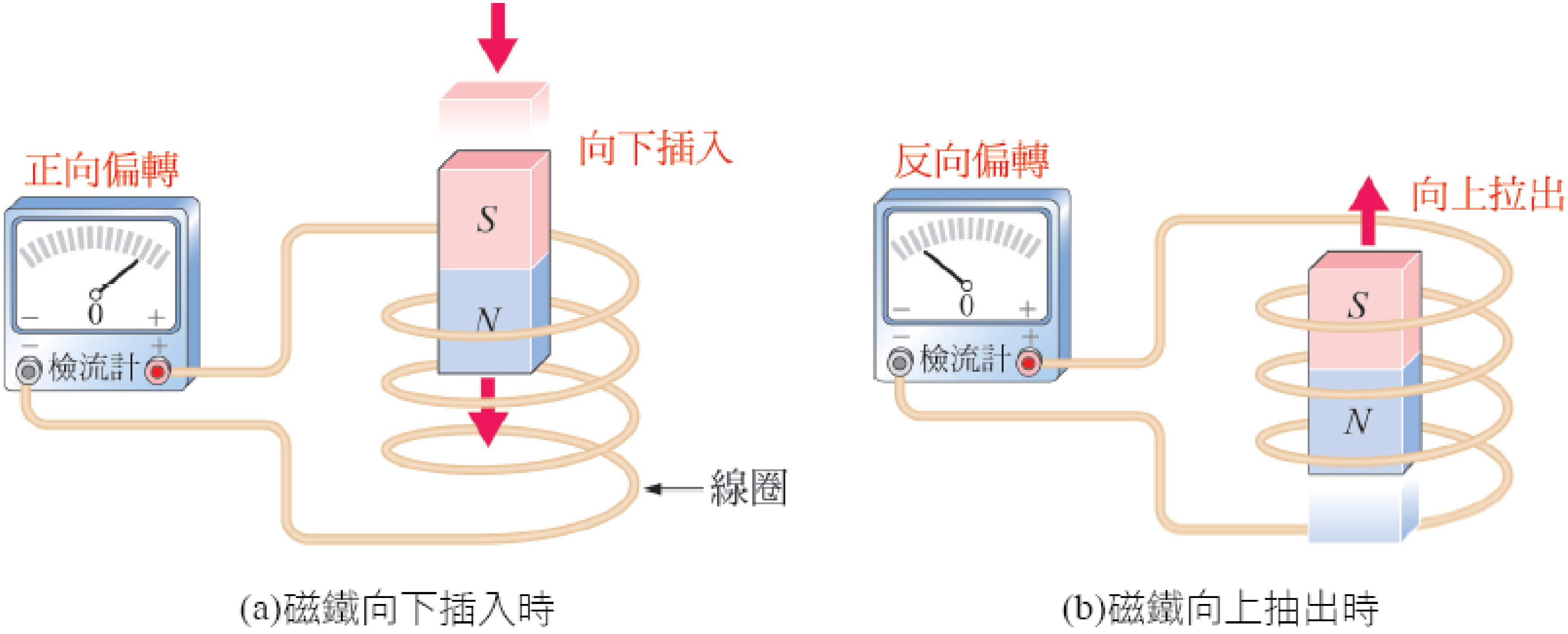
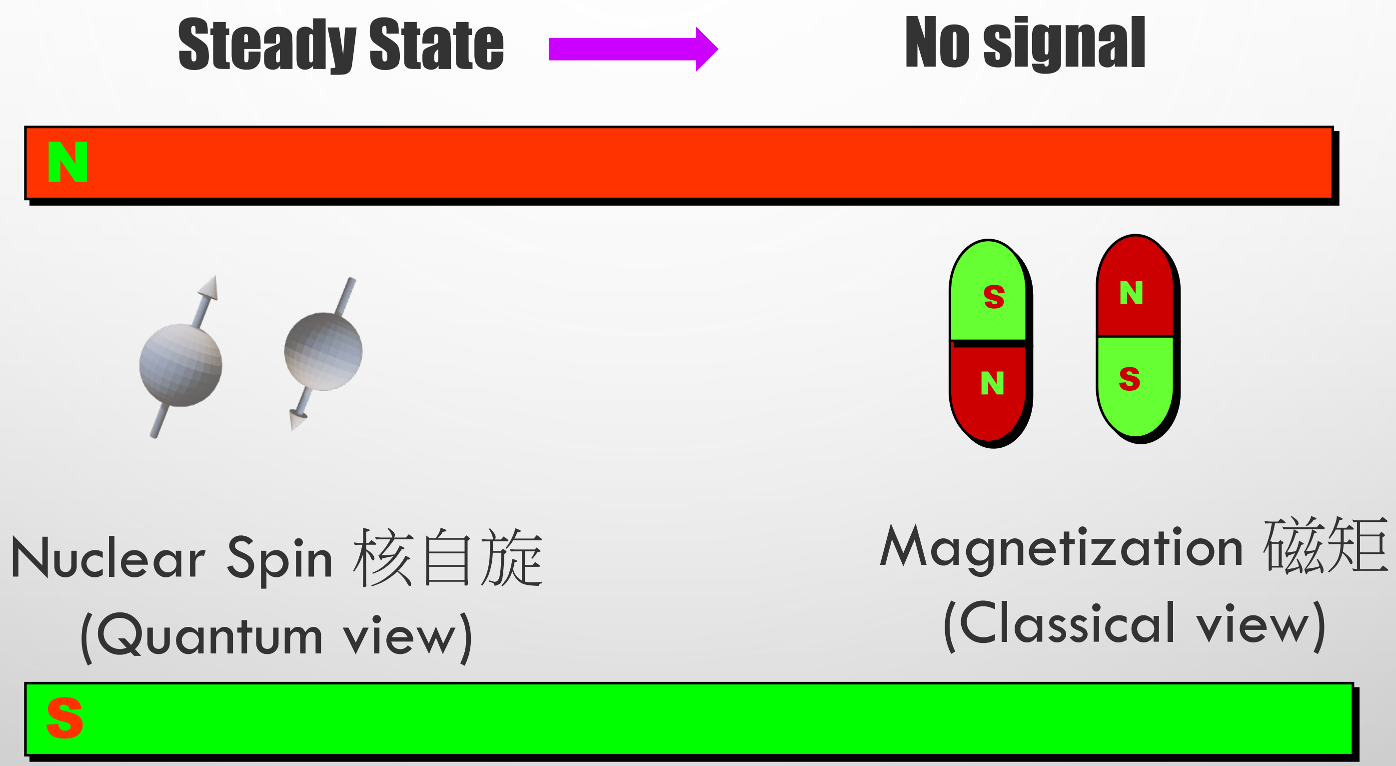
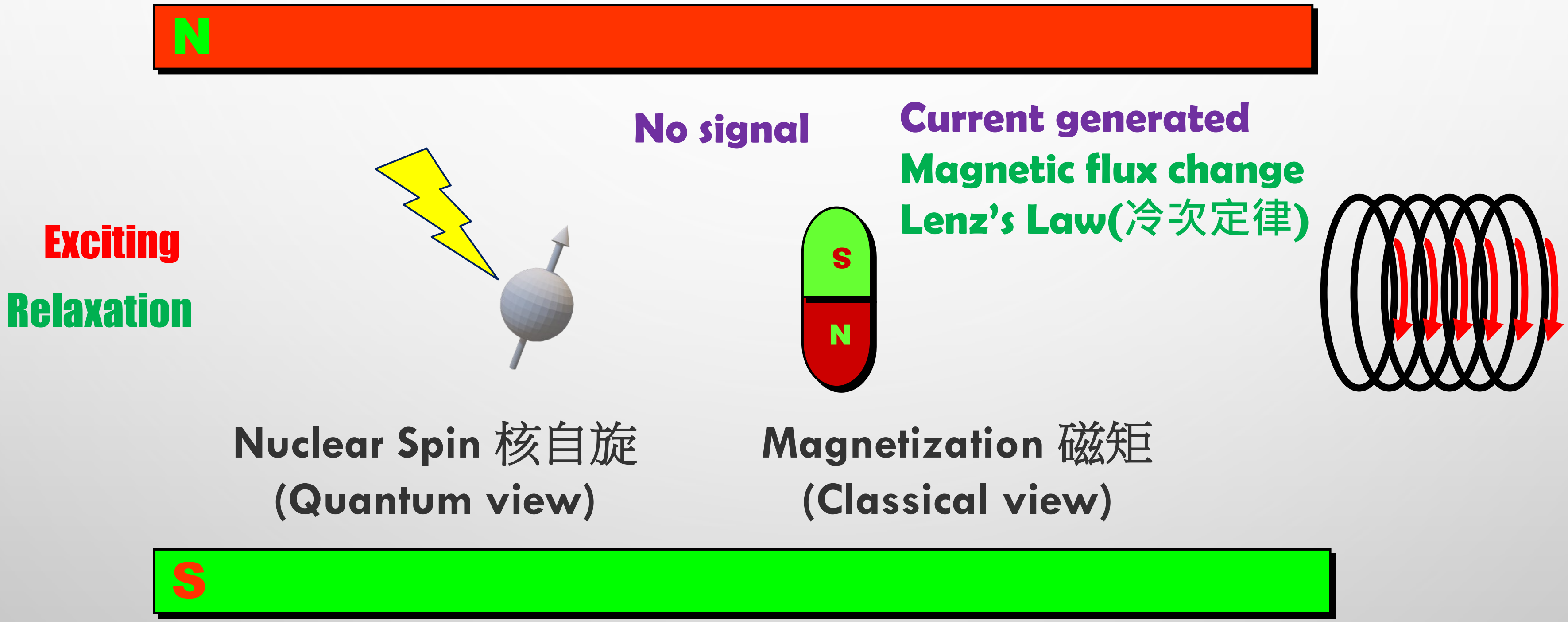


圖 1-14　法拉第電磁感應實驗

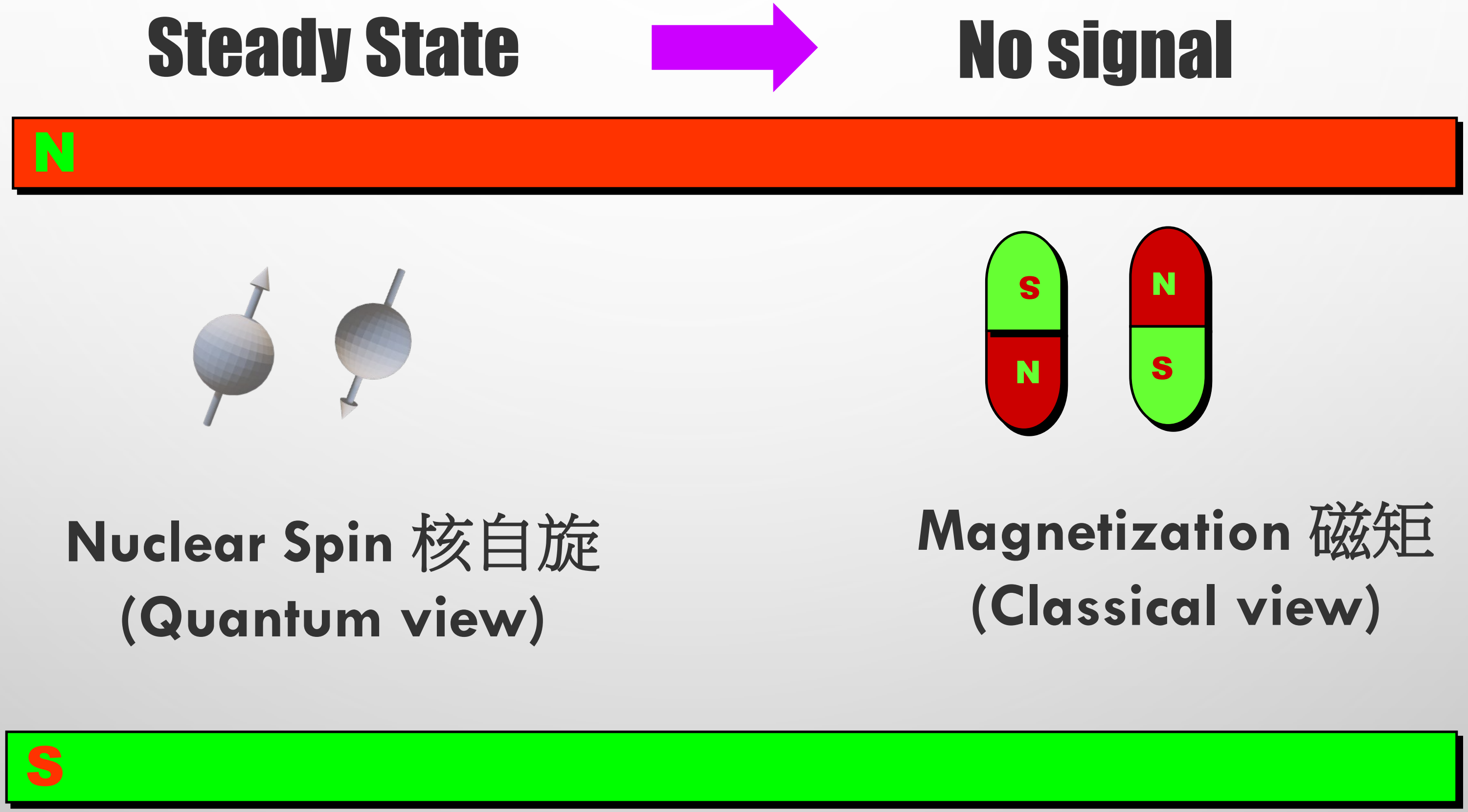
NUCLEAR MAGNETIC RESONANCE



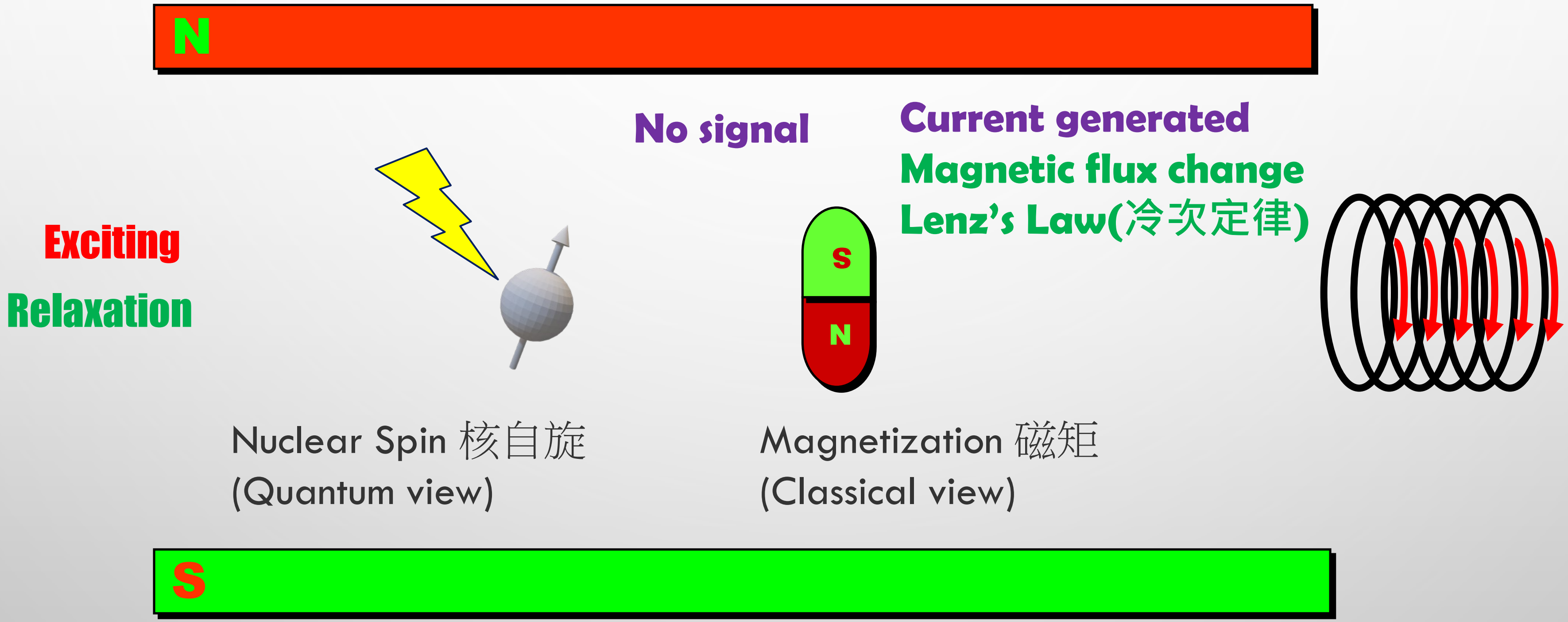
Signal: Free Induction Decay



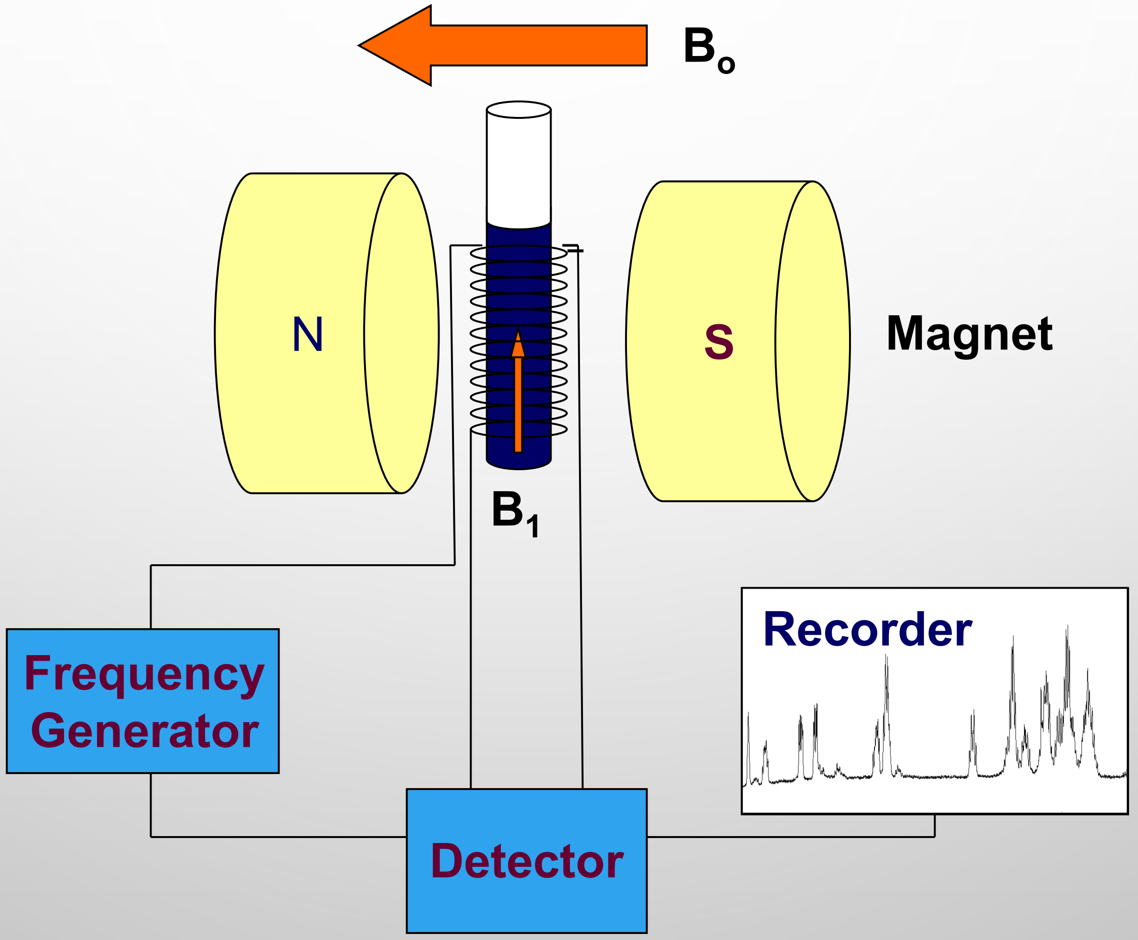
NUCLEAR MAGNETIC RESONANCE



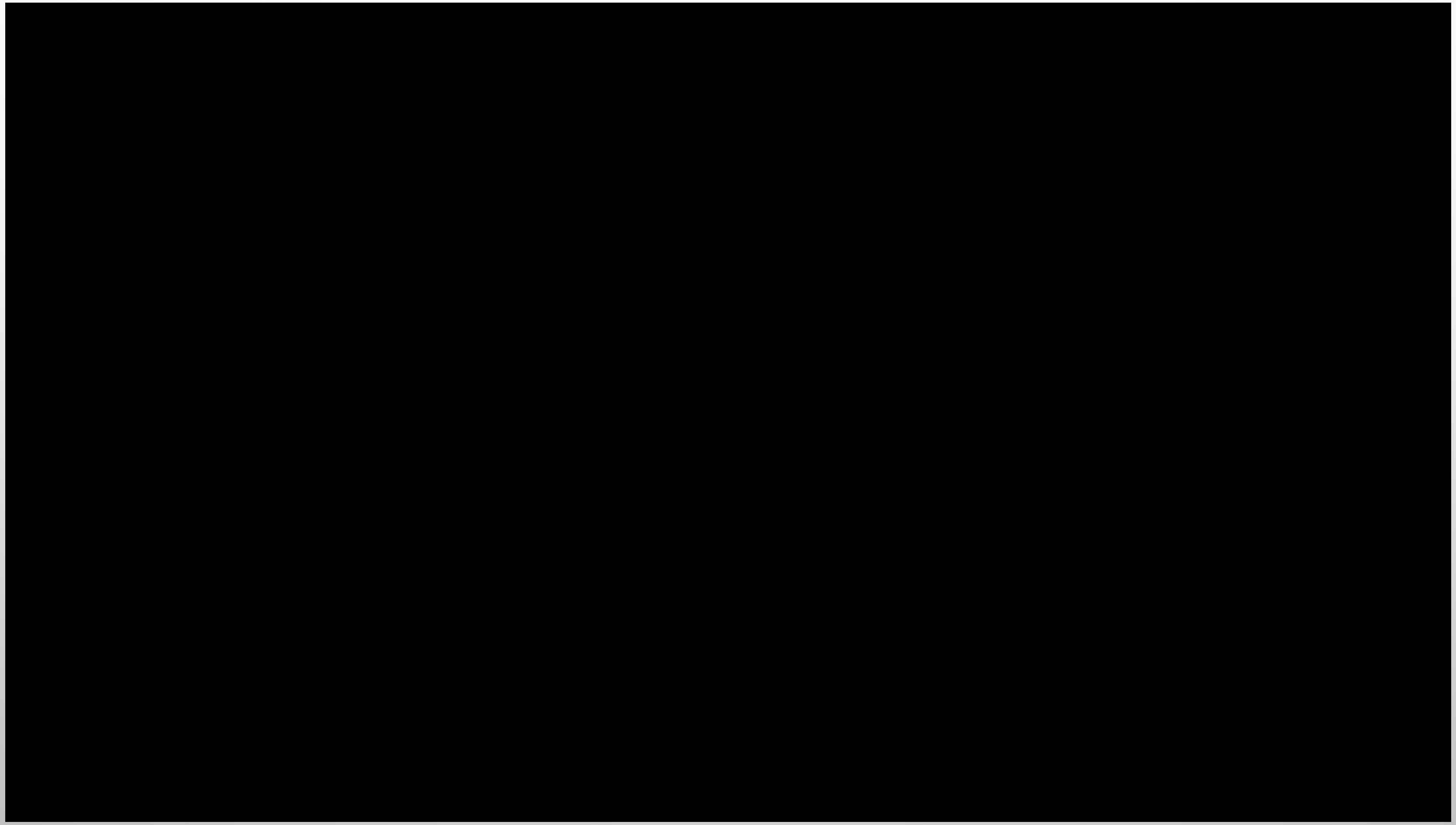
NUCLEAR MAGNETIC RESONANCE

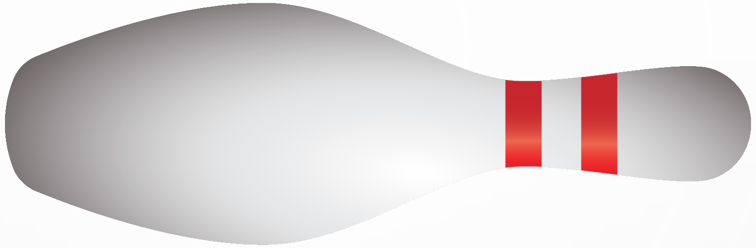


INSTRUMENT 儀器設計



HOW STRONG THE MAGNET IS

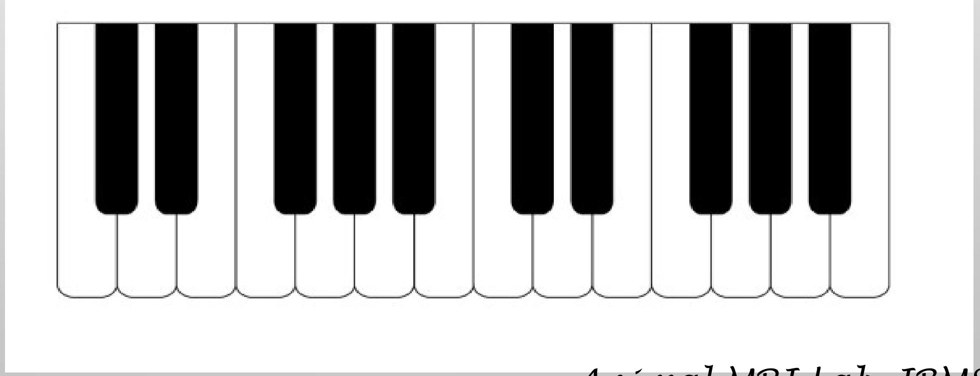




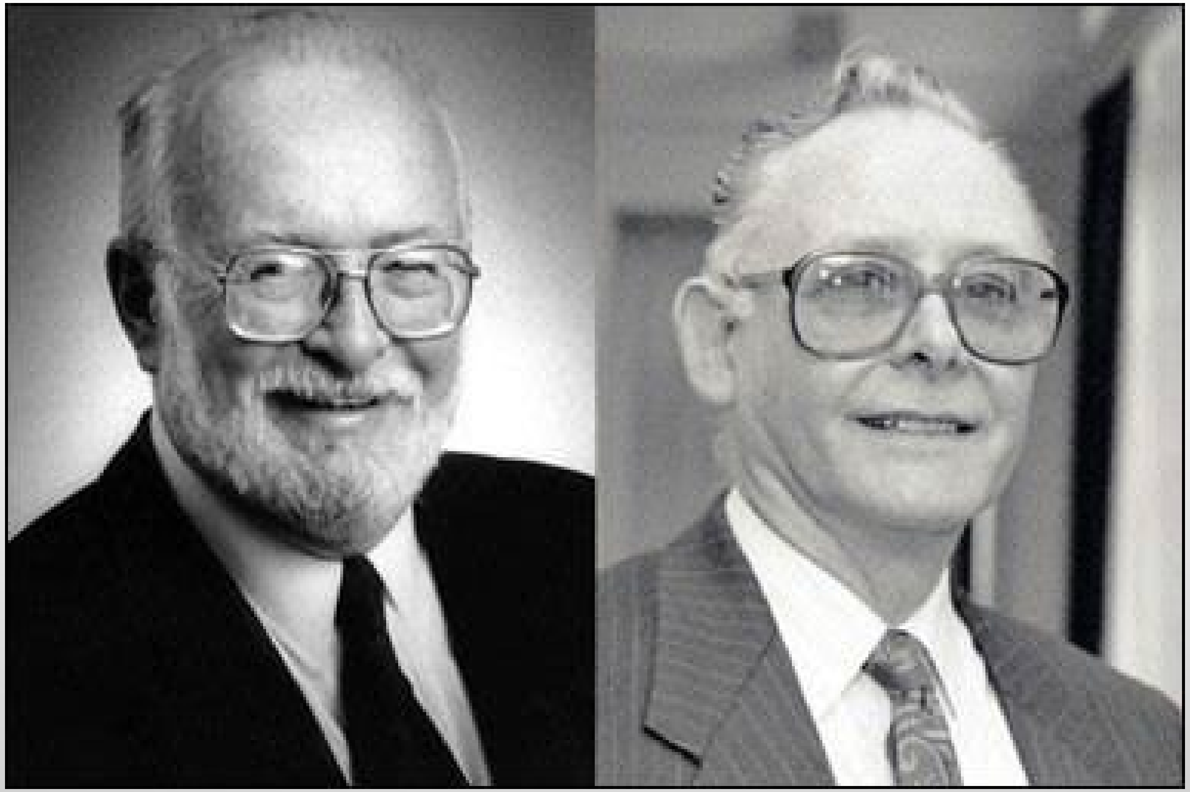
NMR

Frequency = Spatial information

MRI

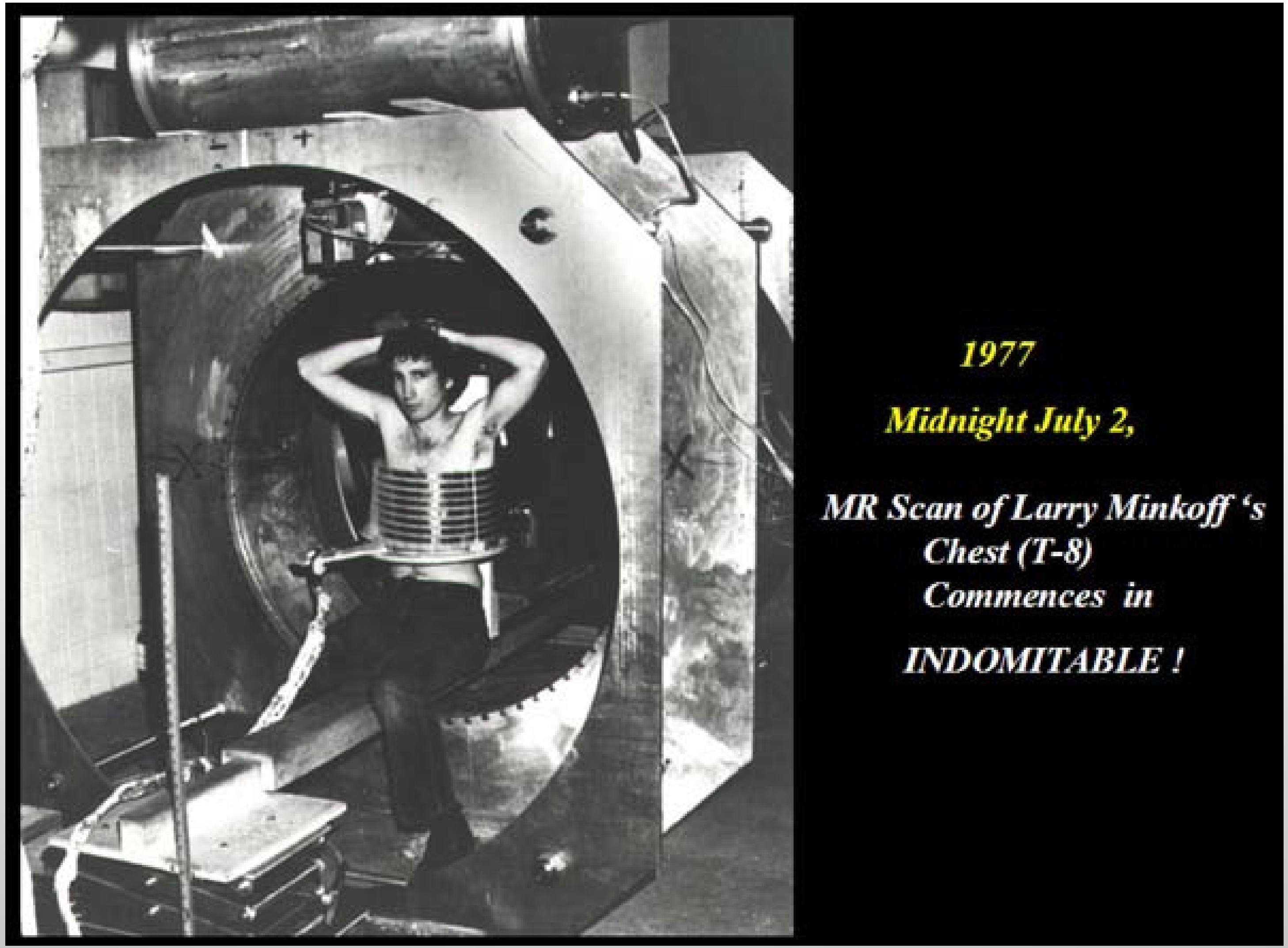


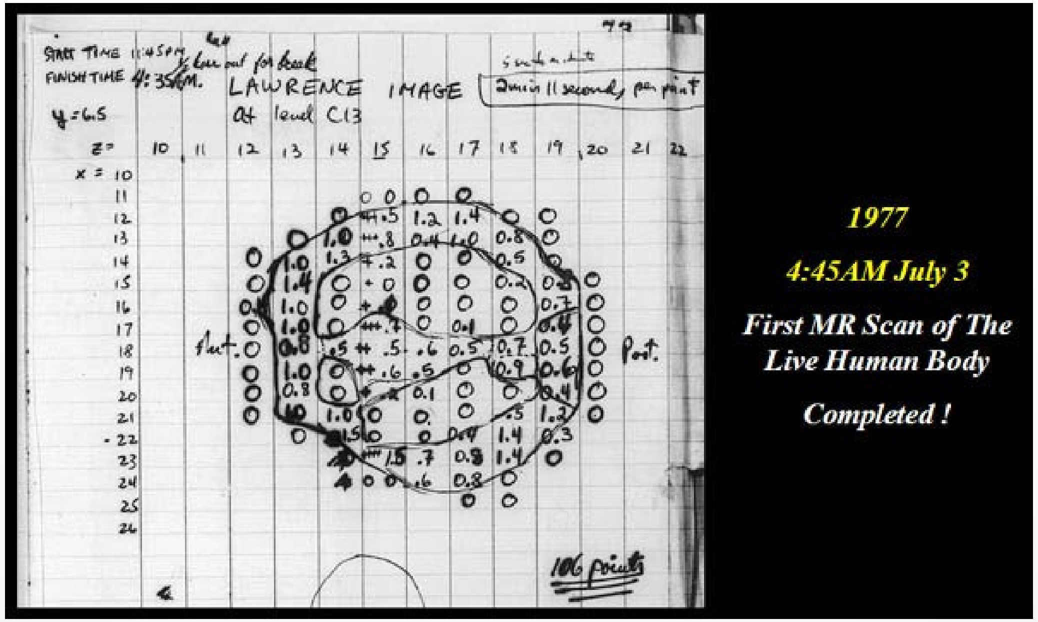
FROM NMR TO MRI



Paul Lauterbur Peter Mansfield

First MRI


1977
Midnight July 2,
MR Scan of Larry Minkoff 's
Chest (T-8)
Commences in
INDOMITABLE !


LAWRENCE IMAGE
1977
4:45AM July 3
First MR Scan of The Live Human Body
Completed !


4:45AM July 3, 1977

MRI NOWADAY

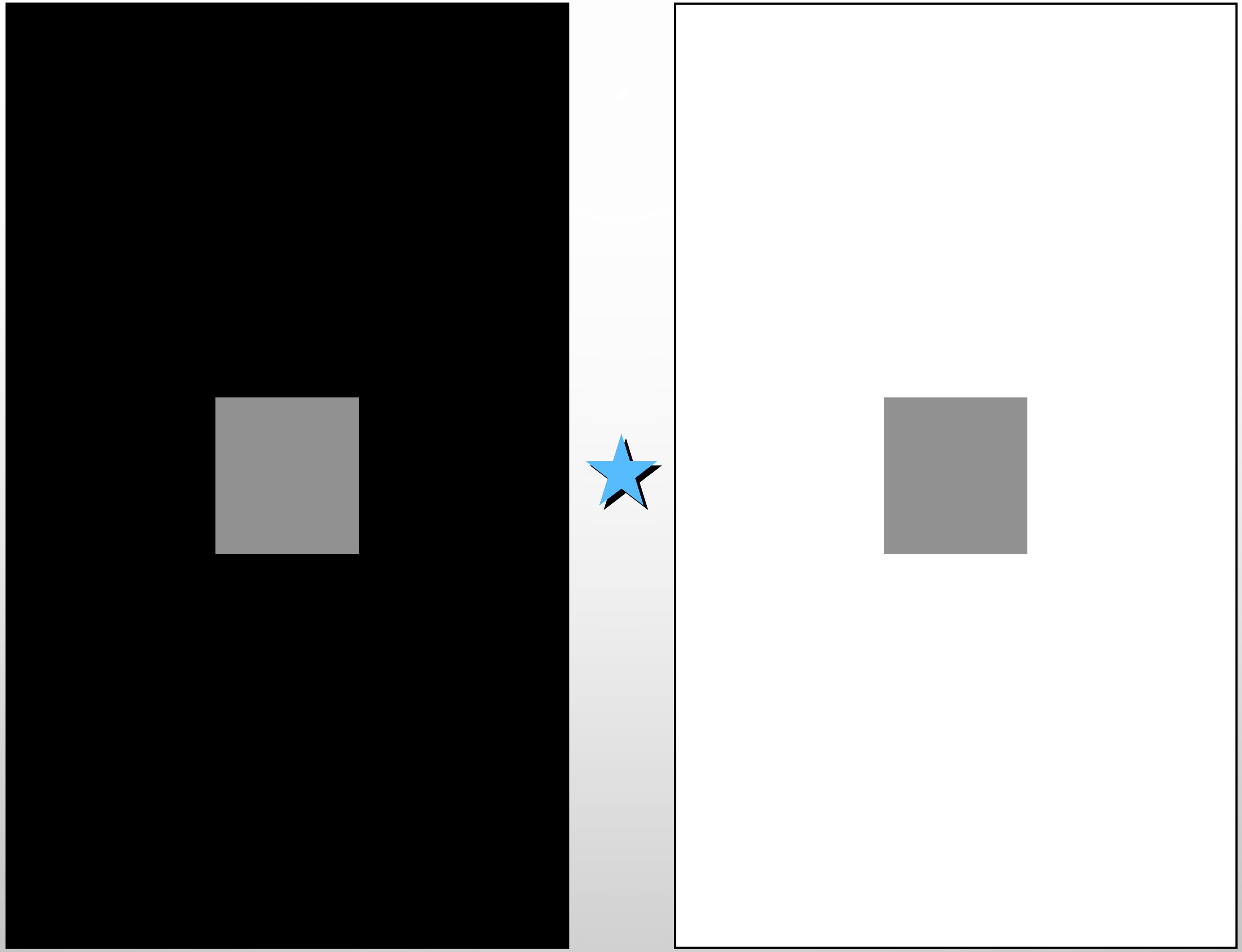
WHAT DO WE CARE IN MRI?

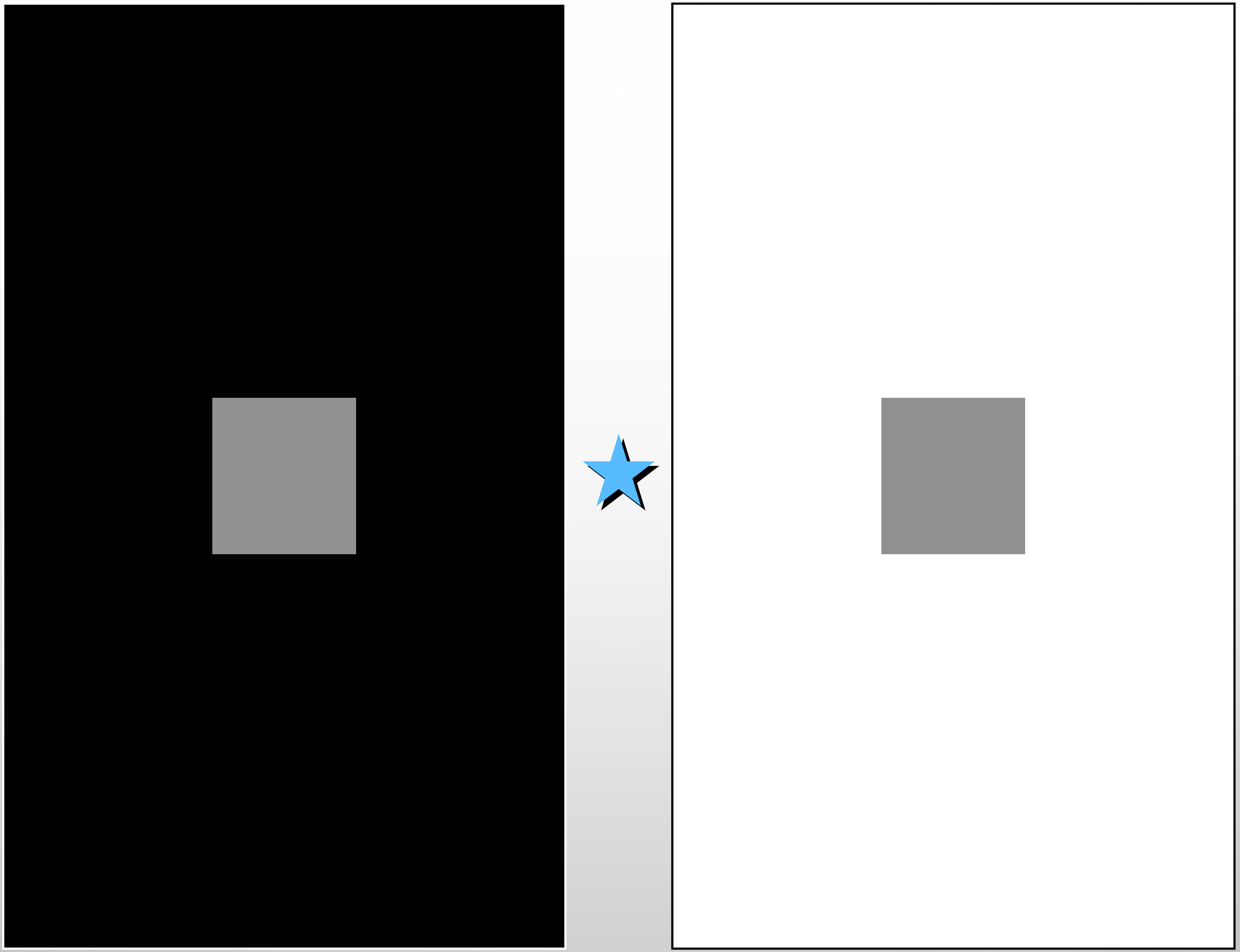
Contrast

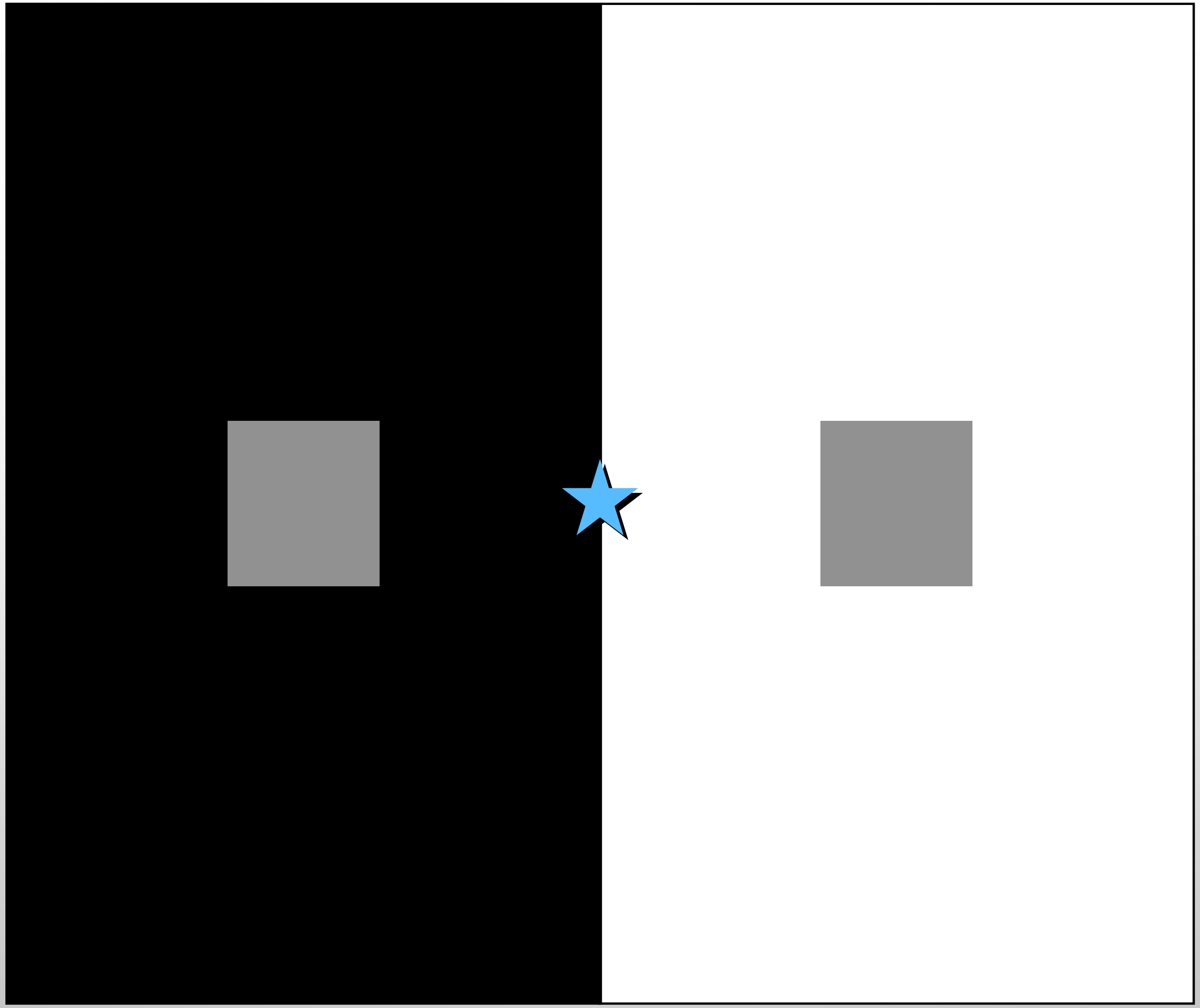
CONTRAST (對比度)

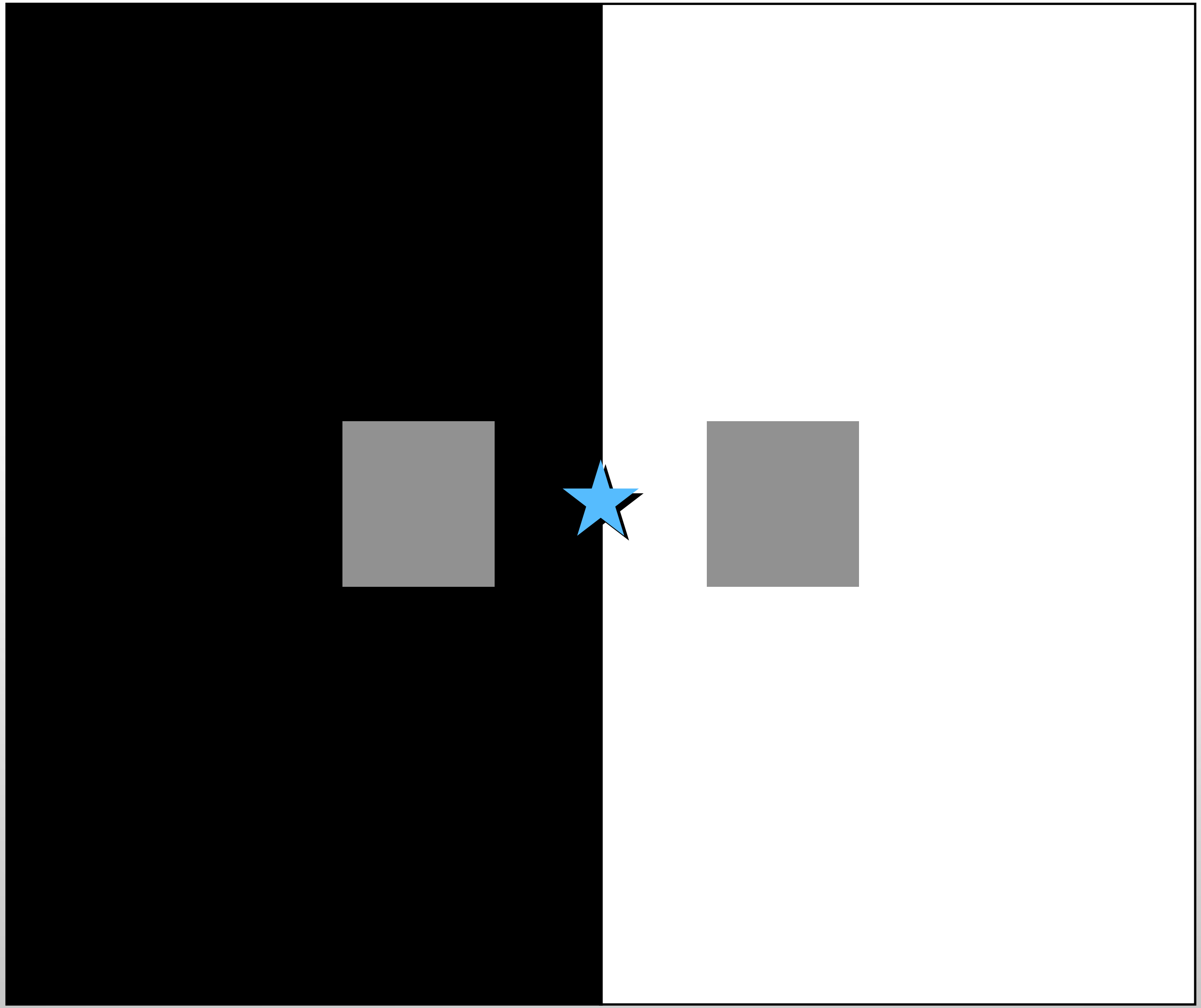
THE ABILITY TO DISCRIMINATE DIFFERENT TISSUES BASED ON THEIR RELATIVE BRIGHTNESS

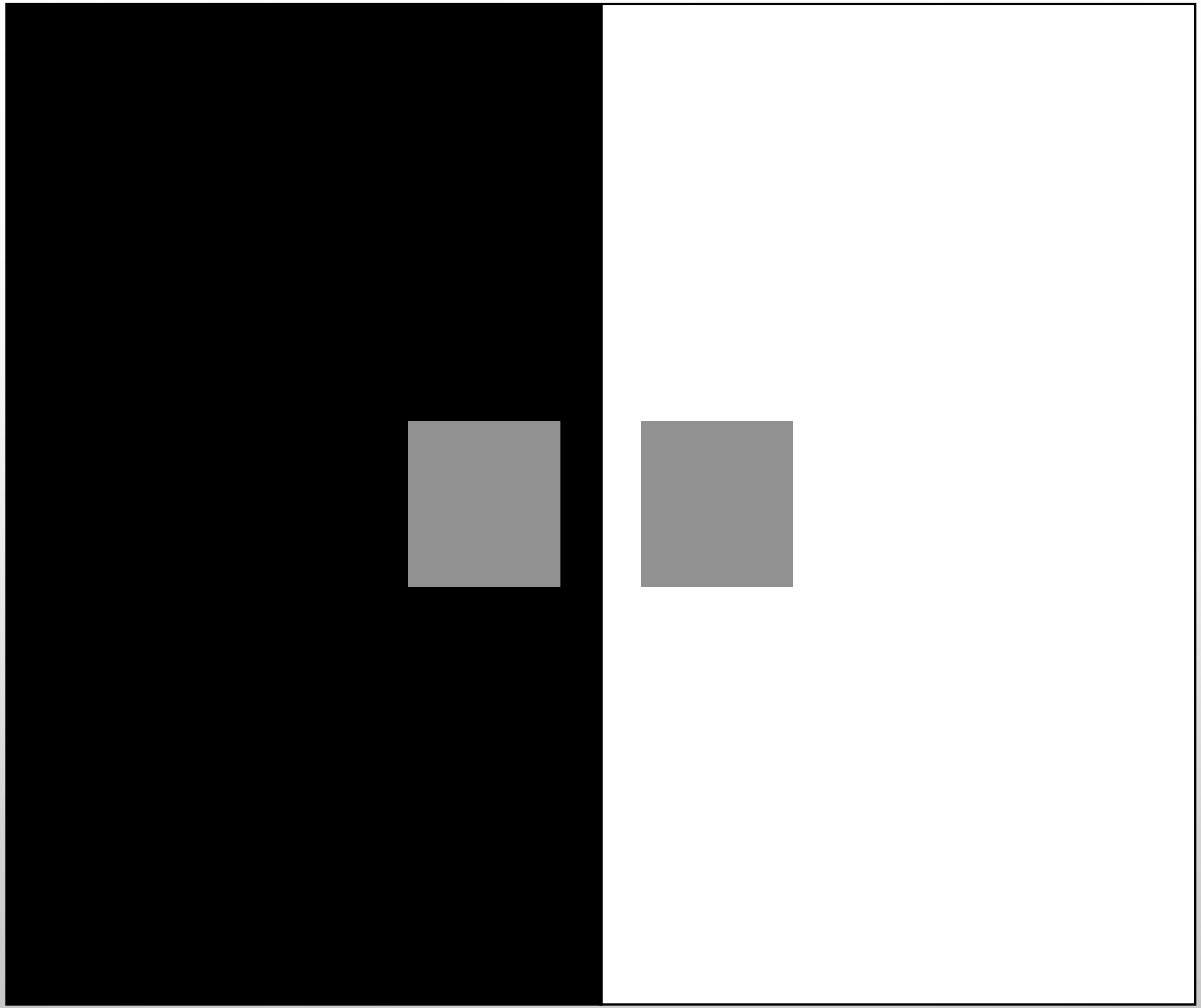
對比度的概念是相對的

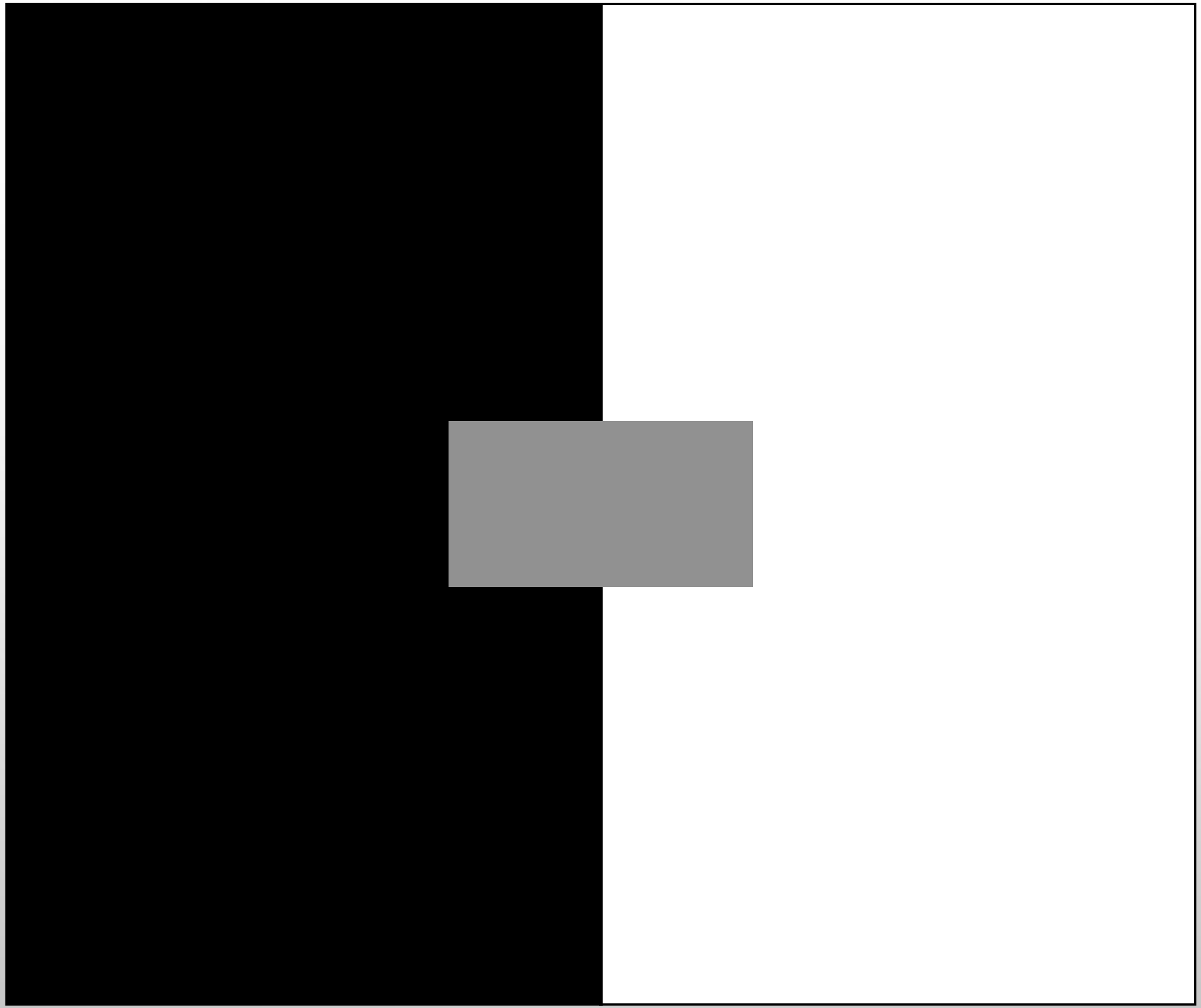






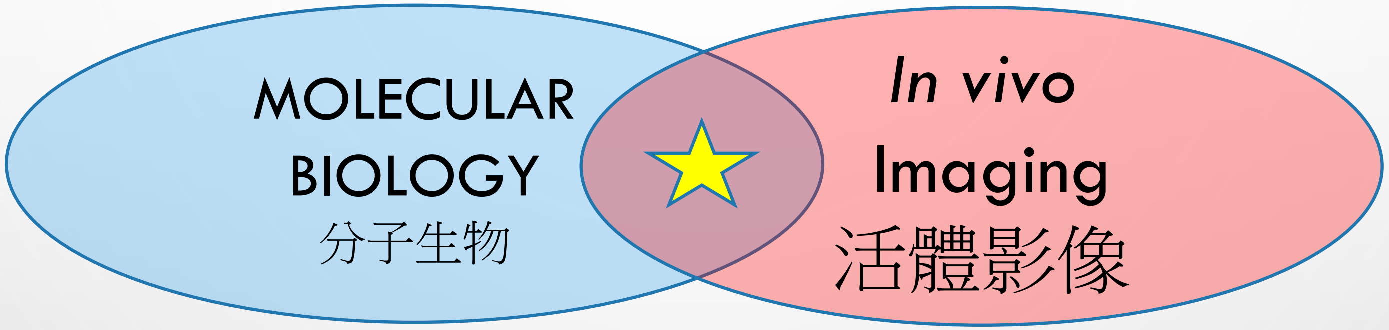






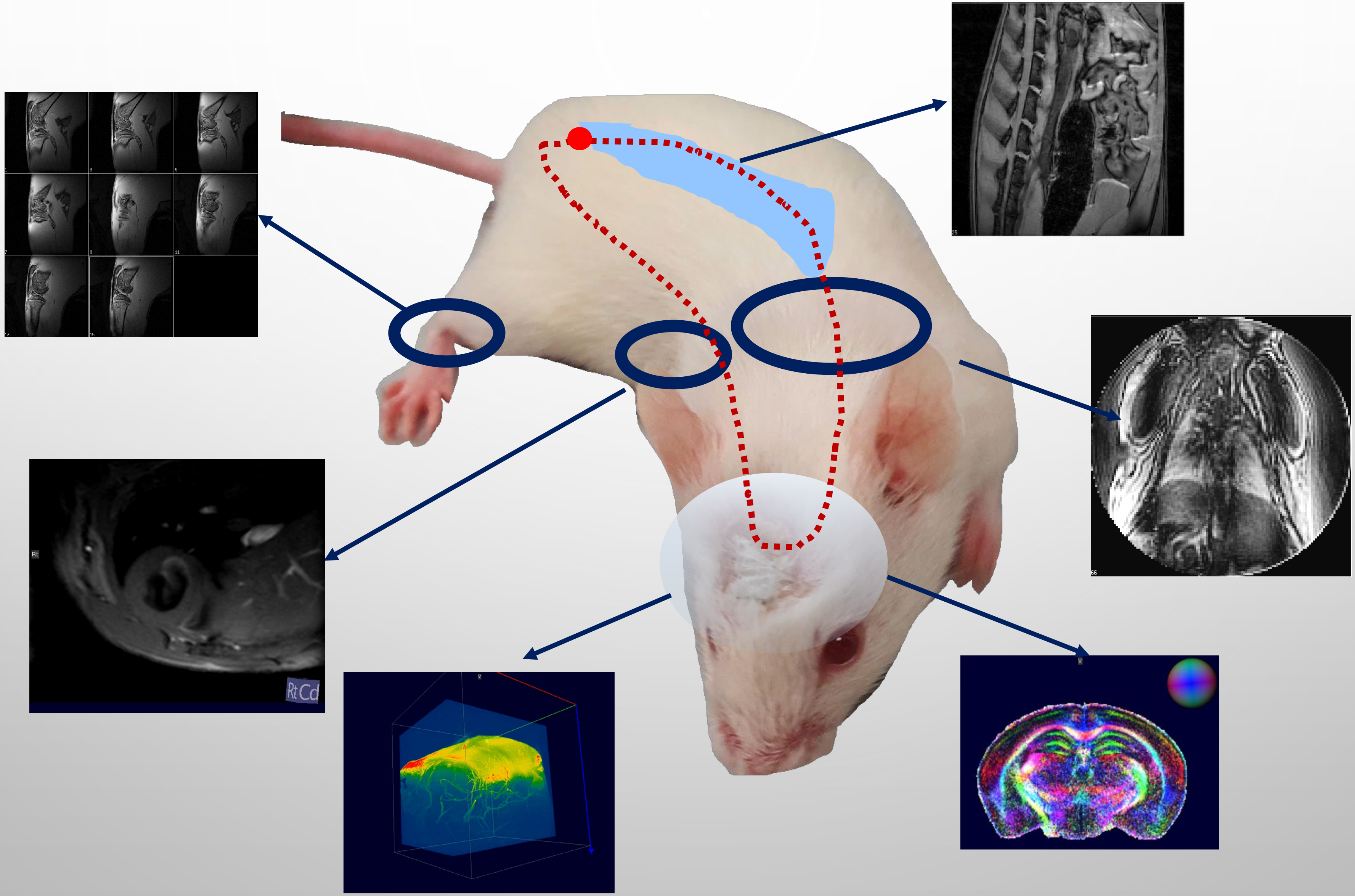
THE IMPORTANCE OF MRI CONTRAST

分子影像 MOLECULAR IMAGING



visualization, characterization and quantification of normal / pathological biological processes at the cellular and molecular level

我們可以做哪些事?



Application-driven Research

Methodology Developments
方法開發

Clinical Application
臨床應用

Drug discovery

MRI development

Pre-Clinical Research
臨床前應用

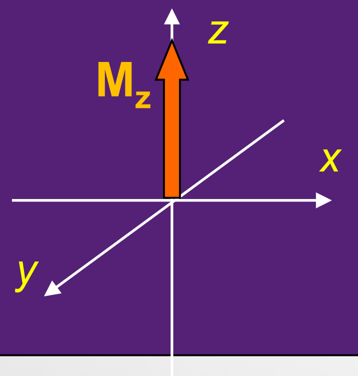
SIZE MATTER!!

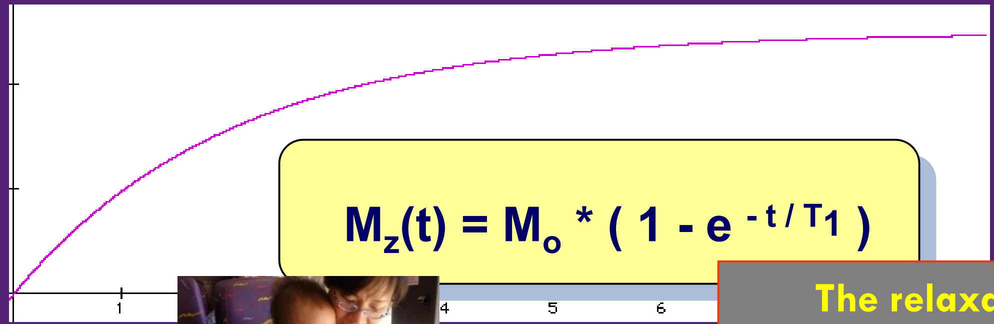
APPLICATION

RELAXATION BASED IMAGING

何謂弛豫? WHAT IS NMR RELAXATION?

Relaxation properties

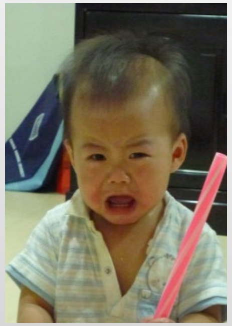




$$M_z(t) = M_o * (1 - e^{-t/T_1})$$

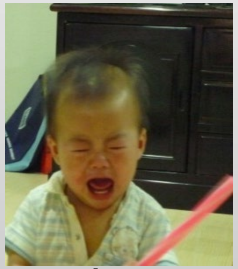
The relaxation behavior can reflect the environment

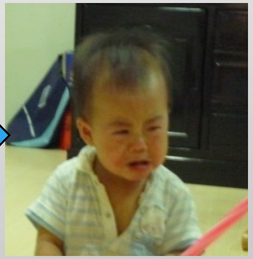
Ground state
(Sleeping)



Excited state
(Angry)

More interaction
(Fast relaxation)



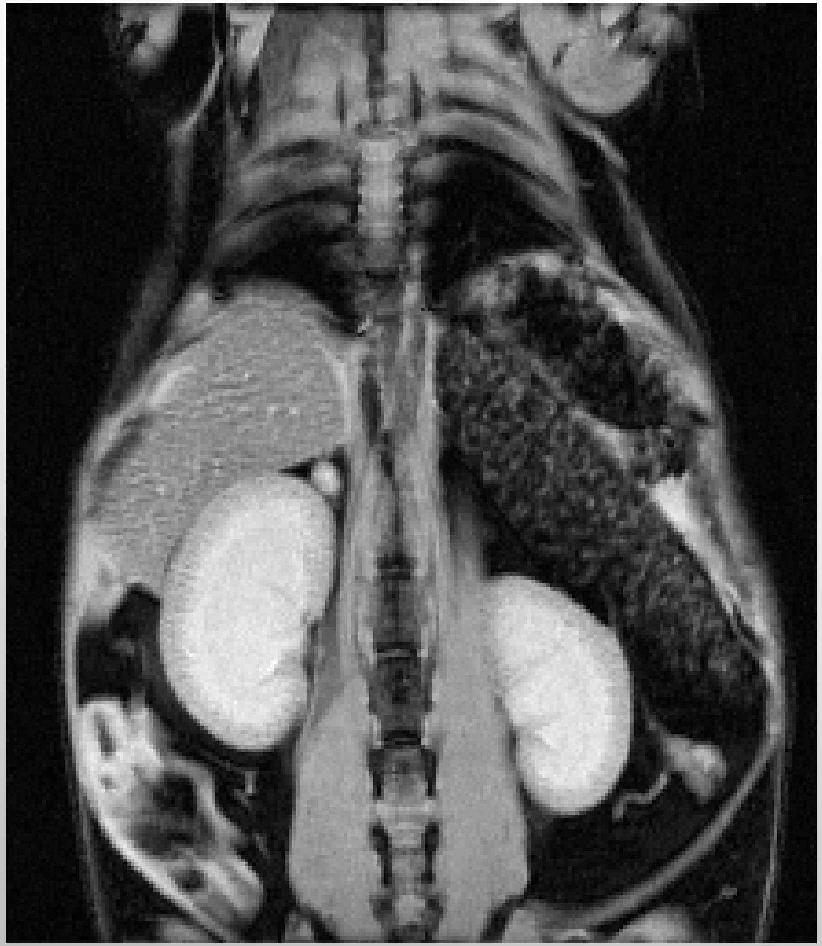


Less interaction
(Slow relaxation)

Ground state
(Sleeping)

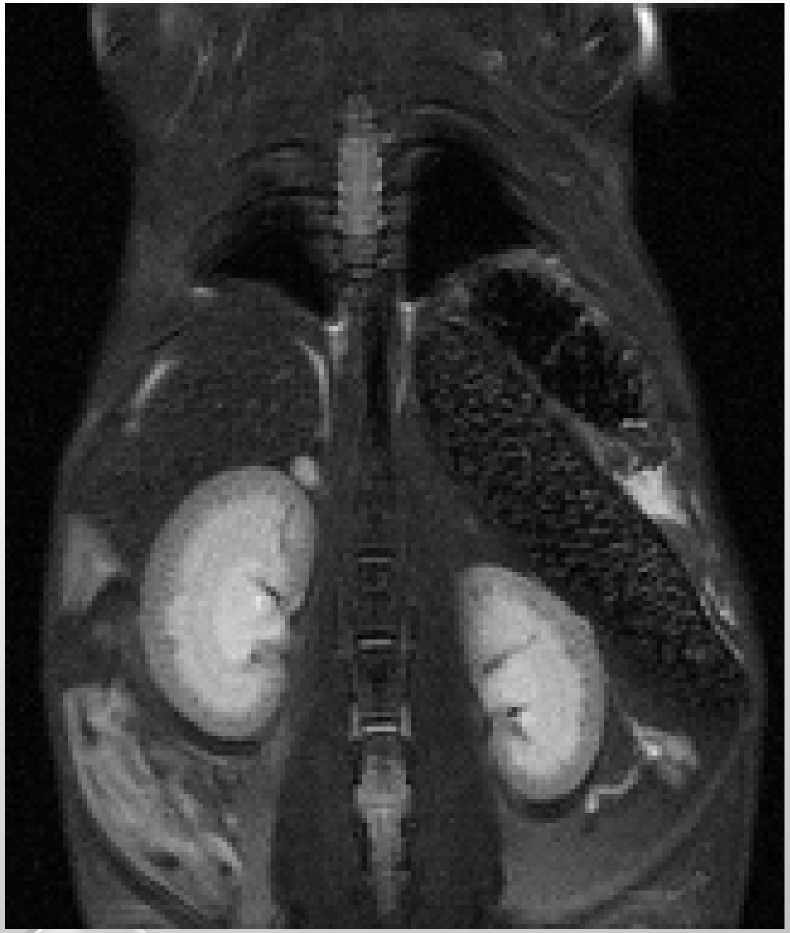
不同的弛豫方式、不同的對比度

T_1WI



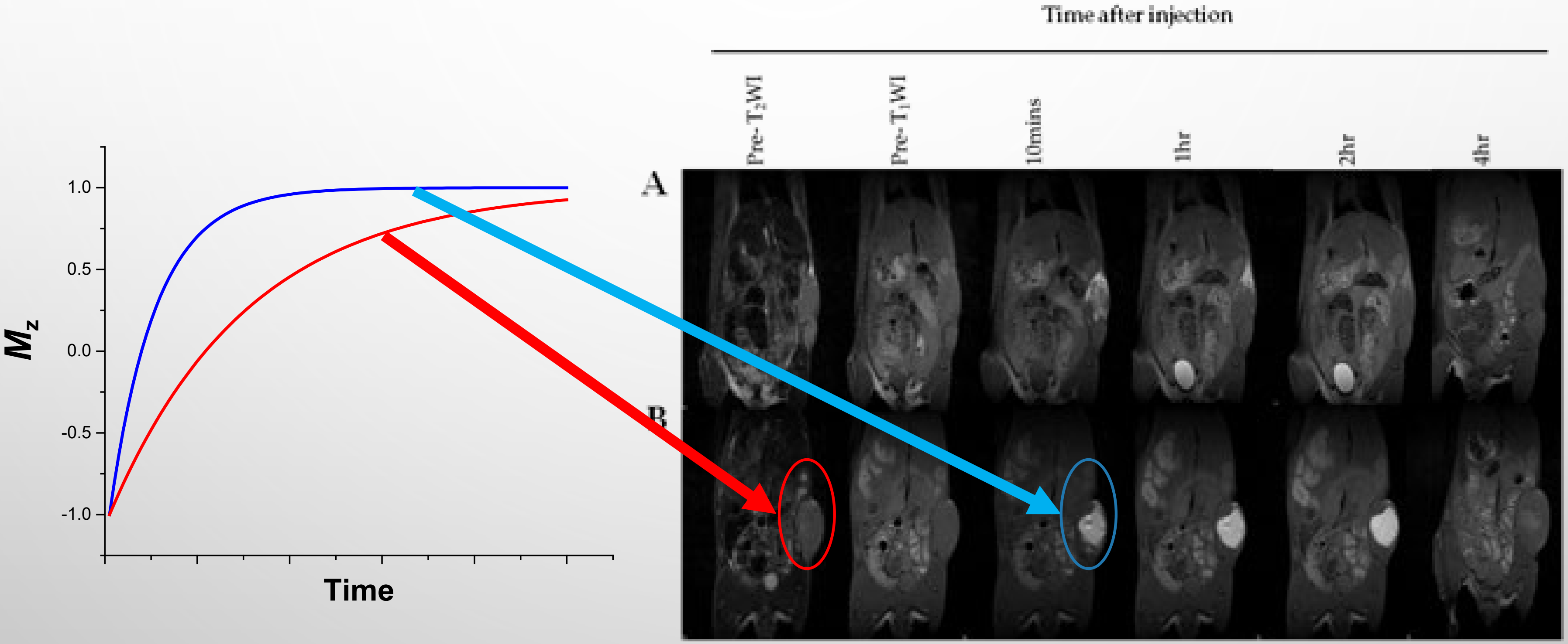
FLASH flow compensated

T_2WI



RARE

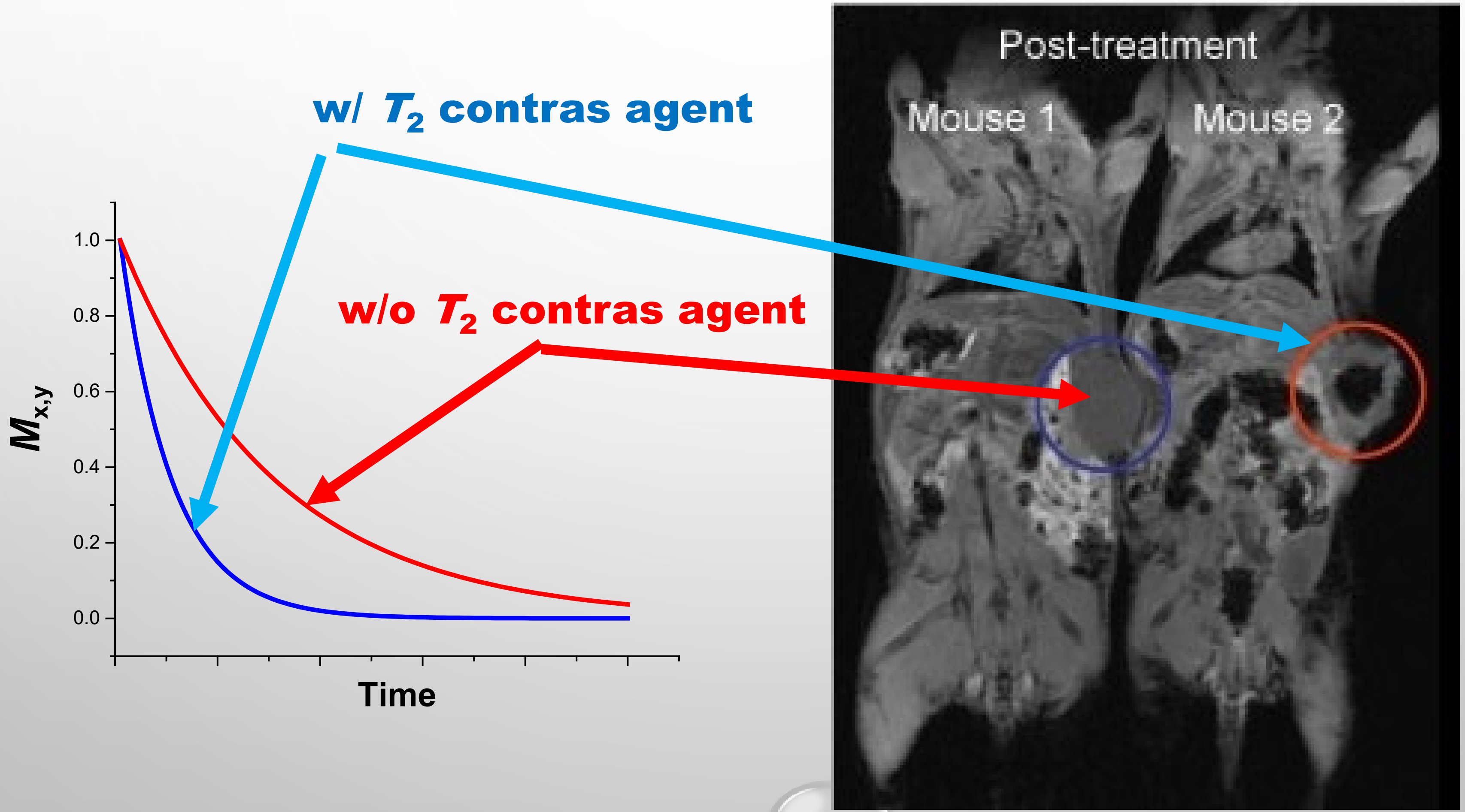
T_1 CONTRAST AGENT (顯影劑)



w/o T_1 contras agent

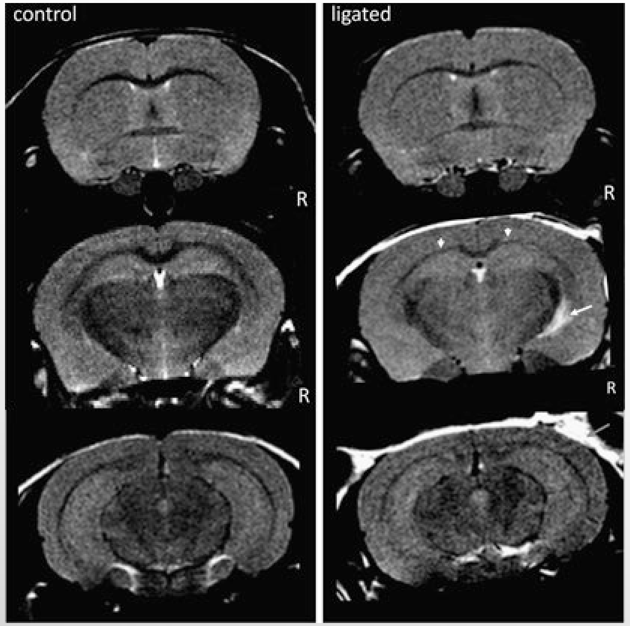
w/ T_1 contras agent

T_2 CONTRAST AGENT



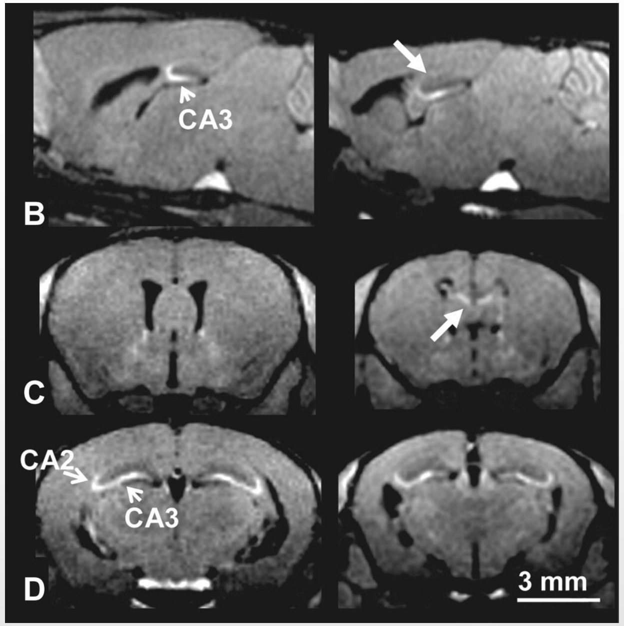
BRAIN STRUCTURE IN MRI

T2WI

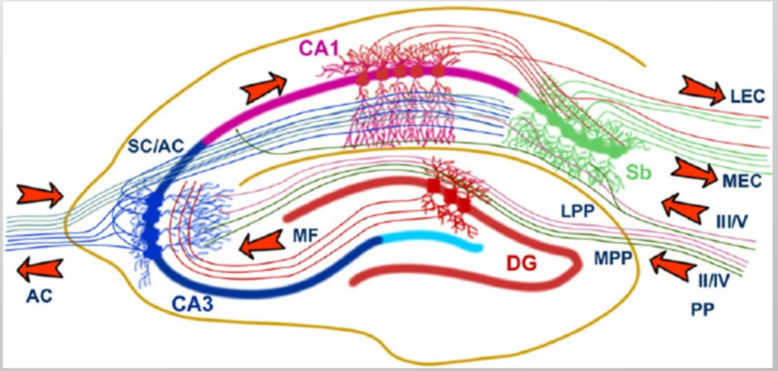


Journal of Cerebral Blood Flow & Metabolism (2011) **31,** 2009–2018;

Mn-enhanced



NeuroImage, Aug. 1, 2007, pp. 82-89.

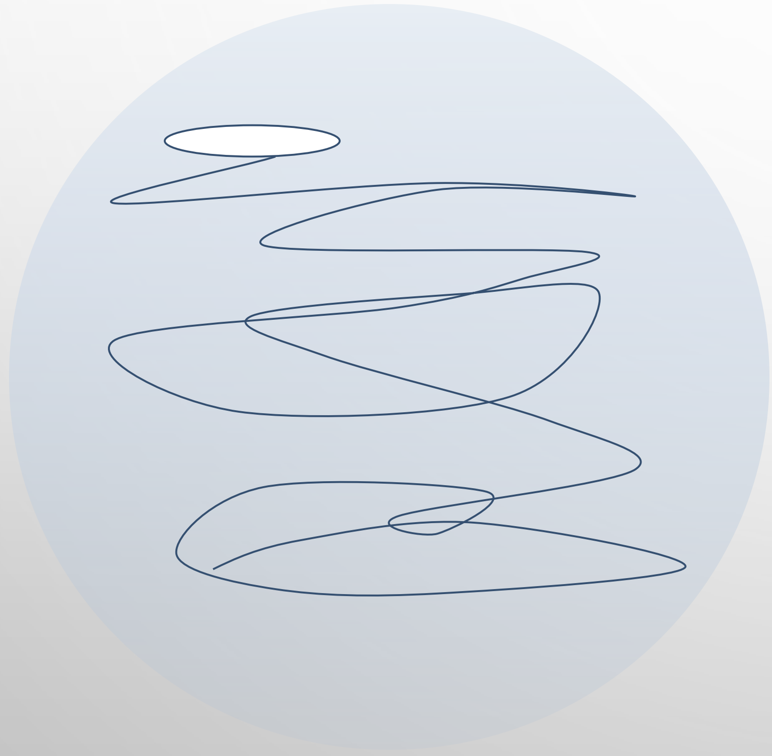


APPLICATIONS

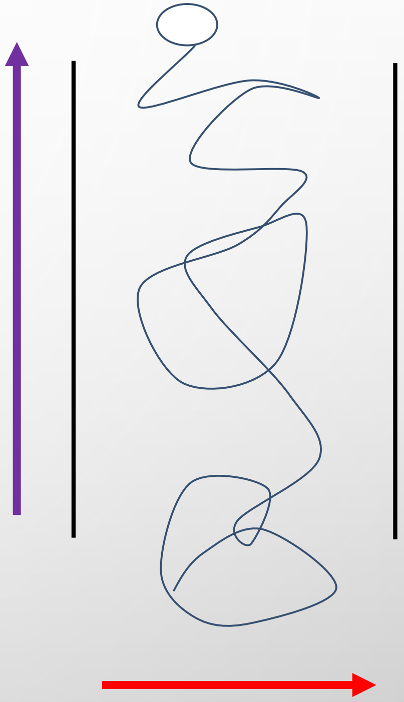
DIFFUSION BASED IMAGING
擴散影像

DIFFUSION TENSOR MRI (DTI)

Diffusion anisotropy

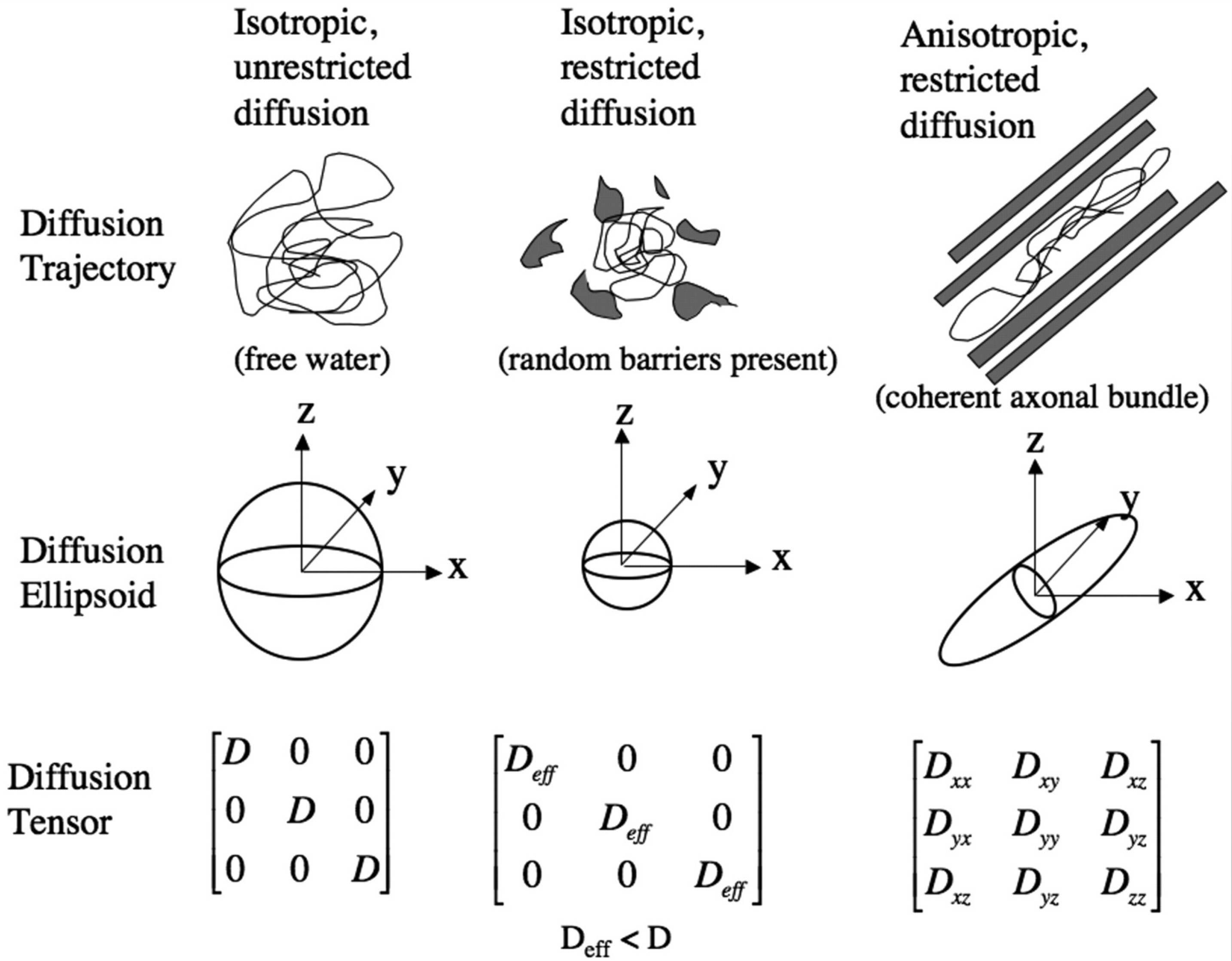


Diffusion is greater in the axis parallel to the orientation of the nerve fibre



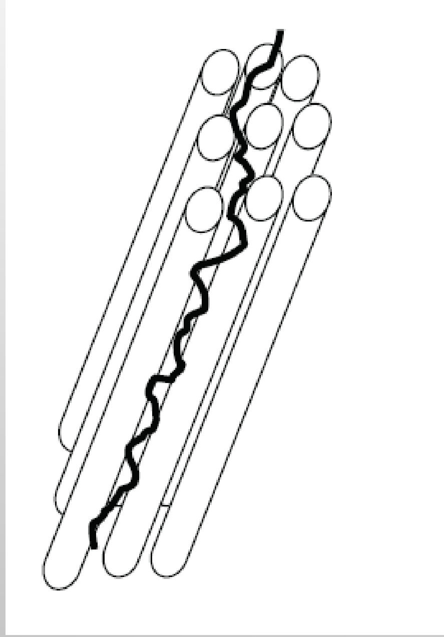
Diffusion is less in the axis perpendicular to the nerve fibre

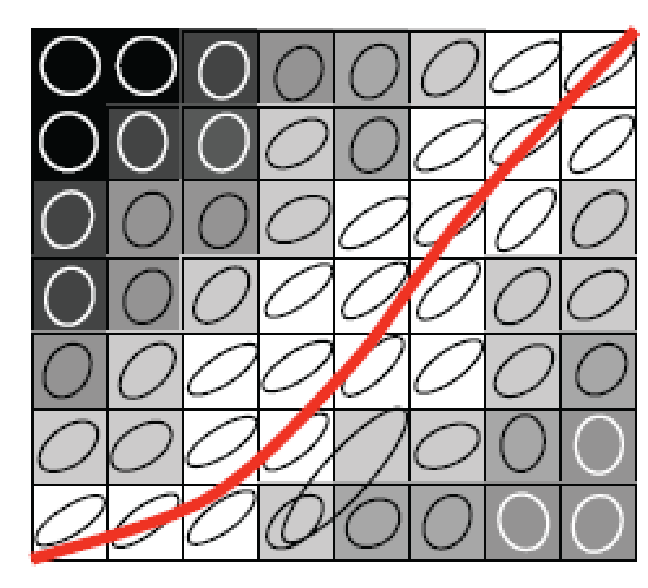
WHAT IS THE DIFFUSION TENSOR?



TRACTOGRAPHY - OVERVIEW

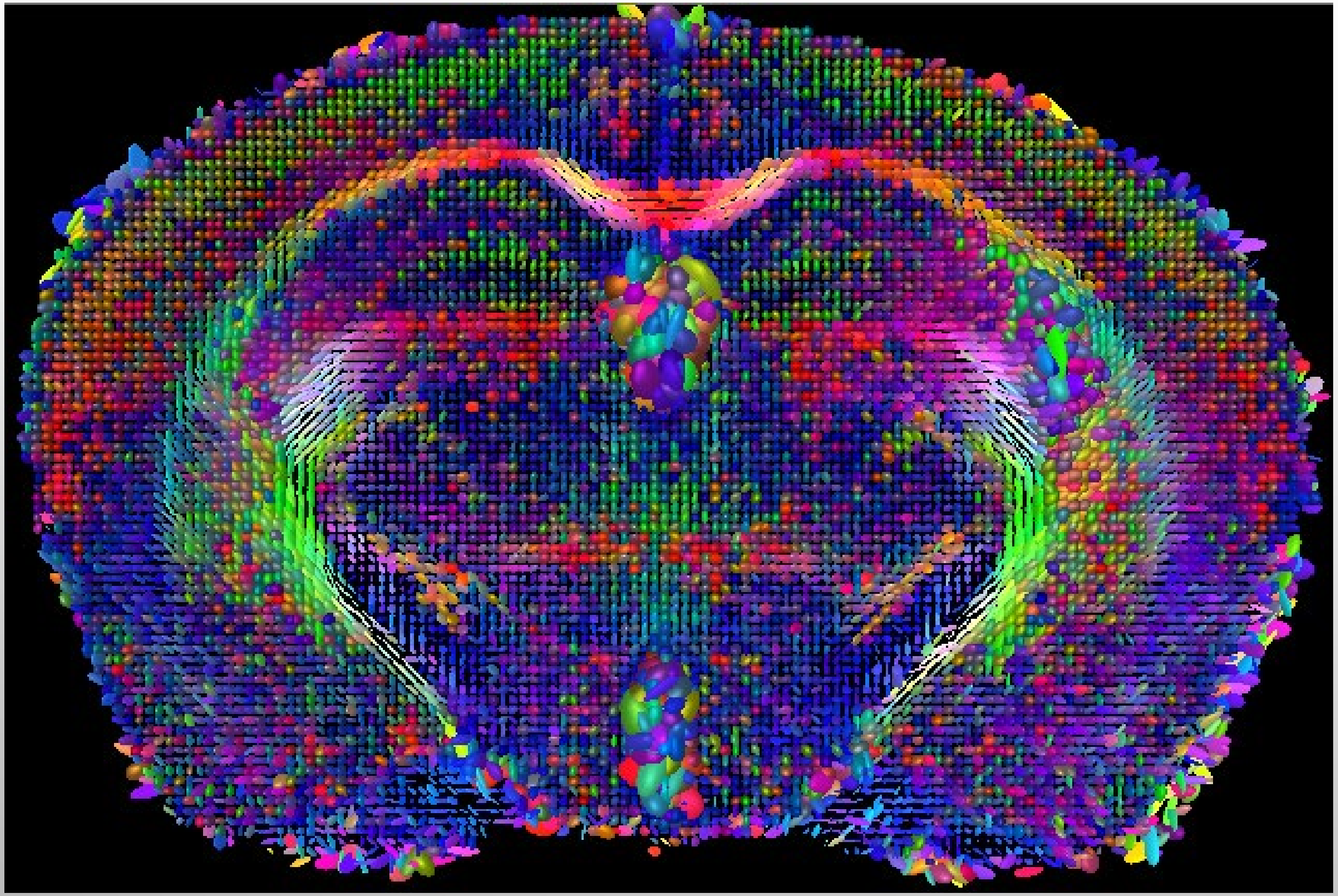
- NOT ACTUALLY A MEASURE OF INDIVIDUAL AXONS, RATHER THE DATA EXTRACTED FROM THE IMAGING DATA IS USED TO INFER WHERE FIBRE TRACTS ARE
- VOXELS ARE CONNECTED BASED UPON SIMILARITIES IN THE MAXIMUM DIFFUSION DIRECTION

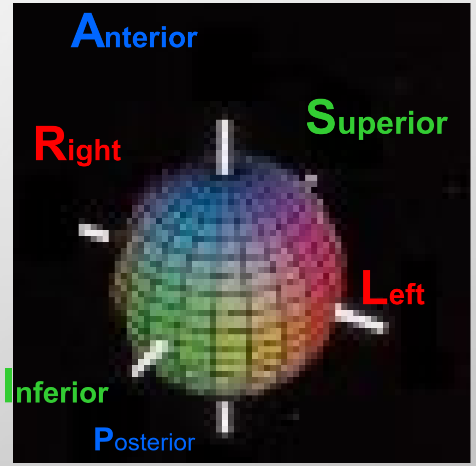




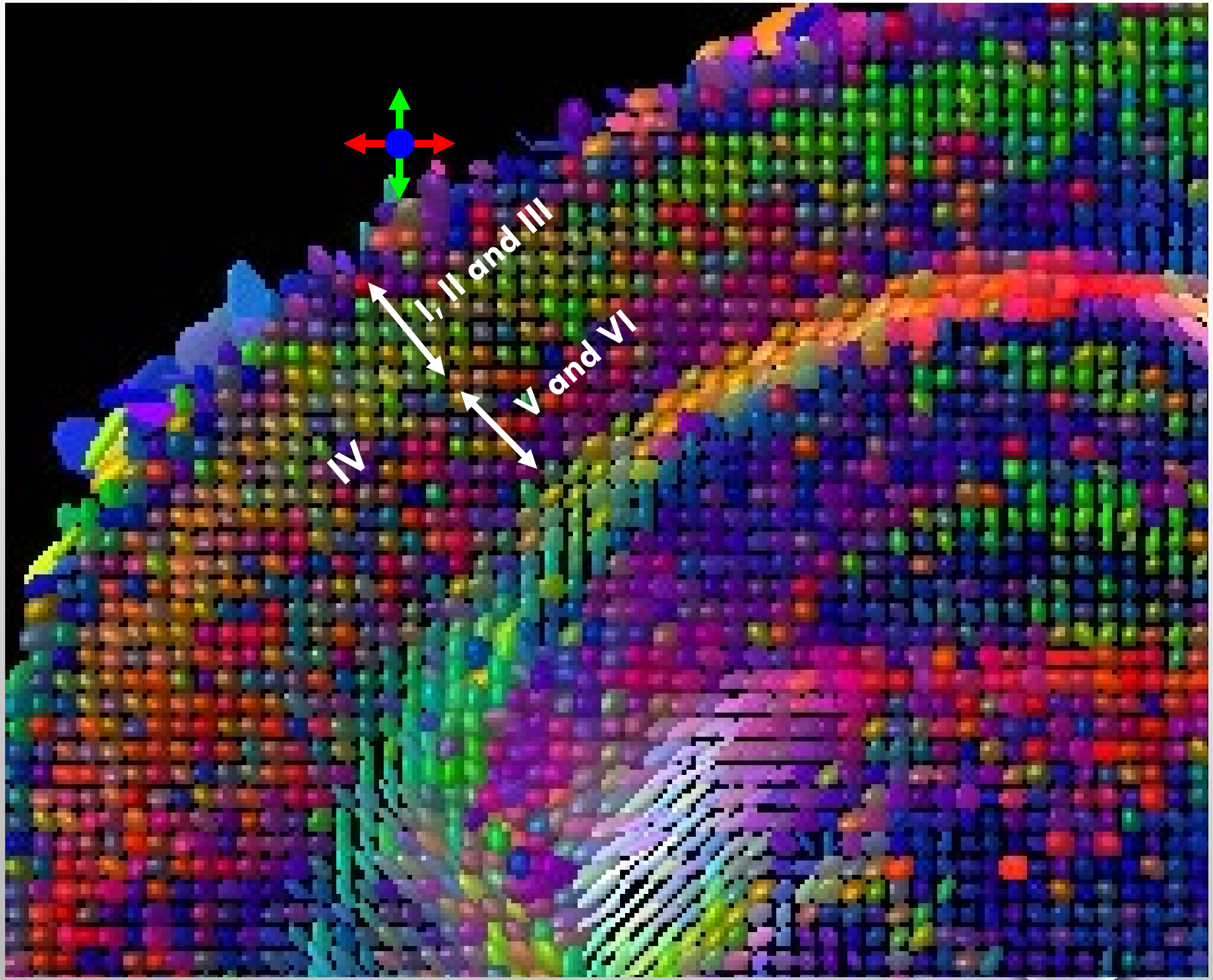
Johansen-Berg et al.
Ann Rev. Neurosci 32:75-94 (2009)

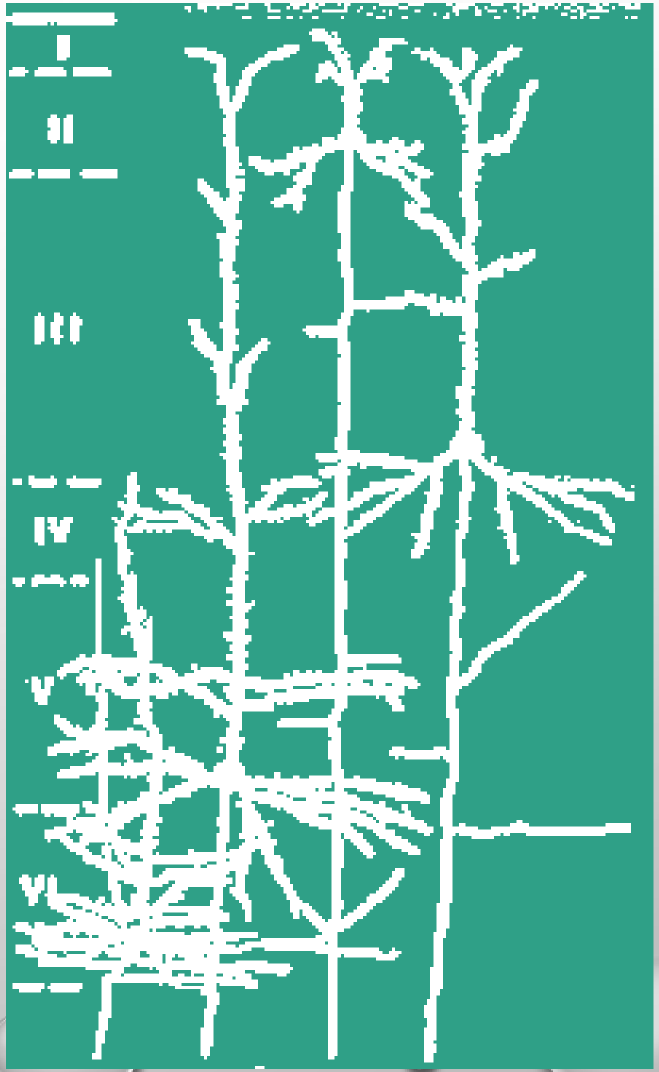
DIFFUSION TENSOR IMAGING (DTI)



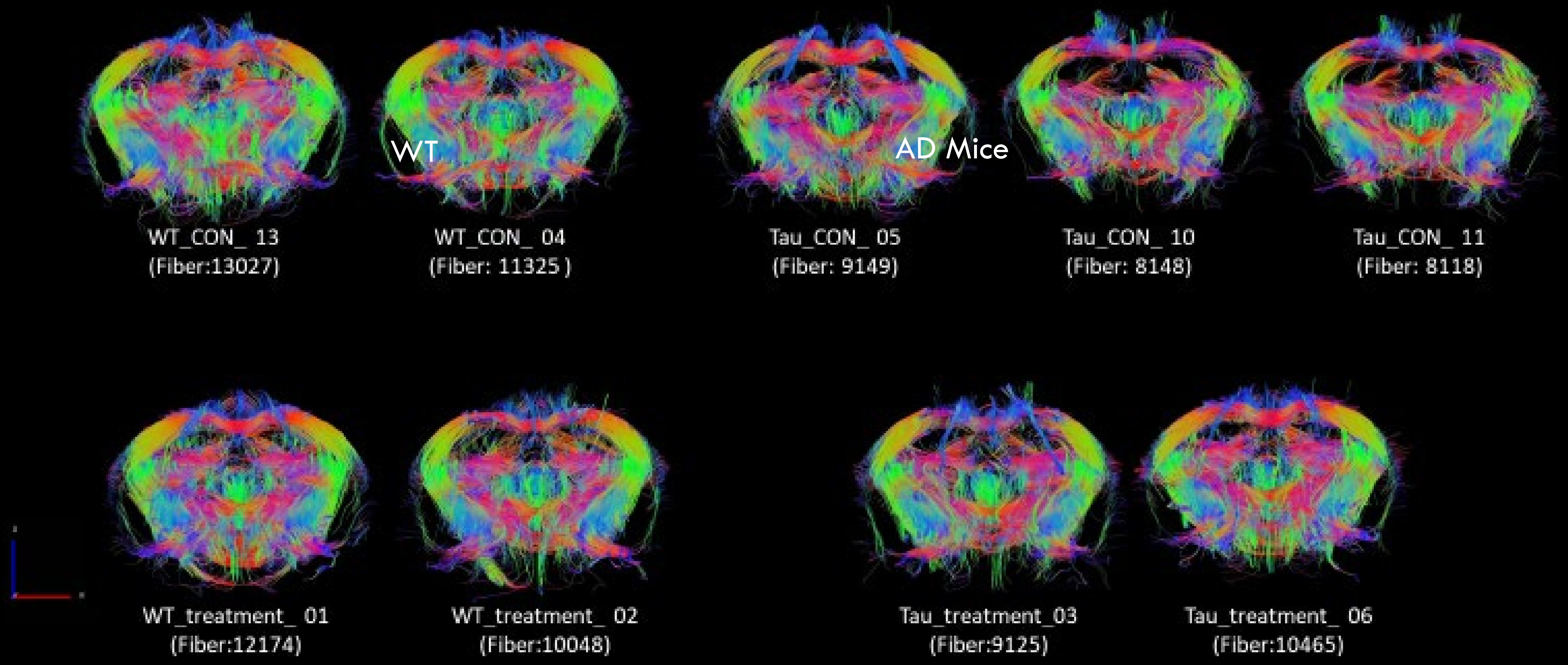


Anisotropy in cortical layer





DTI fiber tracking-Hippocampus



ex vivo squid brain MRI

APPLICATIONS

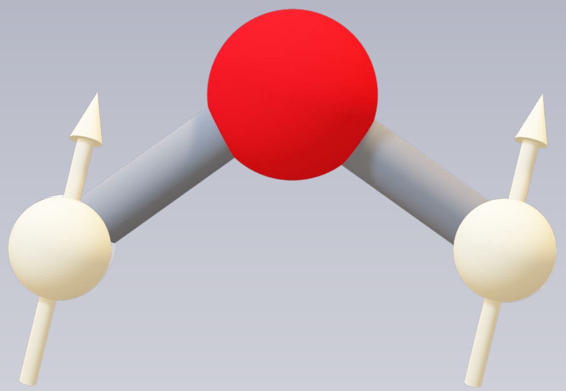
CHEMICAL EXCHANGE SATURATION TRANSFER (CEST) IMAGING

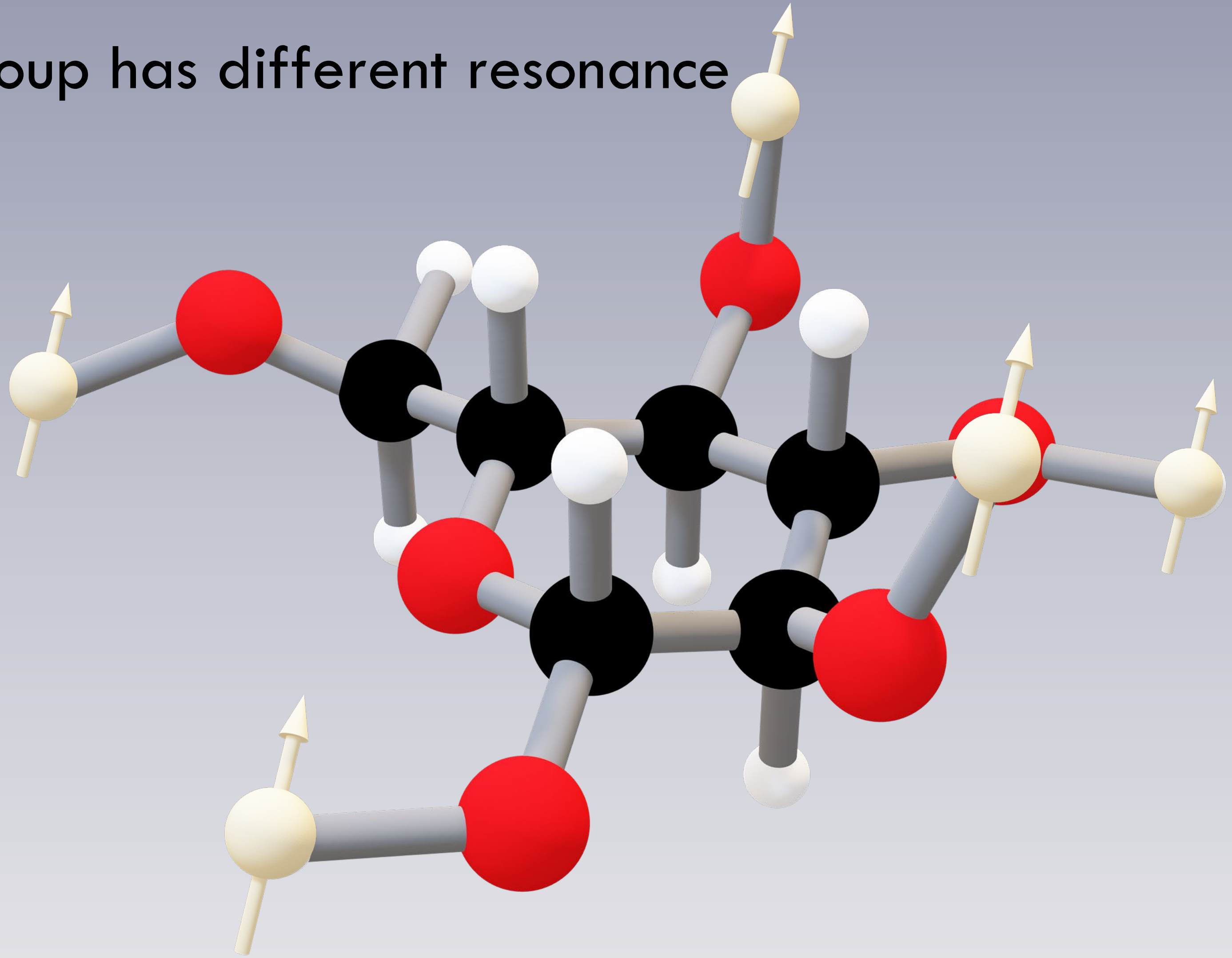
OUTLINE

- What is Chemical Exchange Saturation Transfer (CEST) and Dynamic Glucose Enhanced (DGE) Imaging?
- CEST and Glucose Metabolism
- Application: Tumor Microenvironment differentiation
- Application: Tumor Immune Responses
- Application: Huntington’s Disease Mice

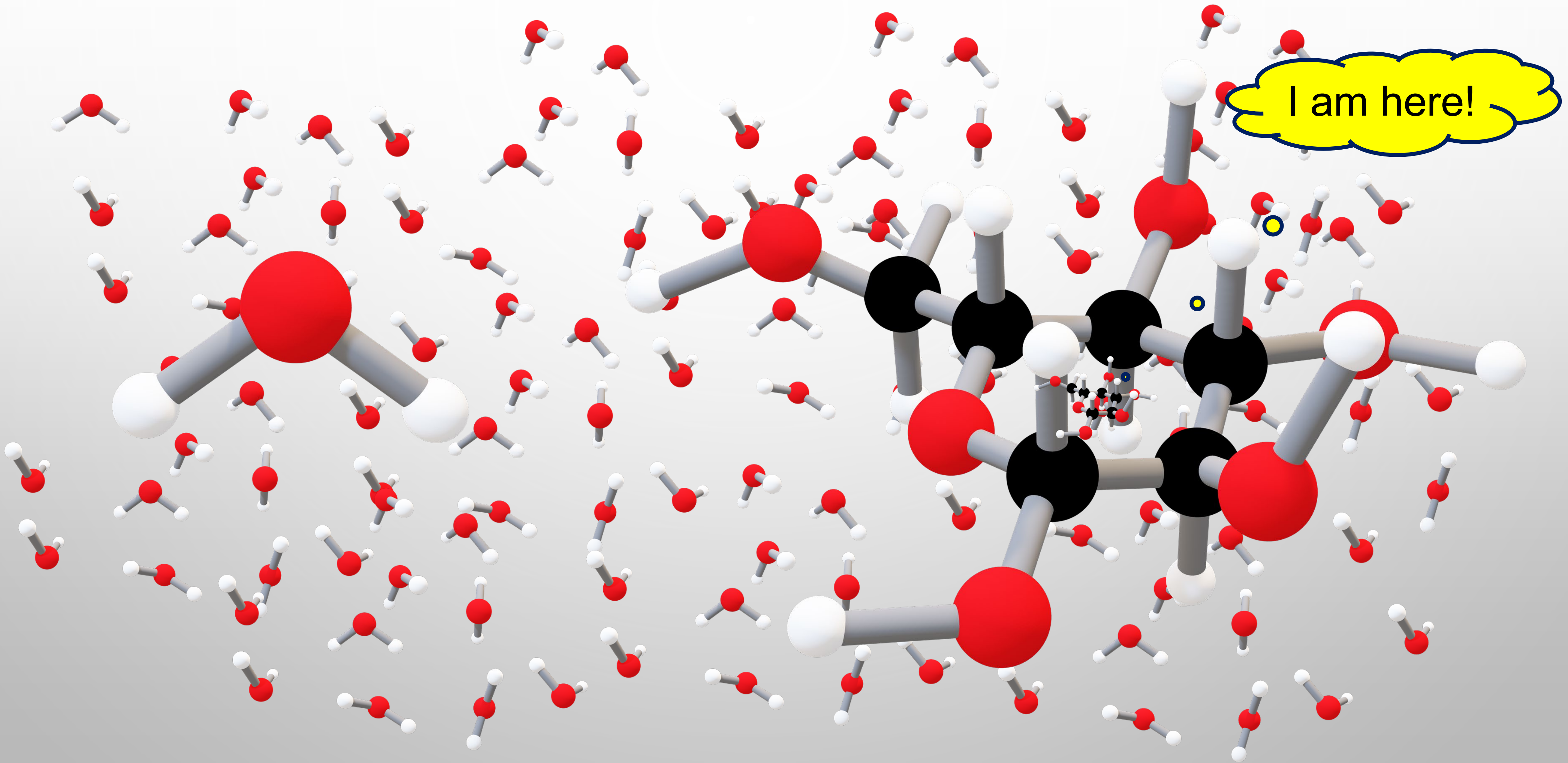
CHEMICAL SHIFT

H nuclei on different functional group has different resonance frequency (chemical shift)

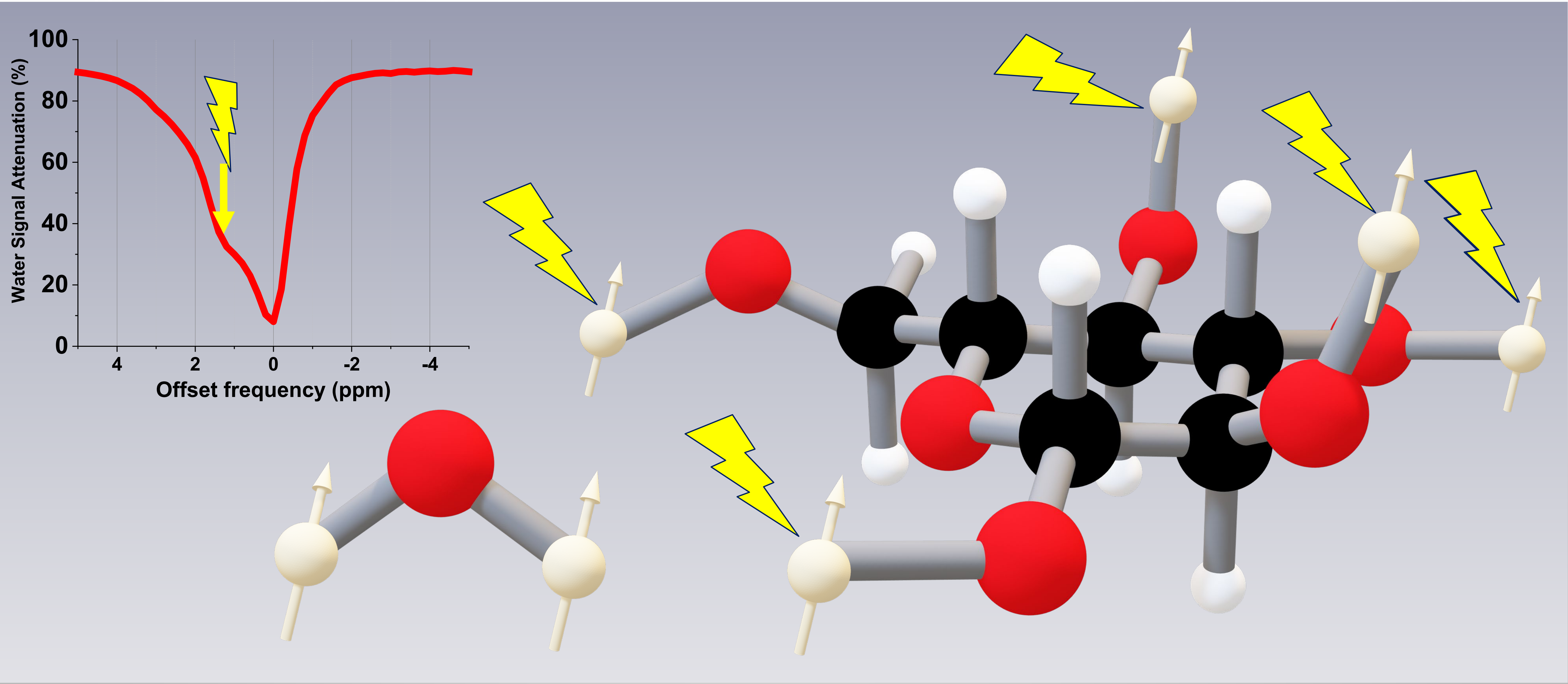




SENSITIVITY LIMITATION OF NMR/MRI

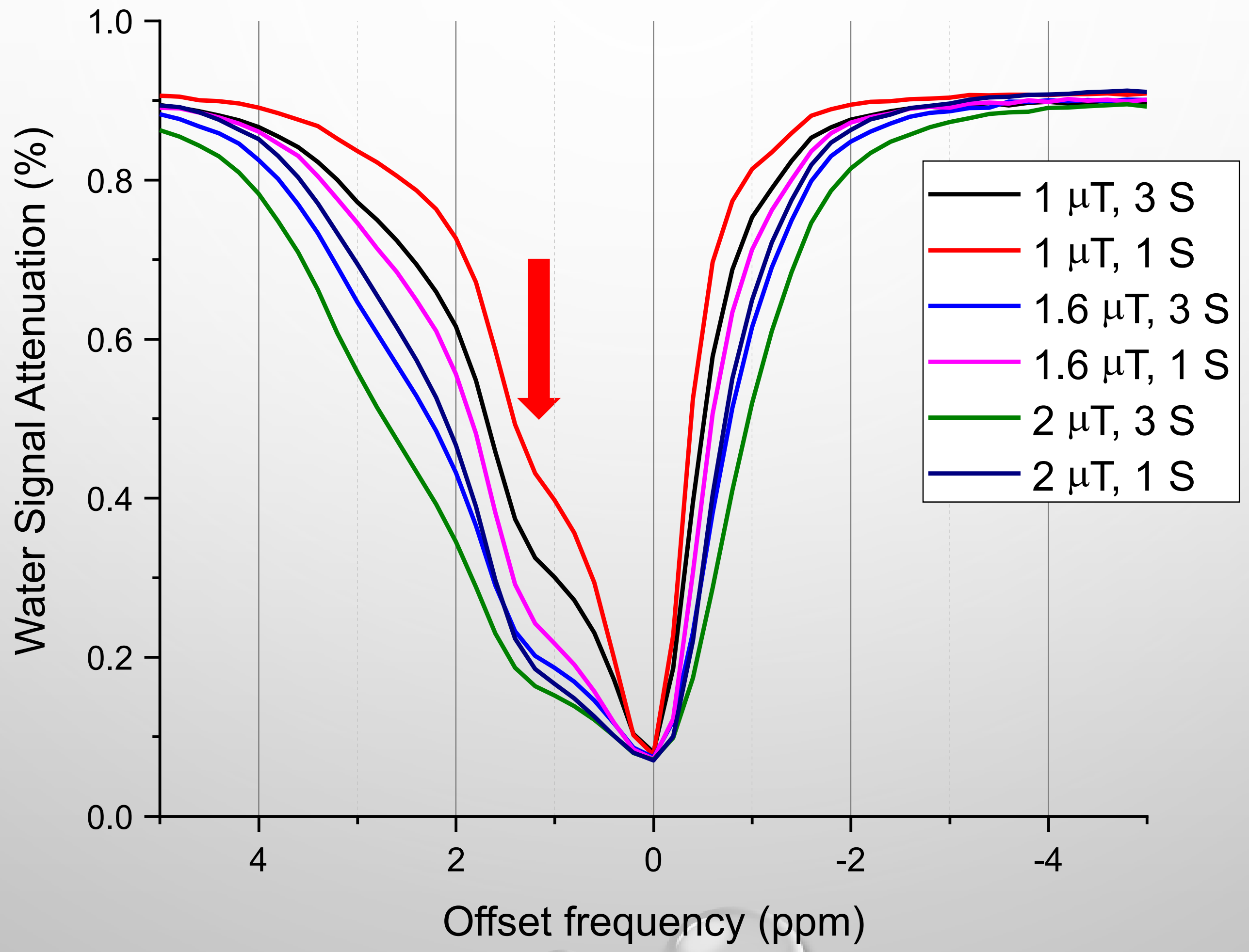


CHEMICAL EXCHANGE SATURATION TRANSFER (CEST)



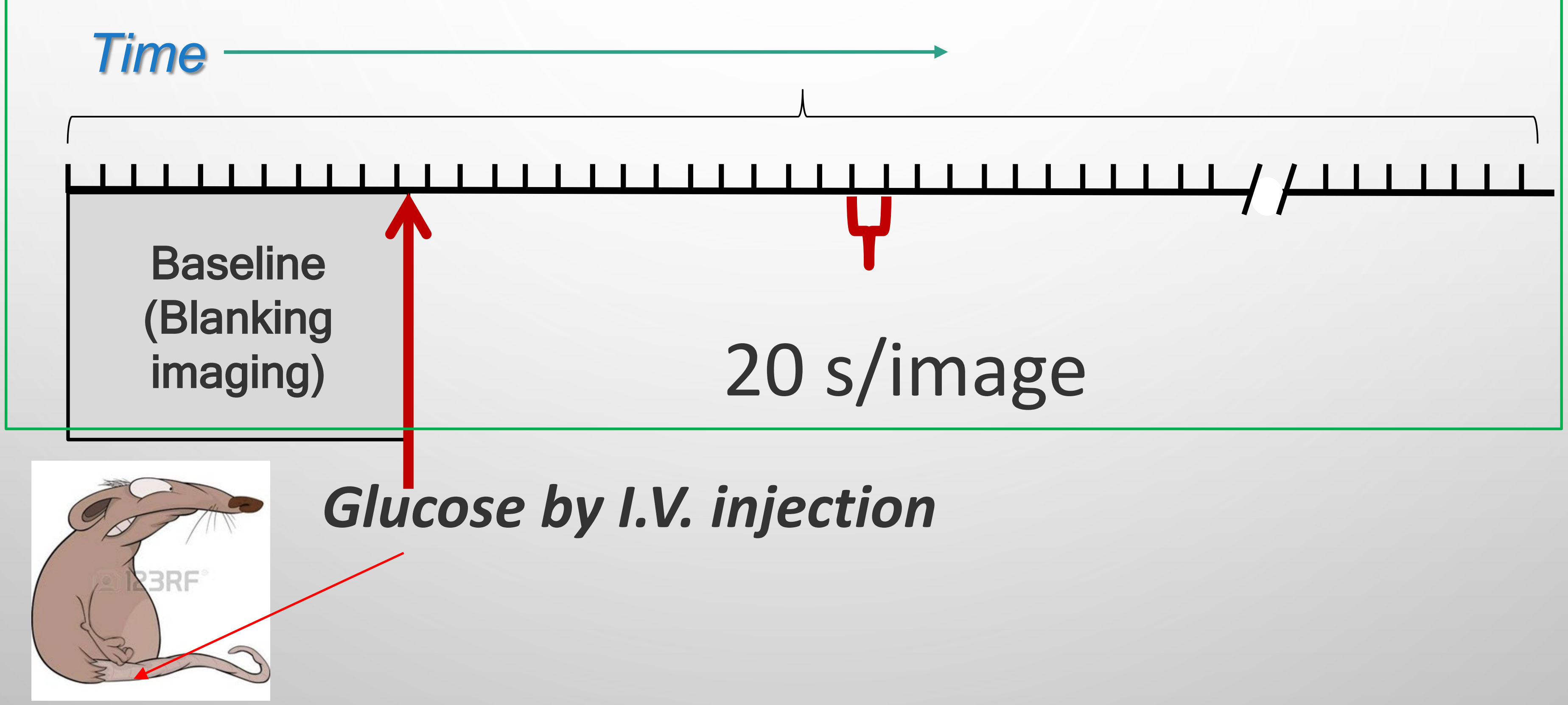
Probing chemicals at Microscopic scale and show at Macroscopic MR resolution (mm)

Z-SPECTRUM OF GLUCOSE PHANTOM



DYNAMIC GLUCOSE ENHANCED (DGE) IMAGING

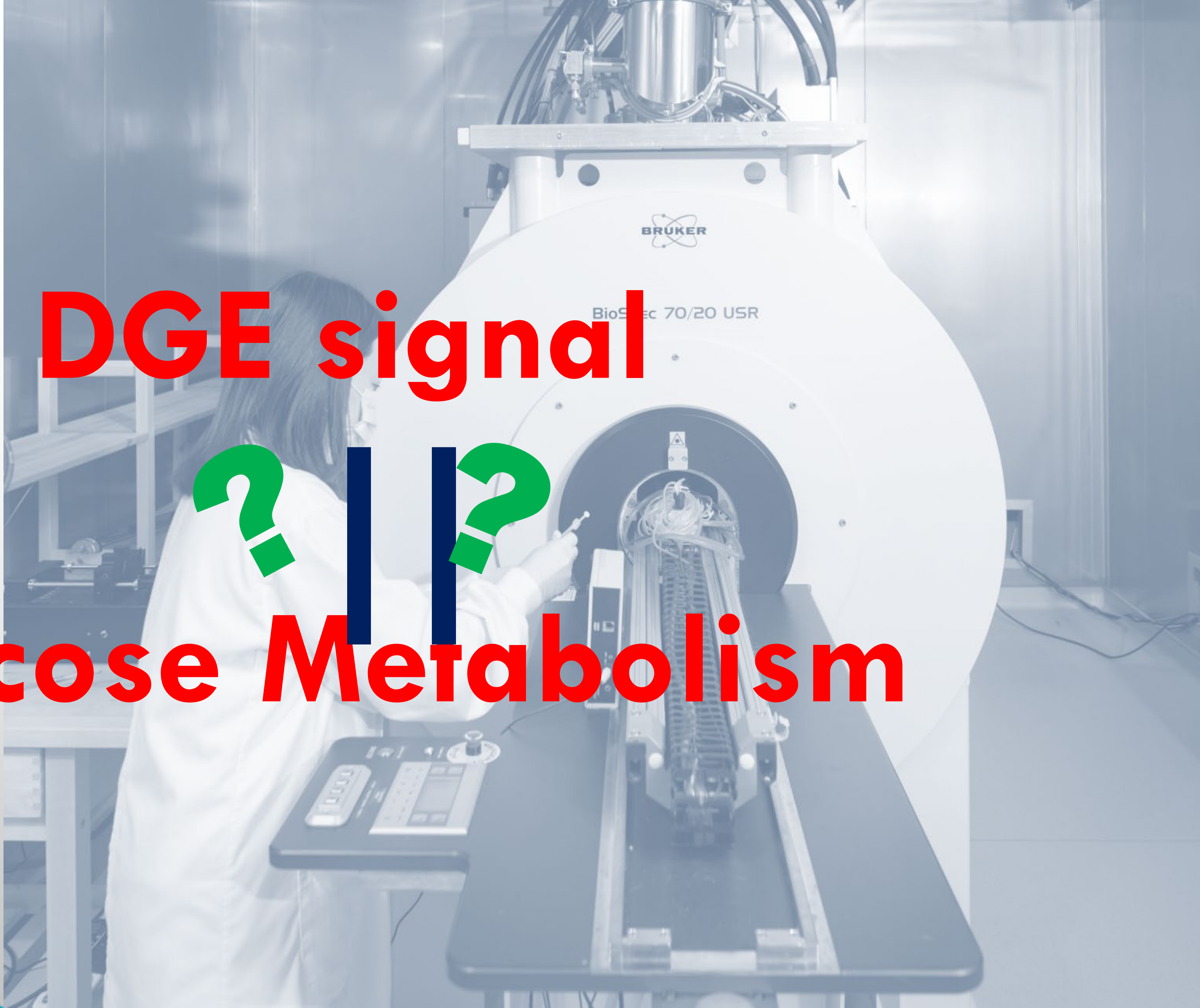
(Imaging the OH group on Glucose by CSET imaging)



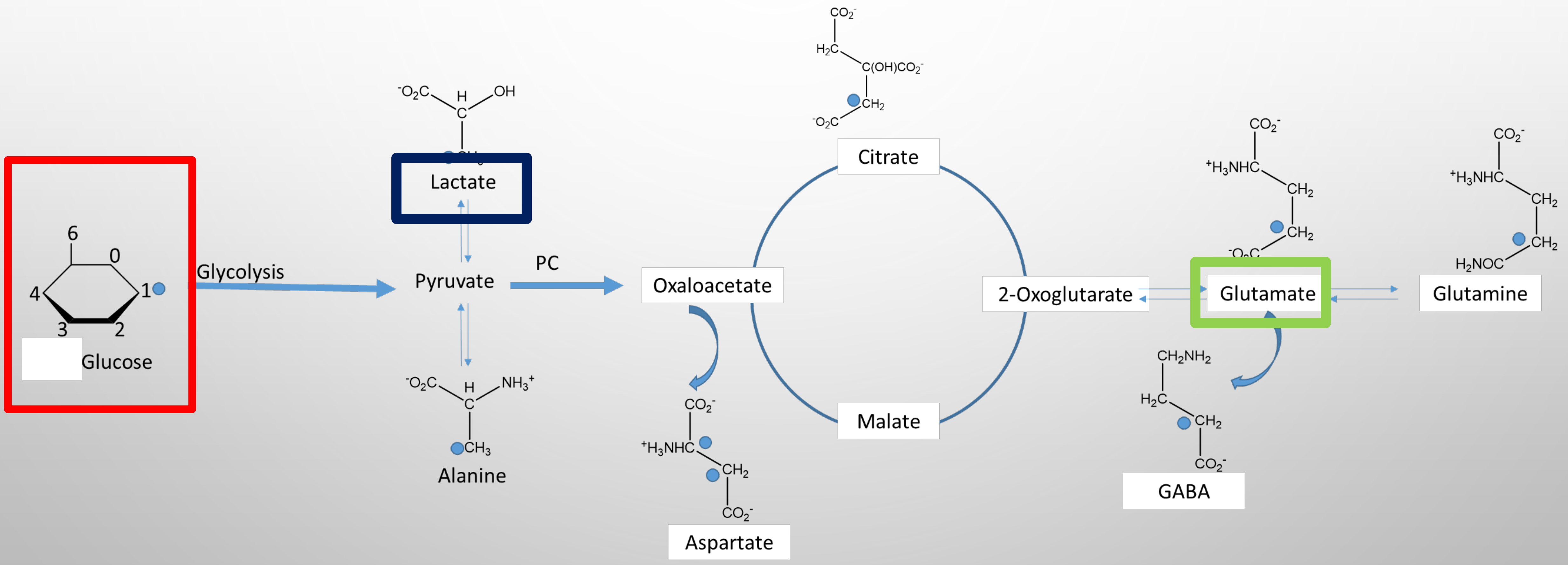
DGE signal

? || ?

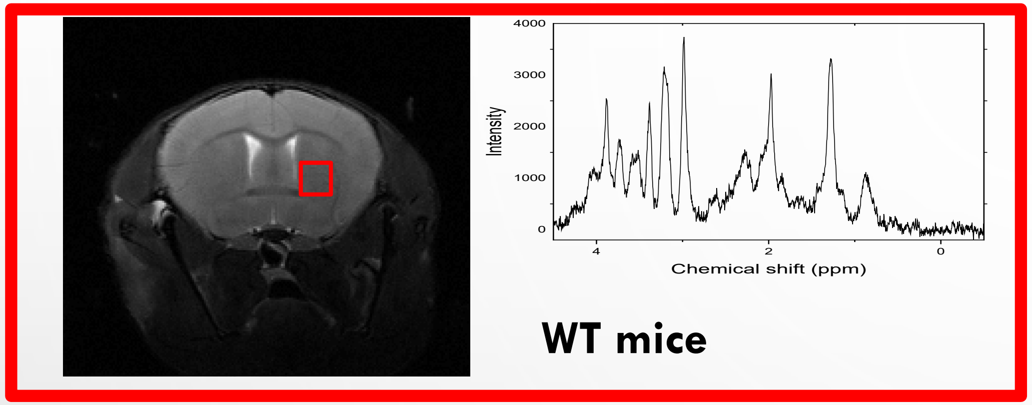
Glucose Metabolism

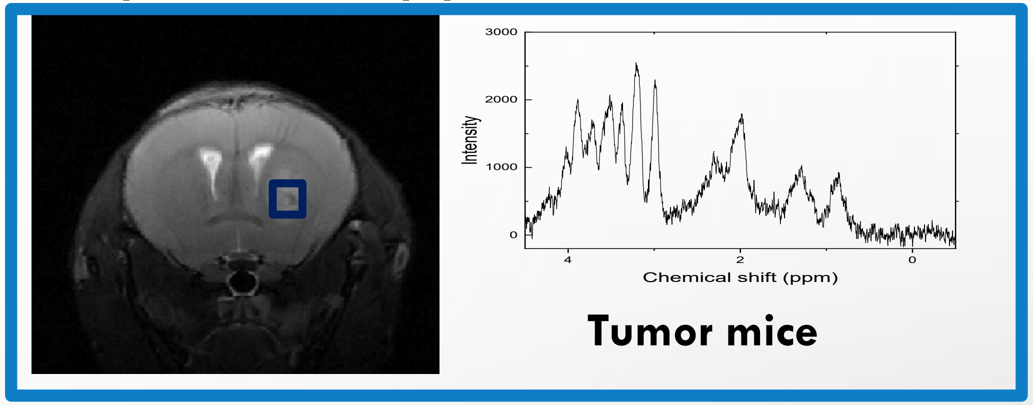


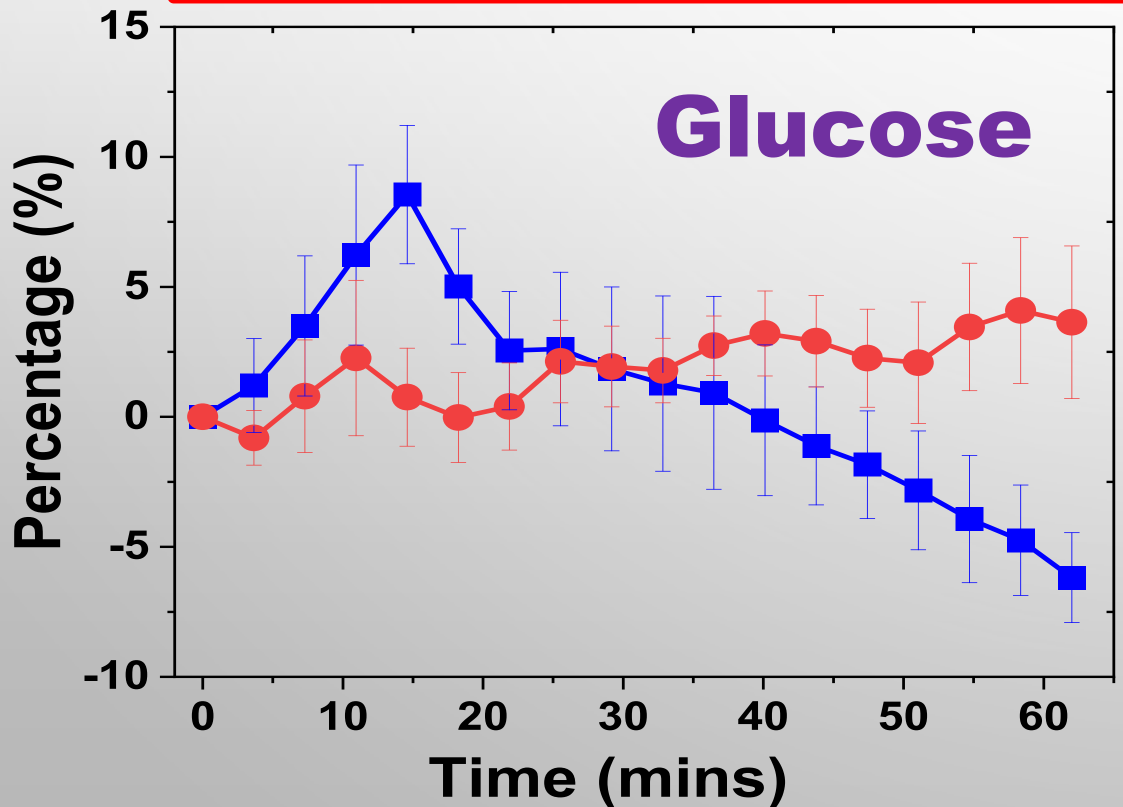
GLUCOSE METABOLISM

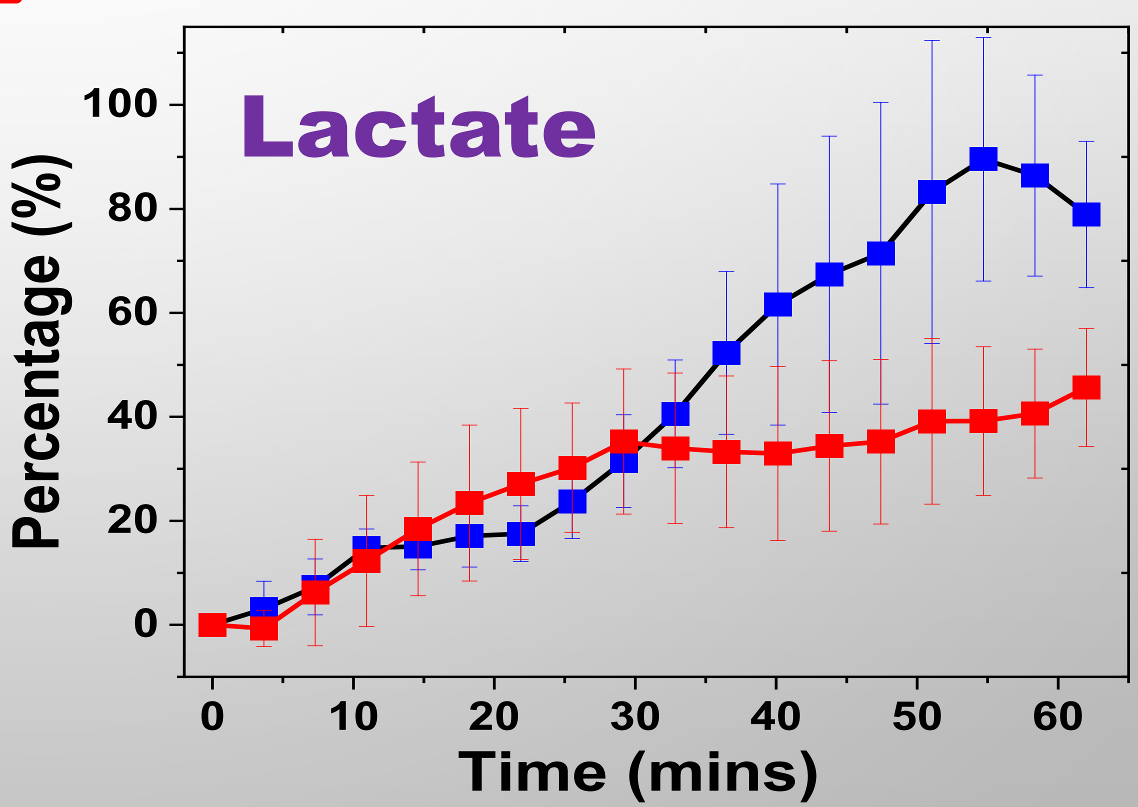


In vivo Magnetic Resonance Spectroscopy



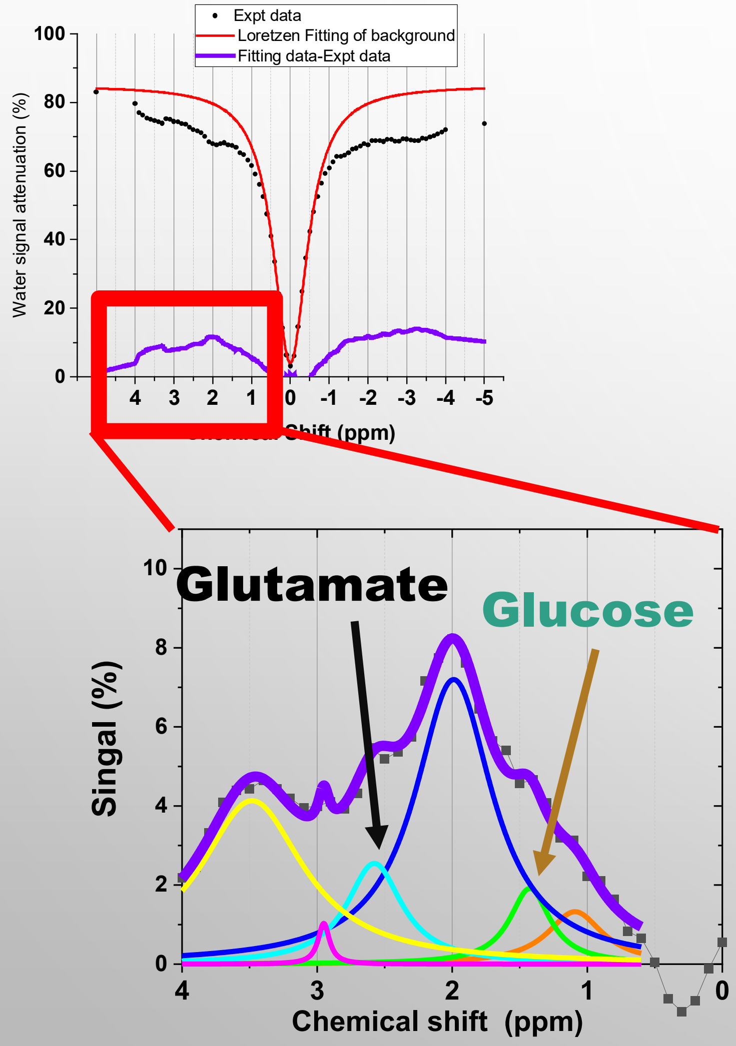




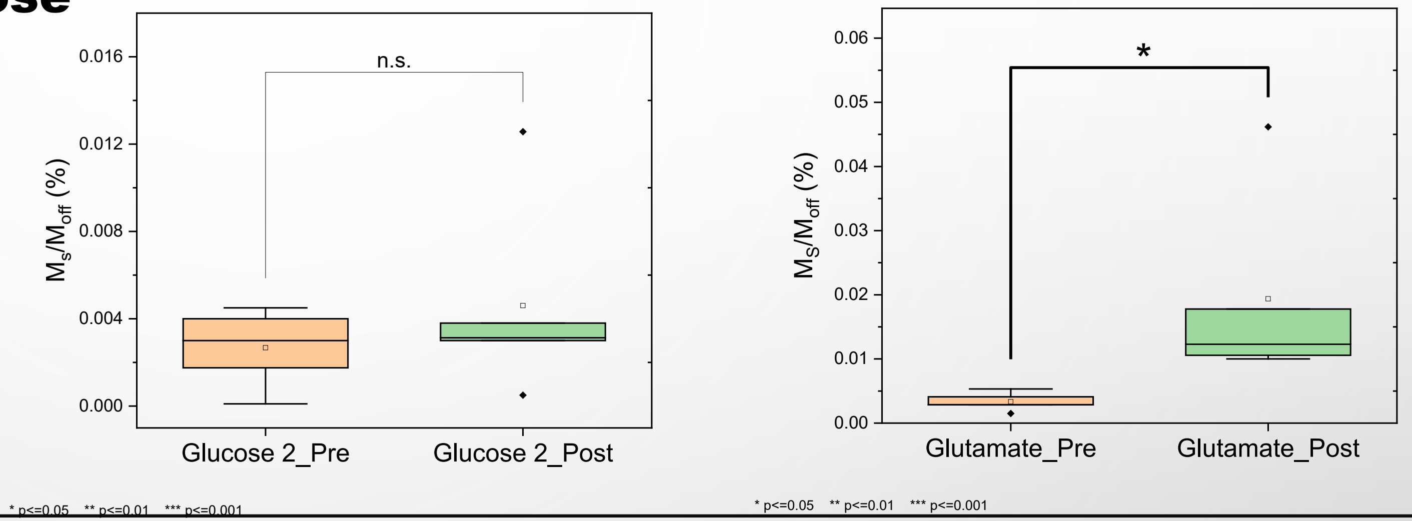


GLUCOSE AND GLUTAMATE

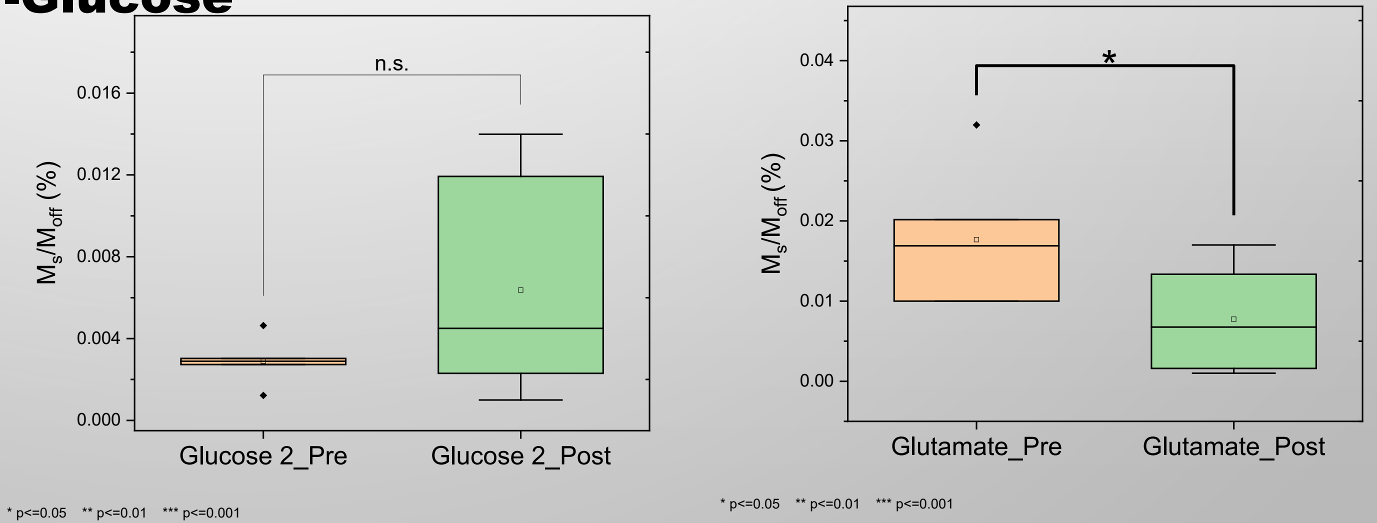
In vivo z-spectra Analysis by CEST (15 mins after glucose injection)



D-Glucose



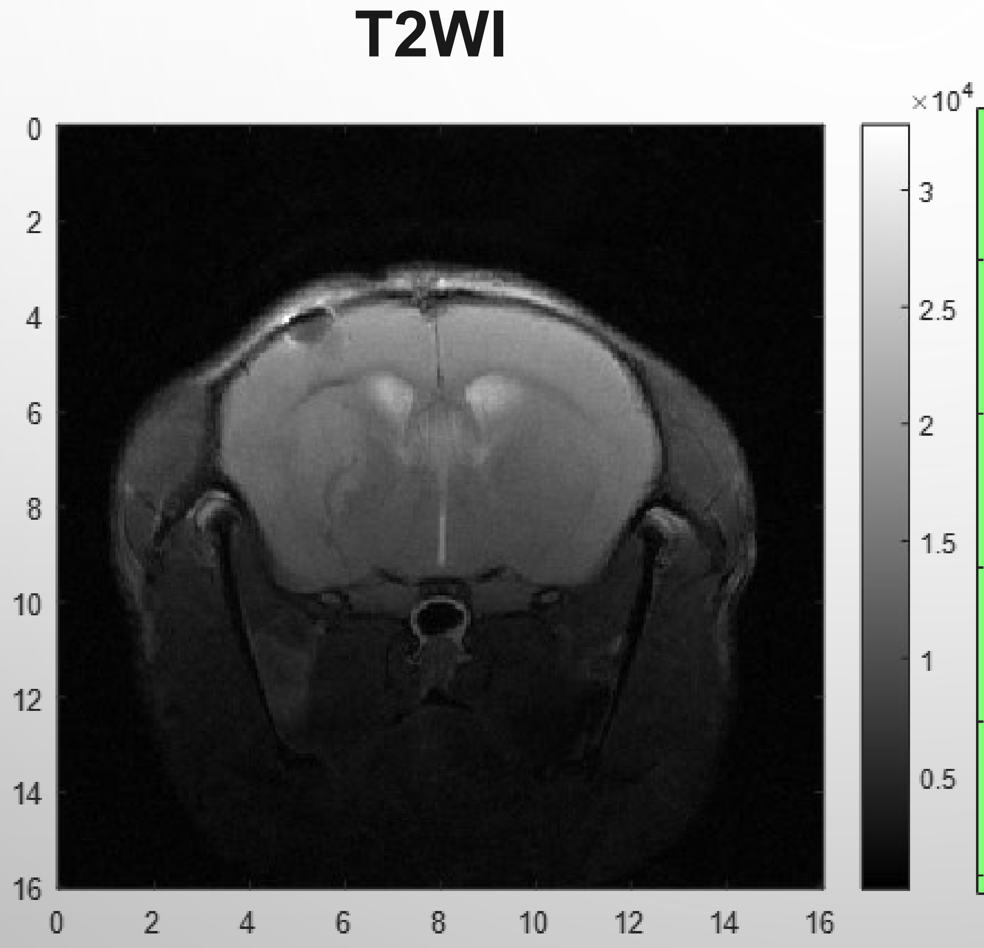
2-Deoxy-Glucose

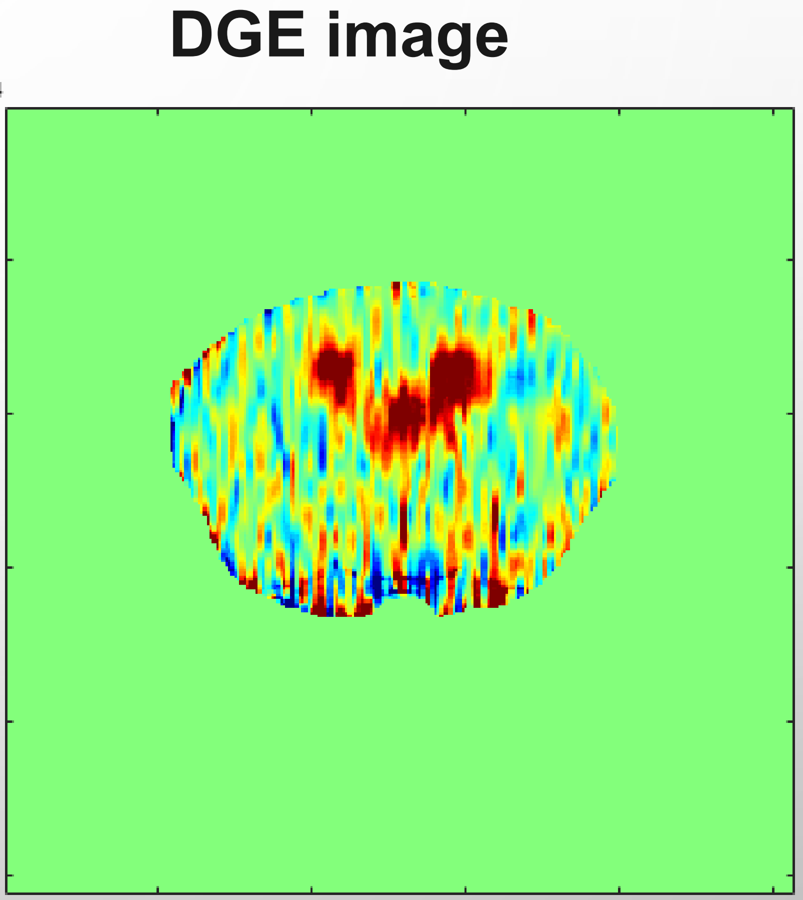


Application: Tumor Microenvironment differentiation

Application: Tumor Microenvironment differentiation

DGE Image of Mice Brain Tumor Model

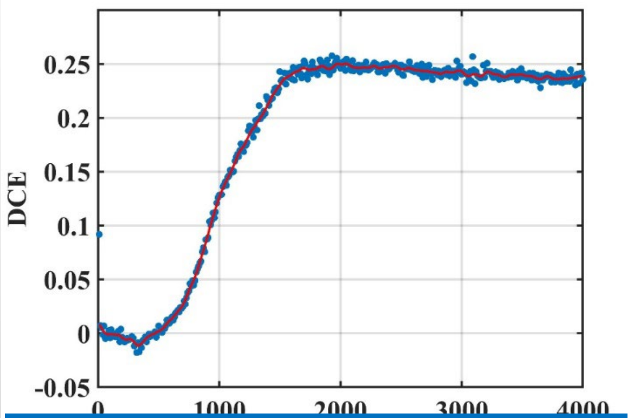




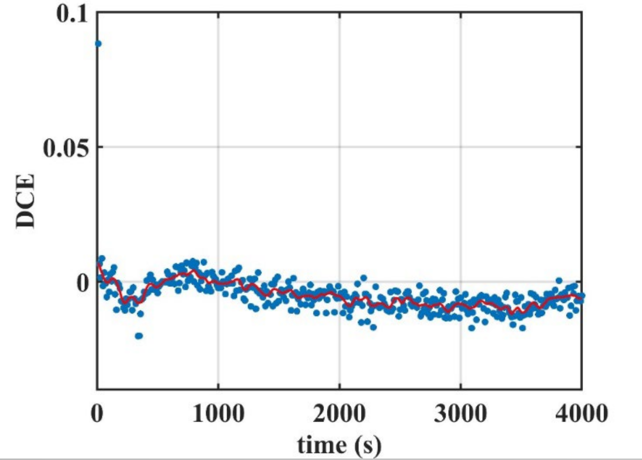
Application: Tumor Microenvironment differentiation

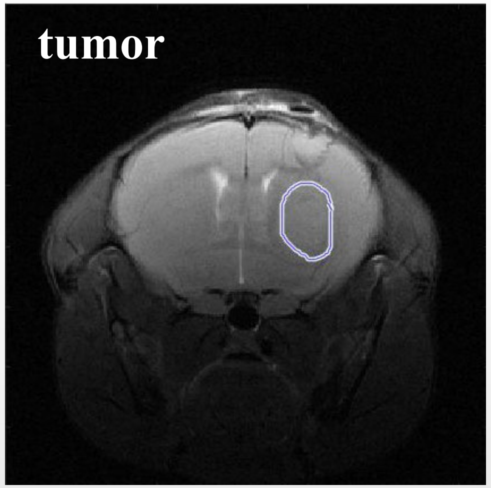
ROI Analysis of dynamic process

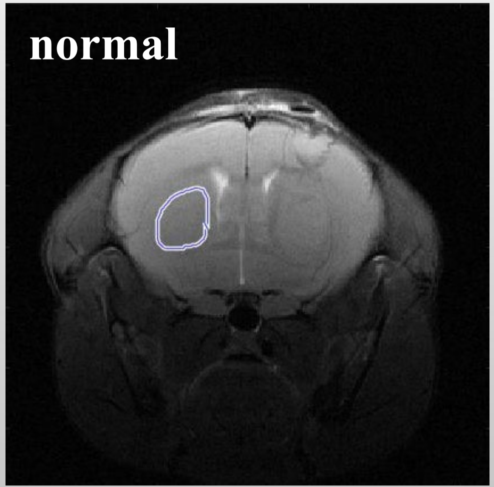
DCE
(Using Contrast Agent)



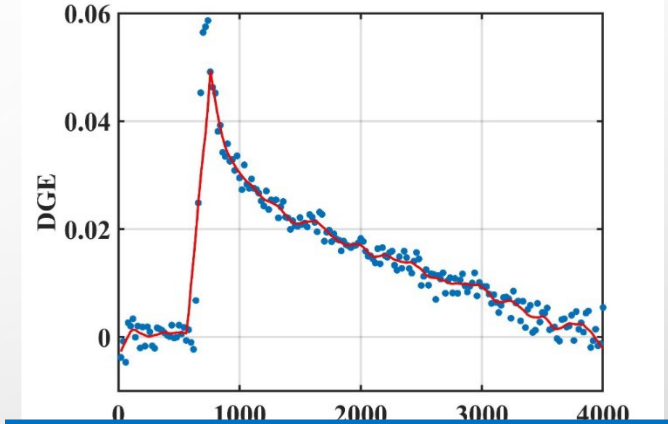
Reflect the BBB leakage



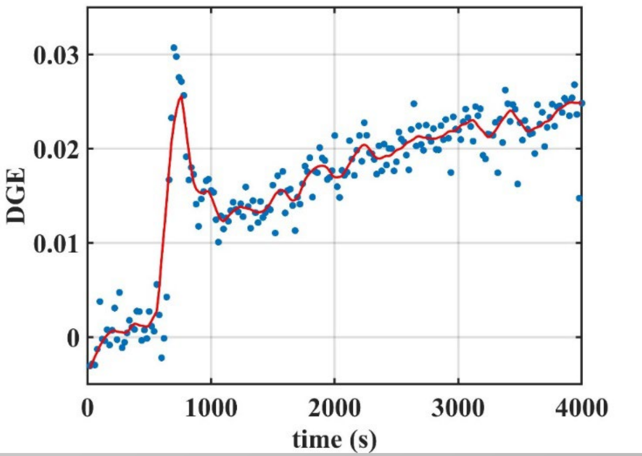




DGE
(Using Glucose)



Reflect glucose metabolism

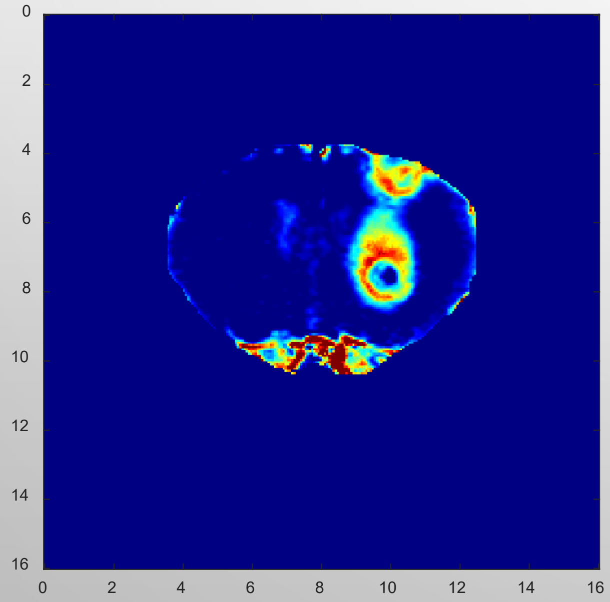


Application: Tumor Microenvironment differentiation

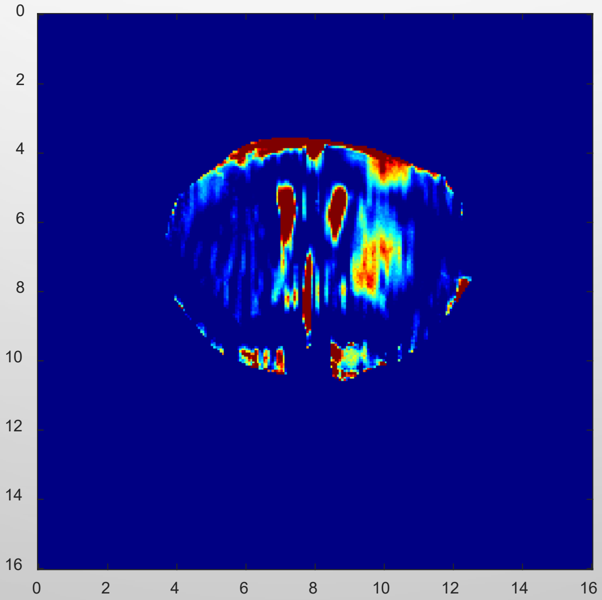
Area Under Curve (AUC) Mapping

Static information

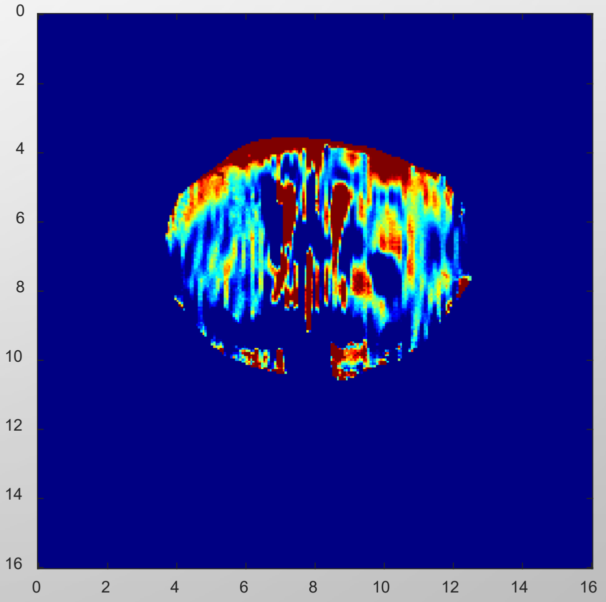
DCE imaging
(0-2000 s)



DGE imaging
(0-2000 s)



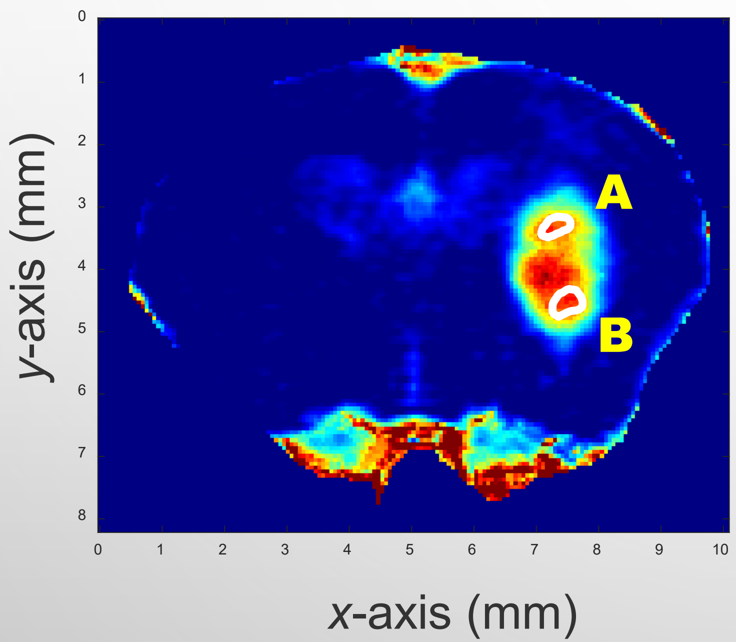
DGE imaging
(0-4000 s)



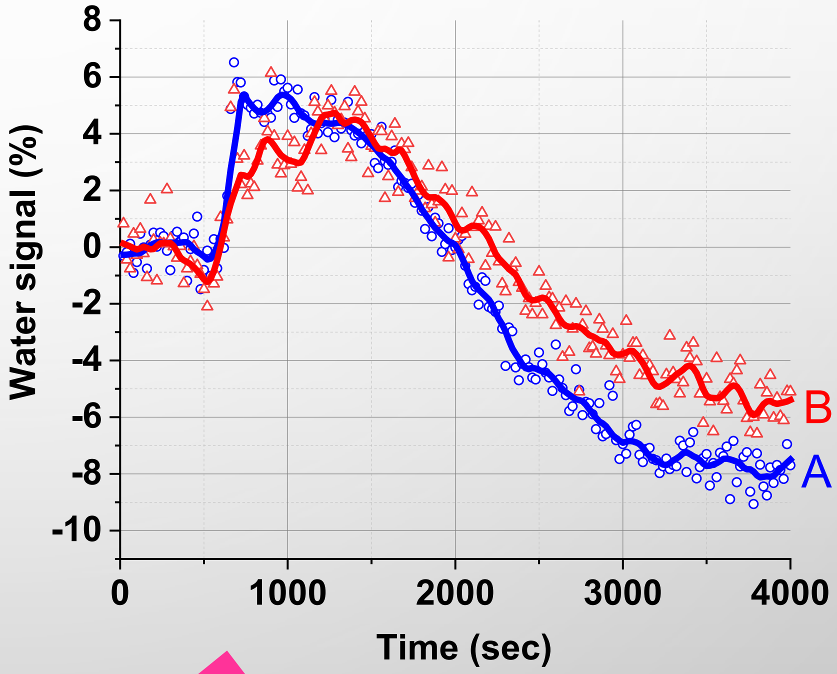
plication: Tumor Microenvironment differentiation

UC mapping of DCE image v.s. DGE urve

AUC mapping of DCE image



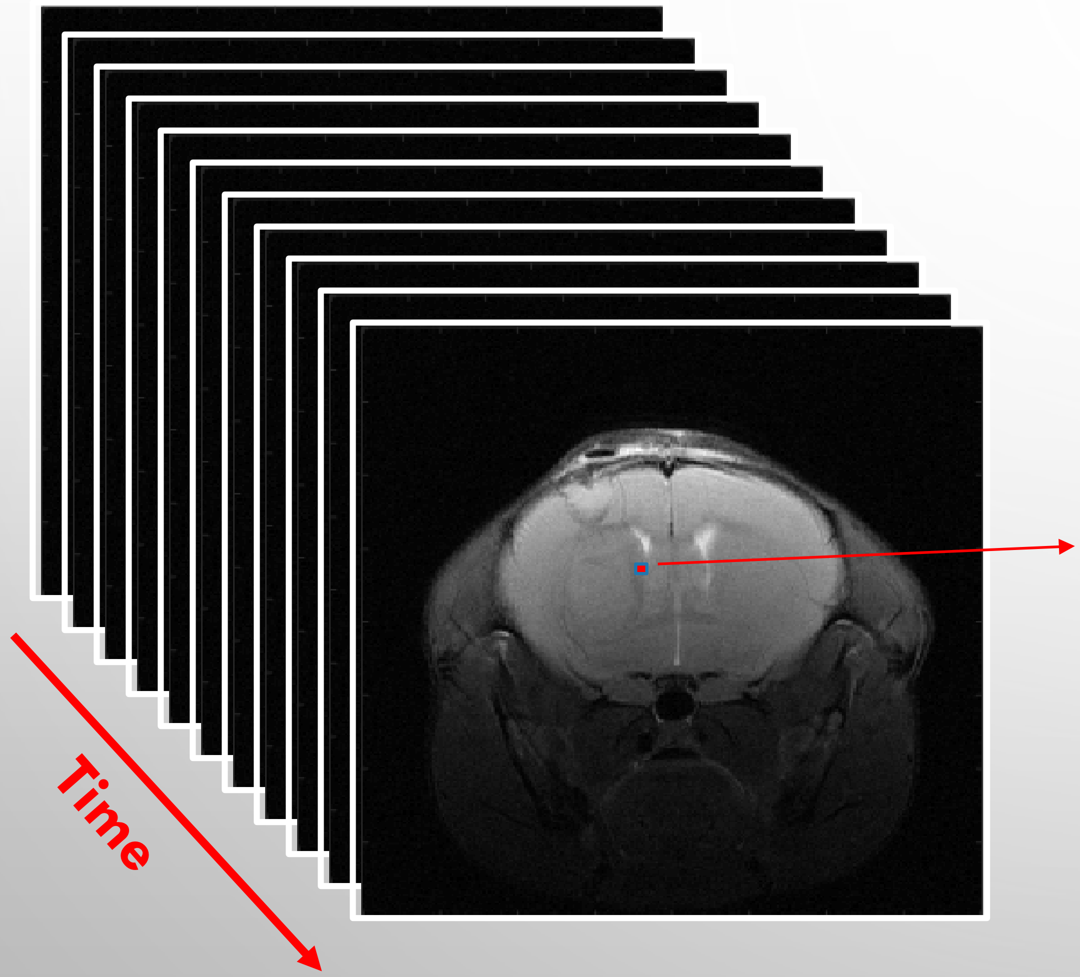
DGE signal



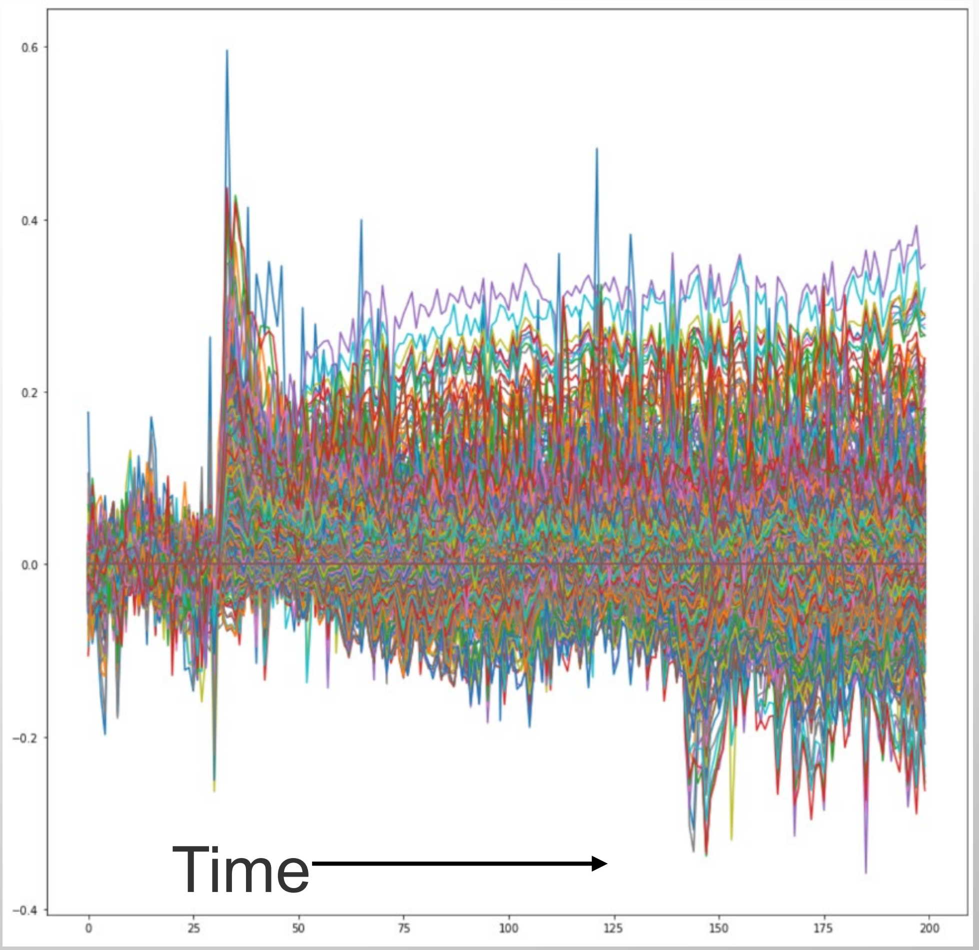
Similar BBB leakage condition but different metabolism rate

Application: Tumor Microenvironment differentiation

Classification of DGE signals

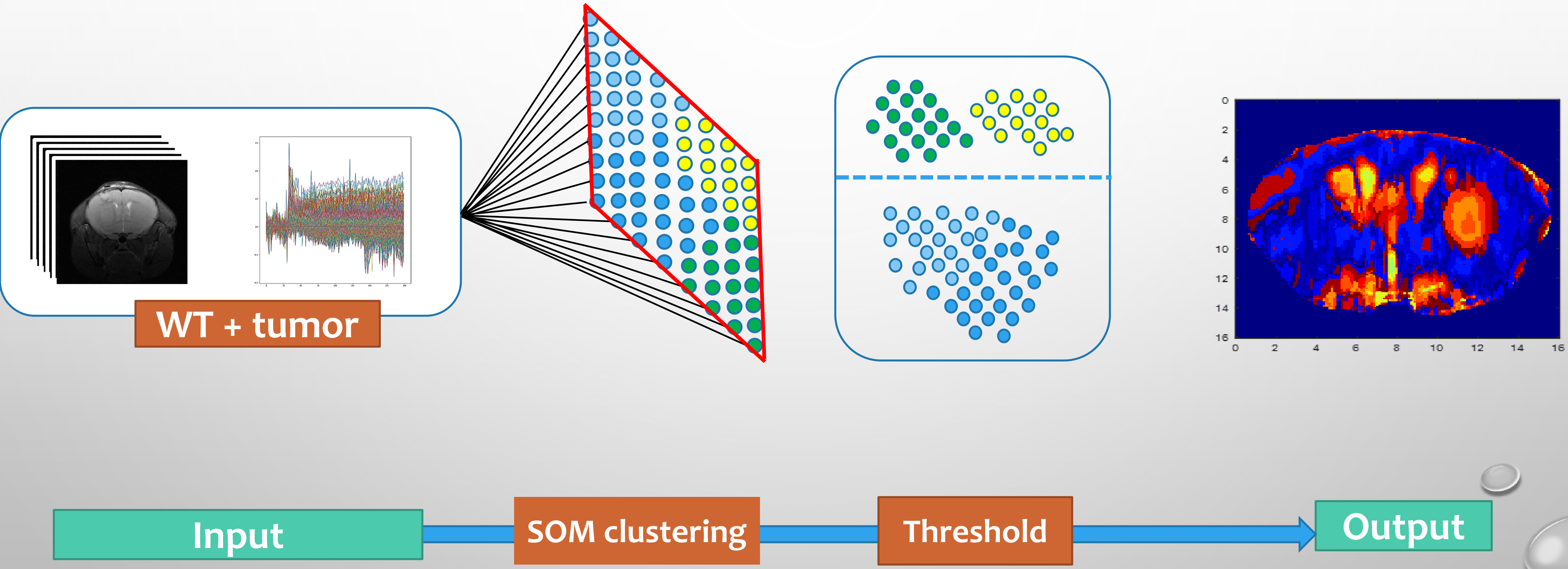


Voxel DGE signal



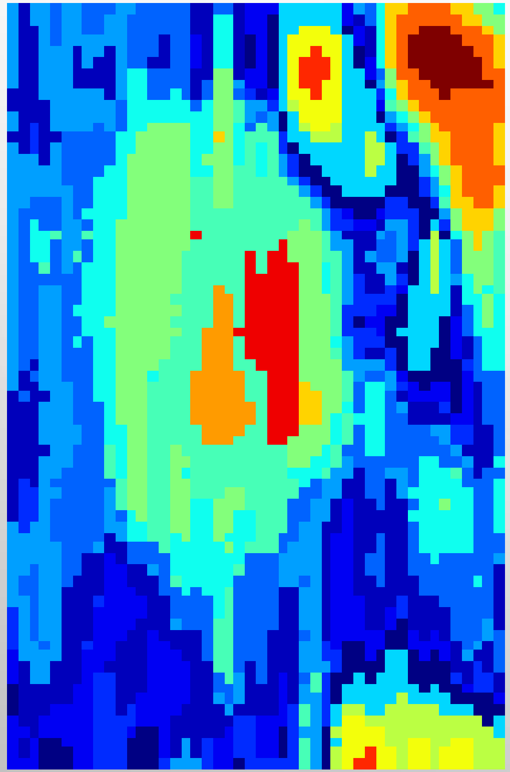
Application: Tumor Microenvironment differentiation

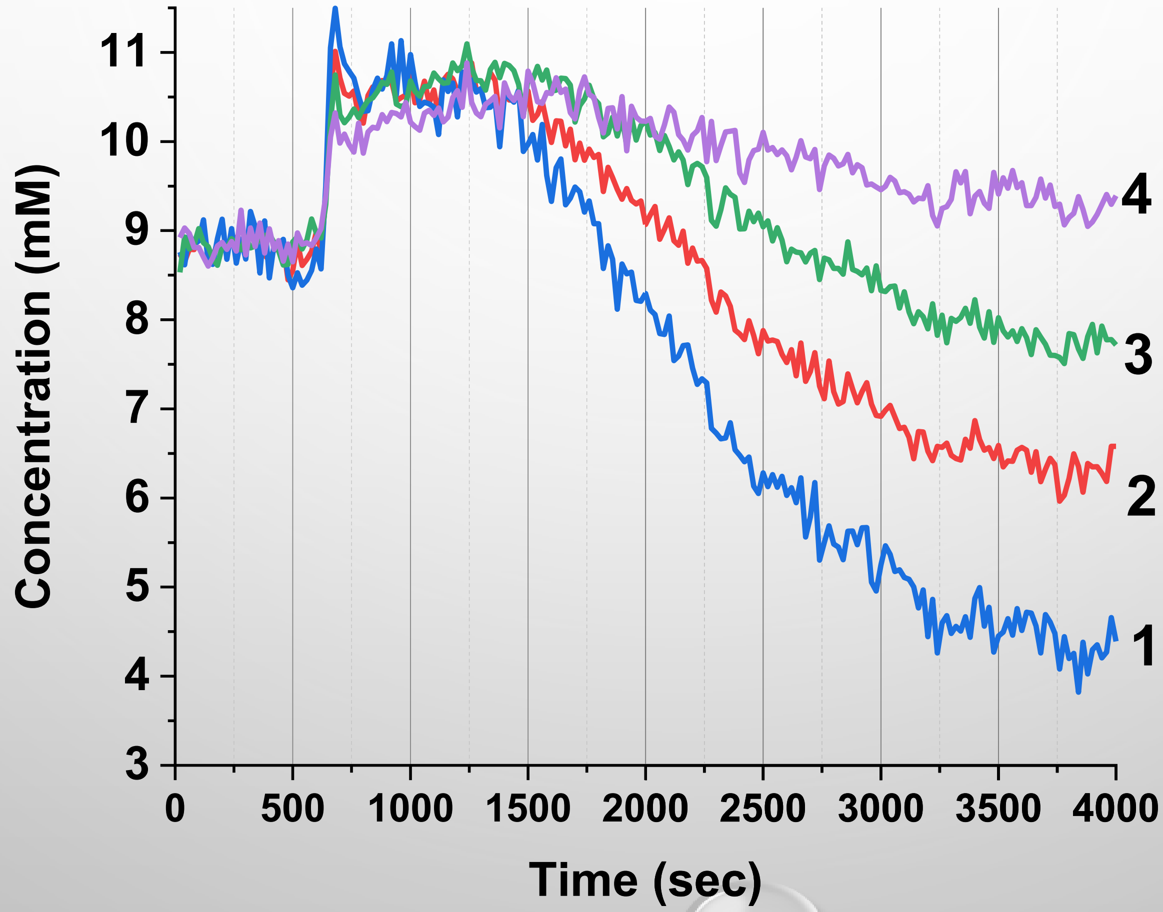
Flowchart of Signal Clustering

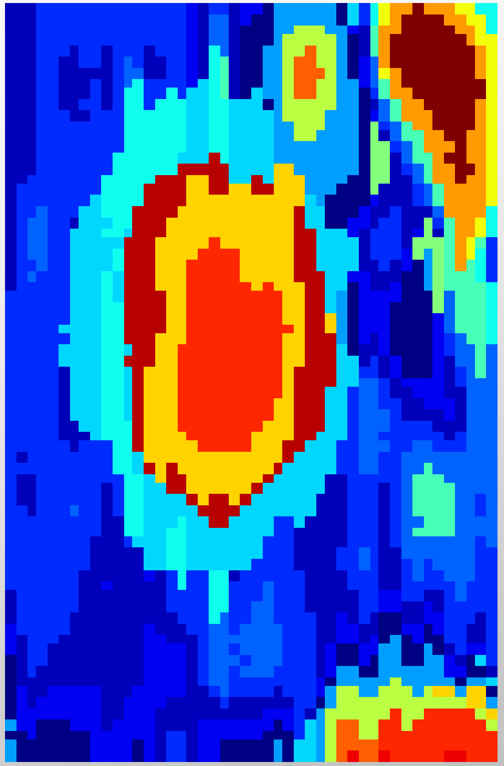


Application: Tumor Microenvironment differentiation

Influence of Time Interval on Dynamics and Mapping Images

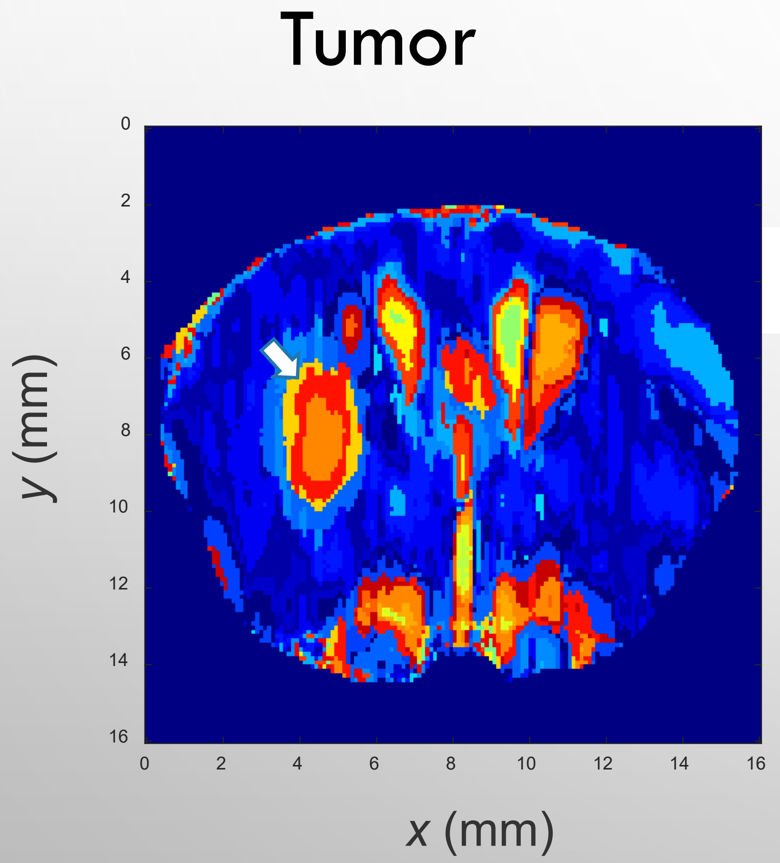


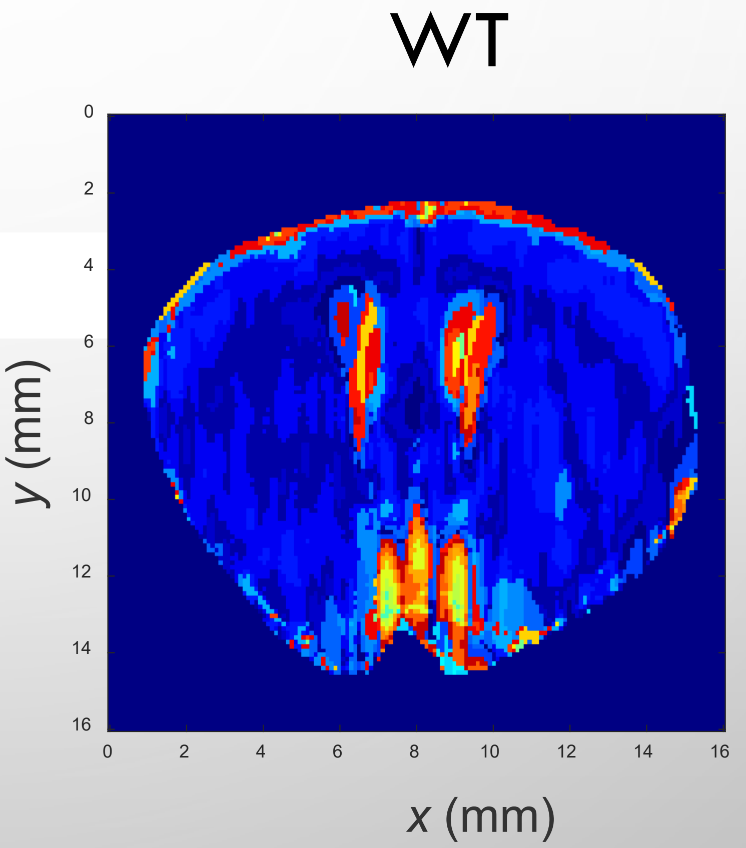




SOM mapping

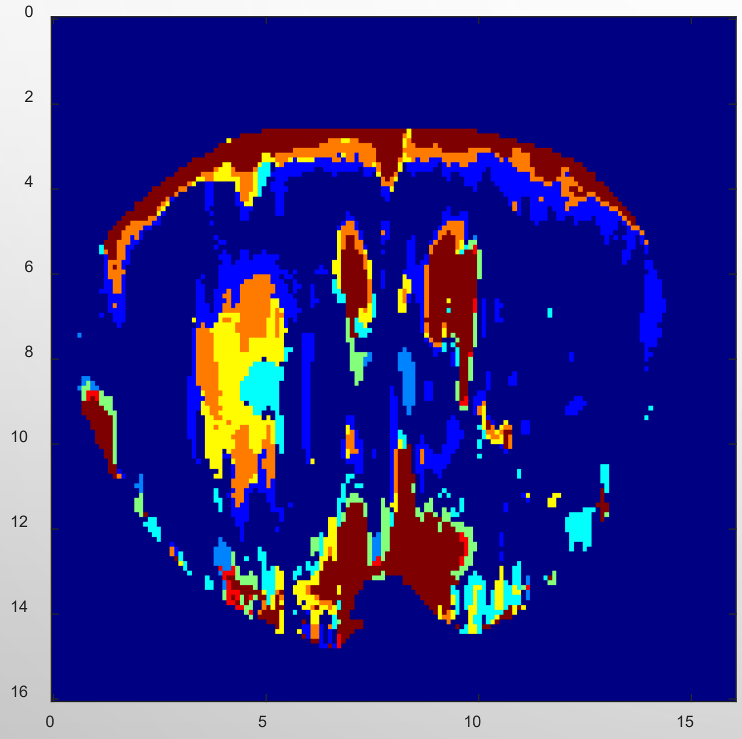
Colors represent different signal types



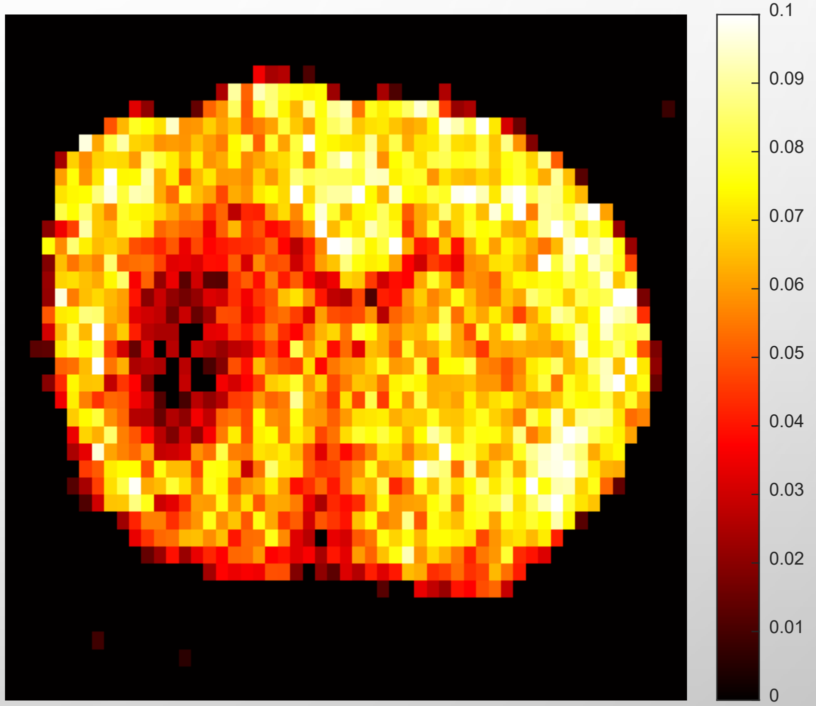


Application: Tumor Microenvironment differentiation

Comparison of SOM and DESI Image

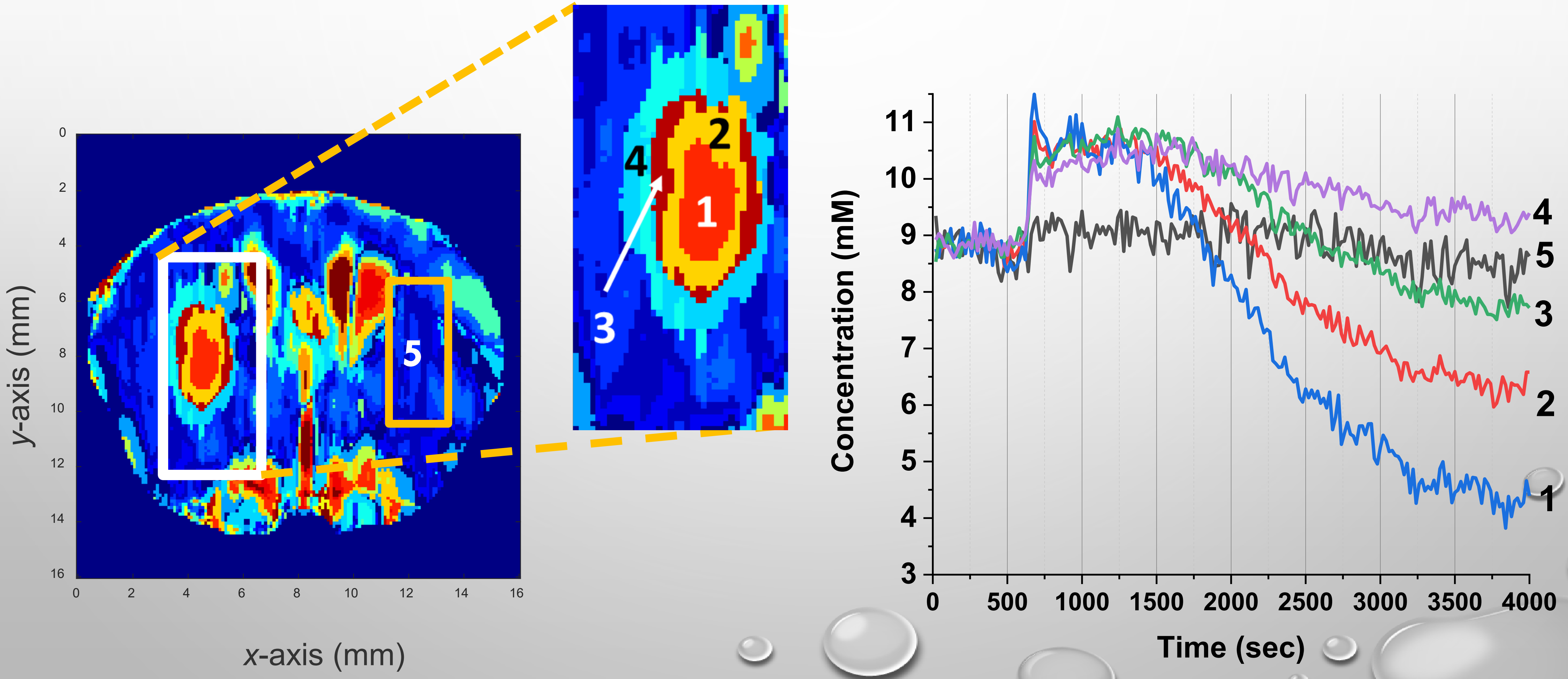


Glutamate image



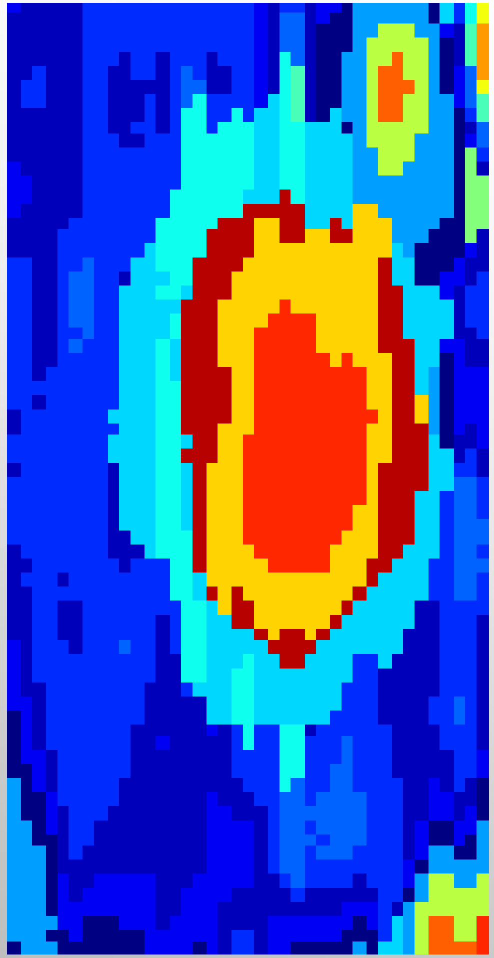
Application: Tumor Microenvironment differentiation

ROI analysis by SOM classification

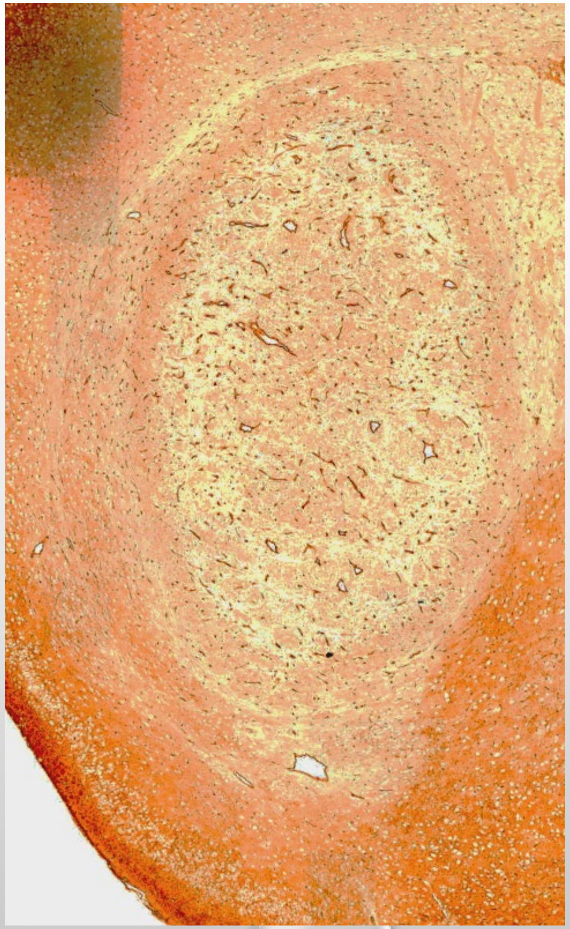


Application: Tumor Microenvironment differentiation

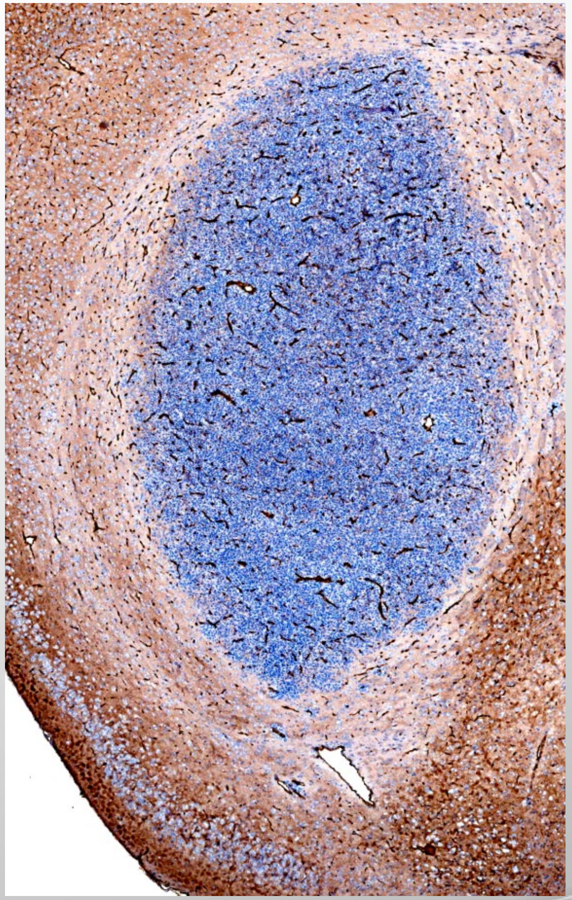
Comparison of SOM and Pathology



GLUT1

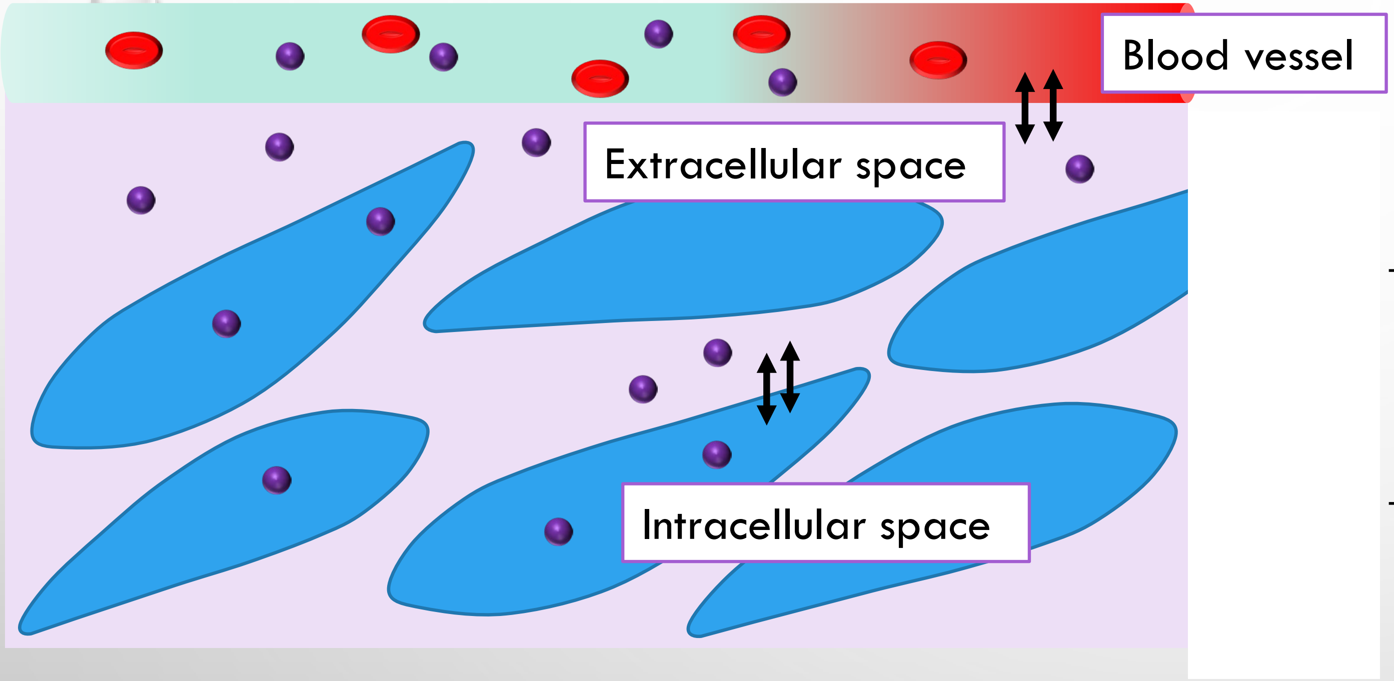


H&E



Application: Tumor Microenvironment differentiation

Theoretical Model of Glucose Transportation

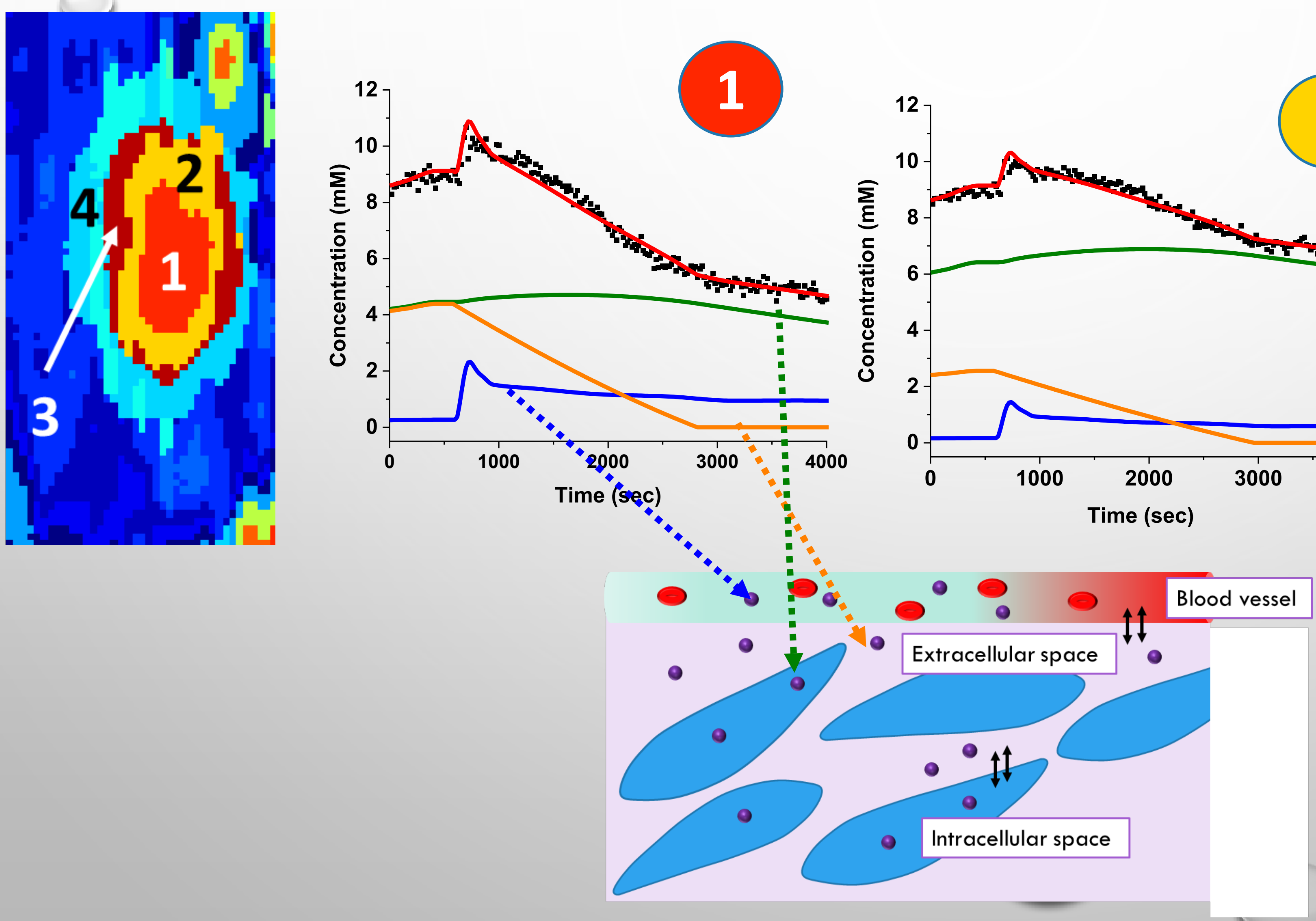


$$\frac{dC_o}{dt} = D(C_p - C_o) + V_{\max}\frac{C_i - C_o}{K_M + C_o + C_i + \frac{C_o C_i}{K_{ii}}}$$

$$\frac{dC_i}{dt} = V_{\max}\frac{C_o - C_i}{K_M + C_o + C_i + \frac{C_o C_i}{K_{ii}}} - R_{meta}$$

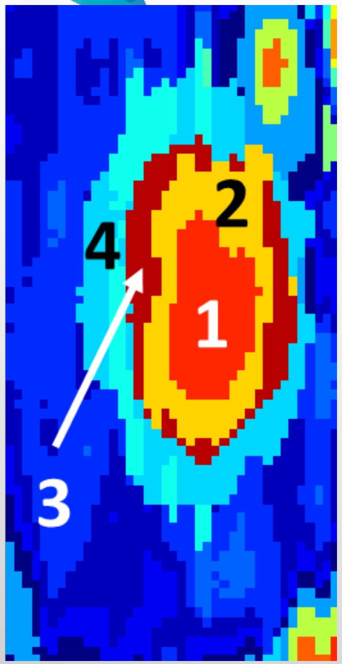
Application: Tumor Microenvironment differentiation

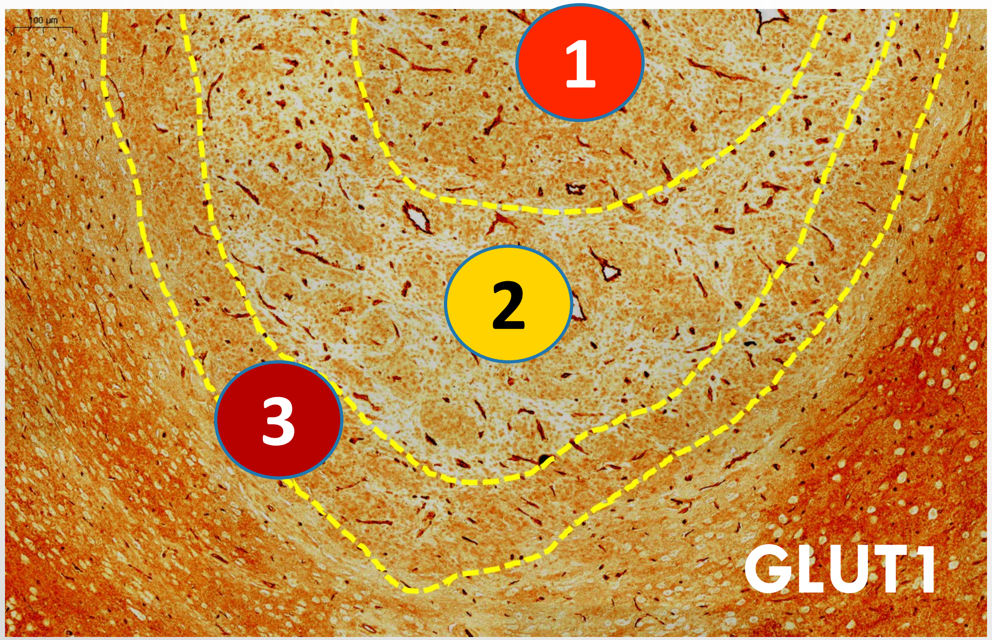
Theoretical Simulation

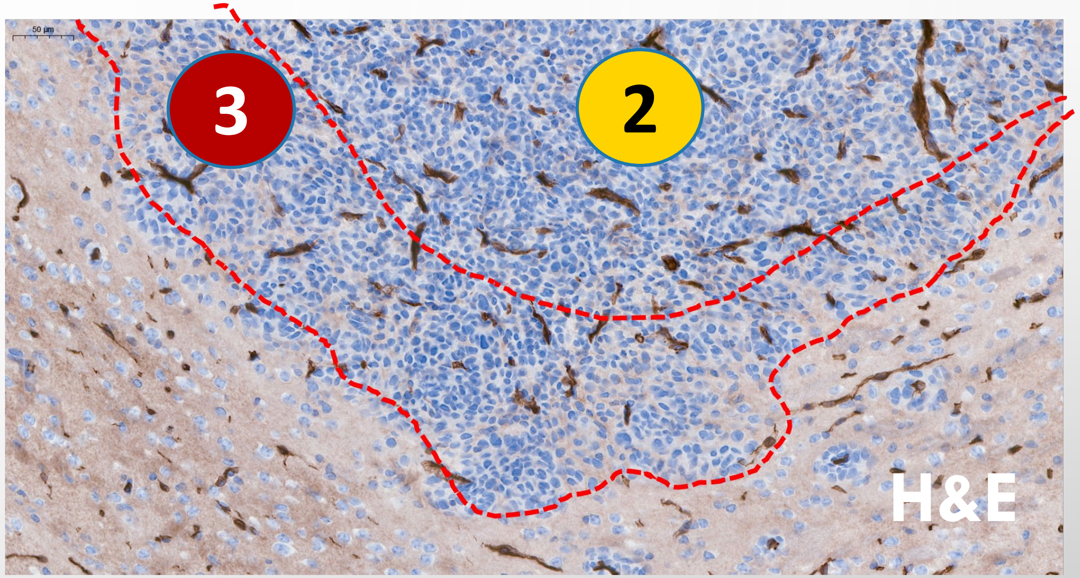


Application: Tumor Microenvironment differentiation

Comparison of Simulation and Pathology





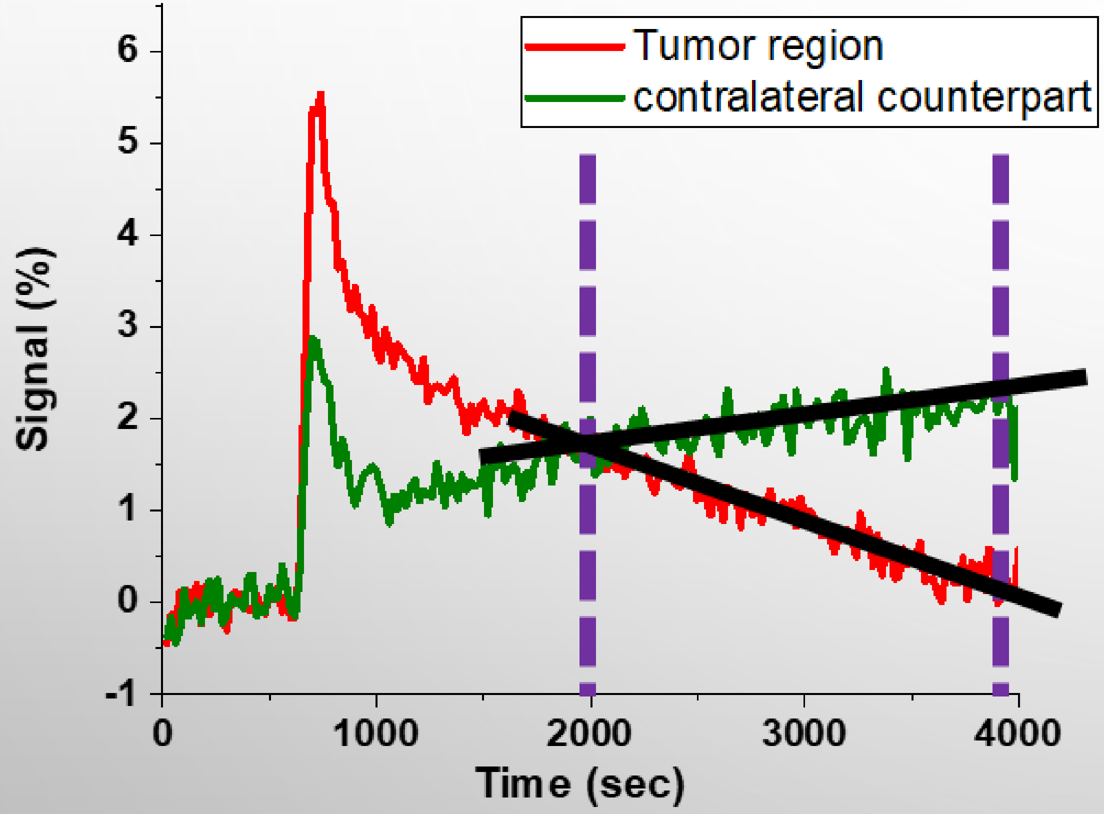


Region	V_{max}/R_{meta}	$P_p : P_o : P_i$
1	0.40	3.0% : 48.7% : 48.3%
2	0.33	1.8% : 70.0%: 28.2%
3	0.34	3.0% : 95.0% : 2%

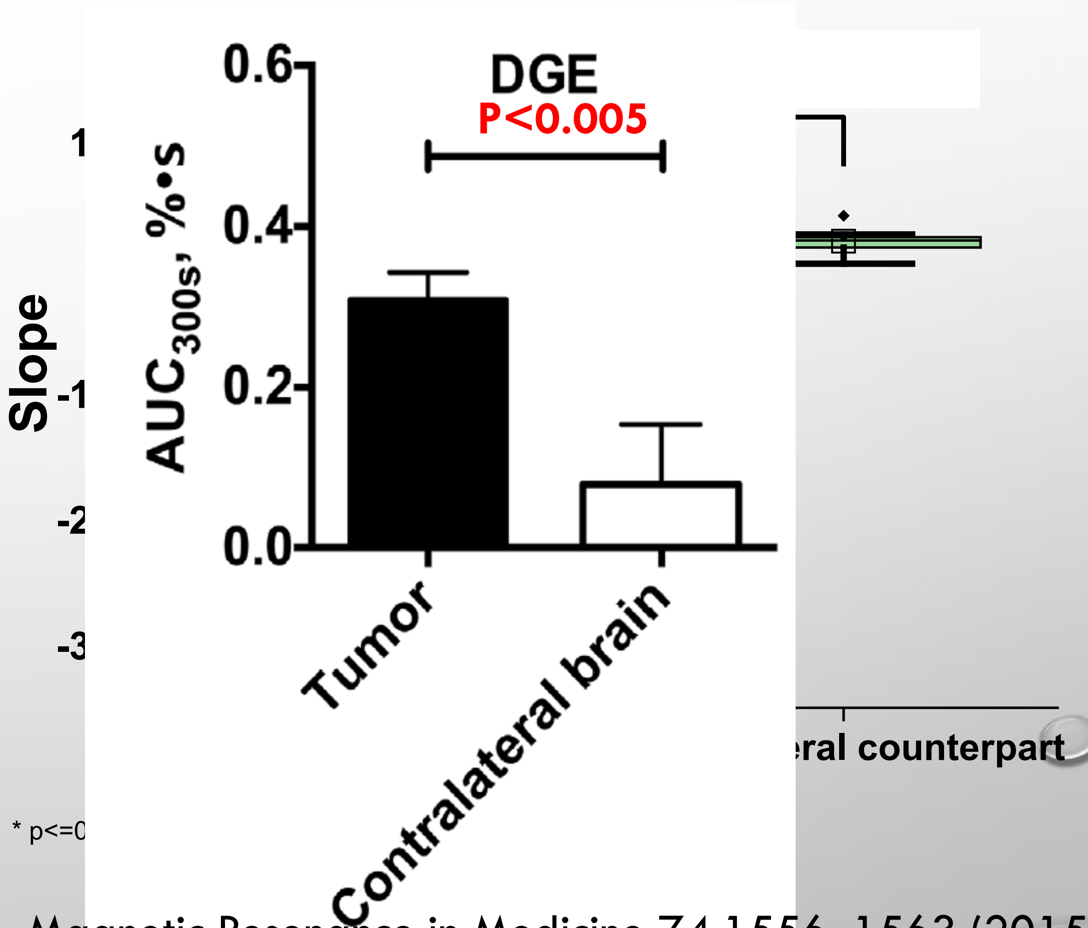
Difference due to the Glut1 distribution

Difference due to the Cell distribution

Wash-out Slope as An Image Biomarker



Previous Work

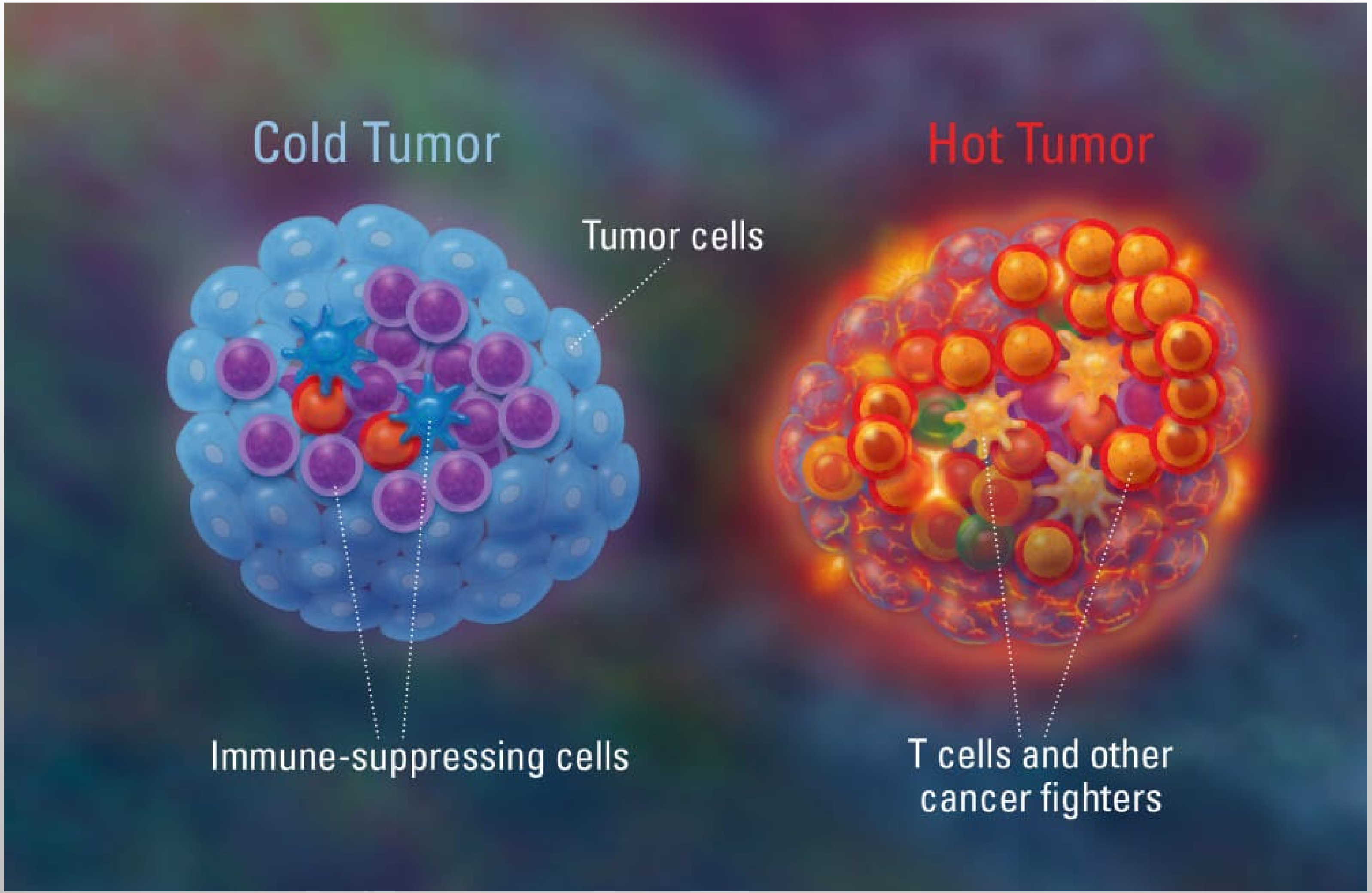


Magnetic Resonance in Medicine 74:1556–1563 (2015)

Application: Tumor Immune Responses

Application: Tumor Immune Responses

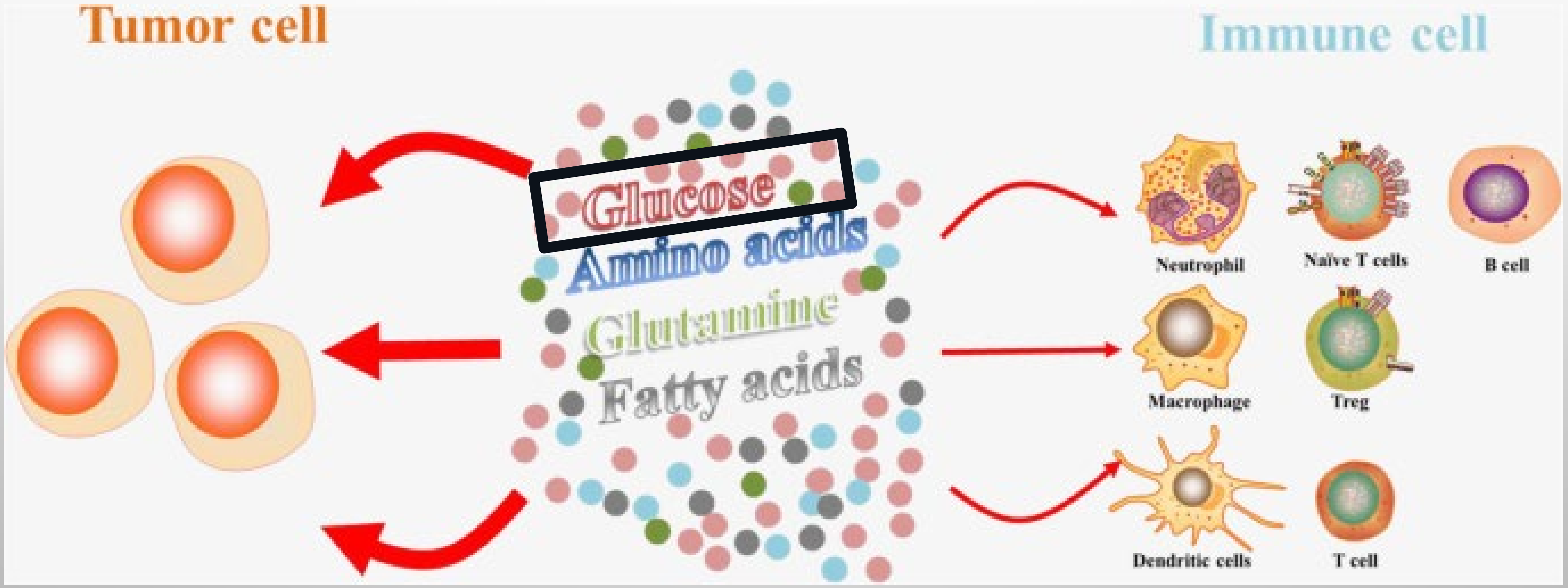
Hot and Cold Tumor



https://blog.dana-farber.org/insight/

Application: Tumor Immune Responses

The Nutritional Competition between Tumor and Immune Cells



Longzheng Xia et al., Molecular Cancer 2021

Application: Tumor Immune Responses

Tumor Size of Hot and Cold Tumor

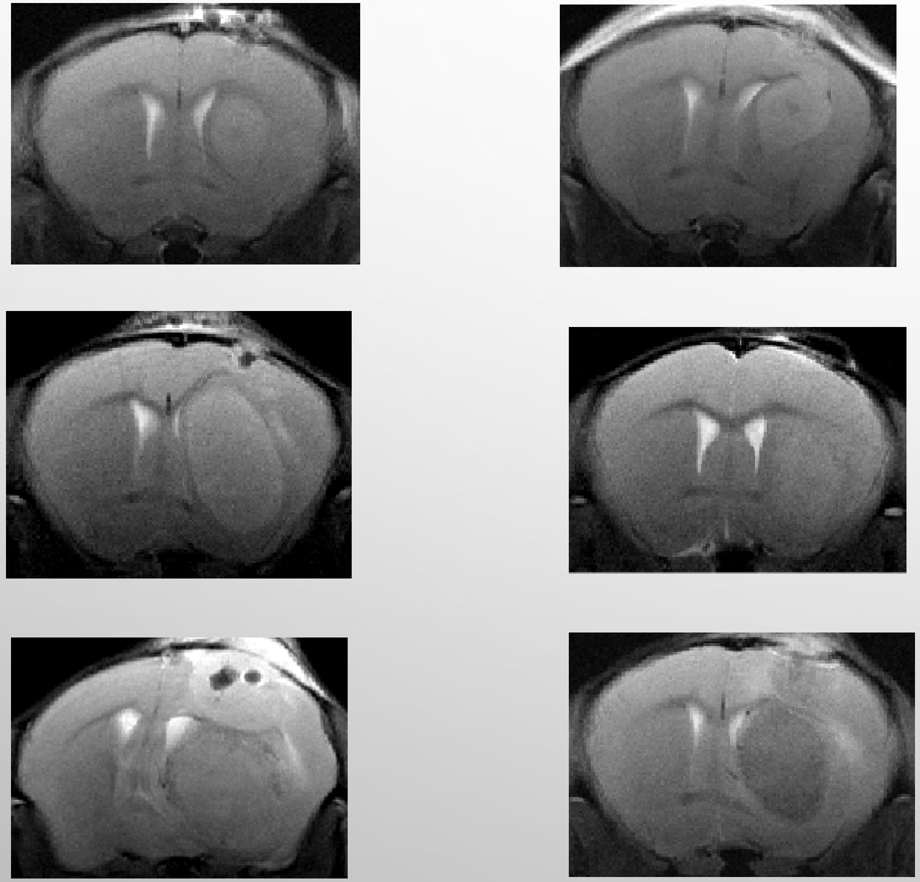
Cold tumor — w/o Tamoxifen tumor

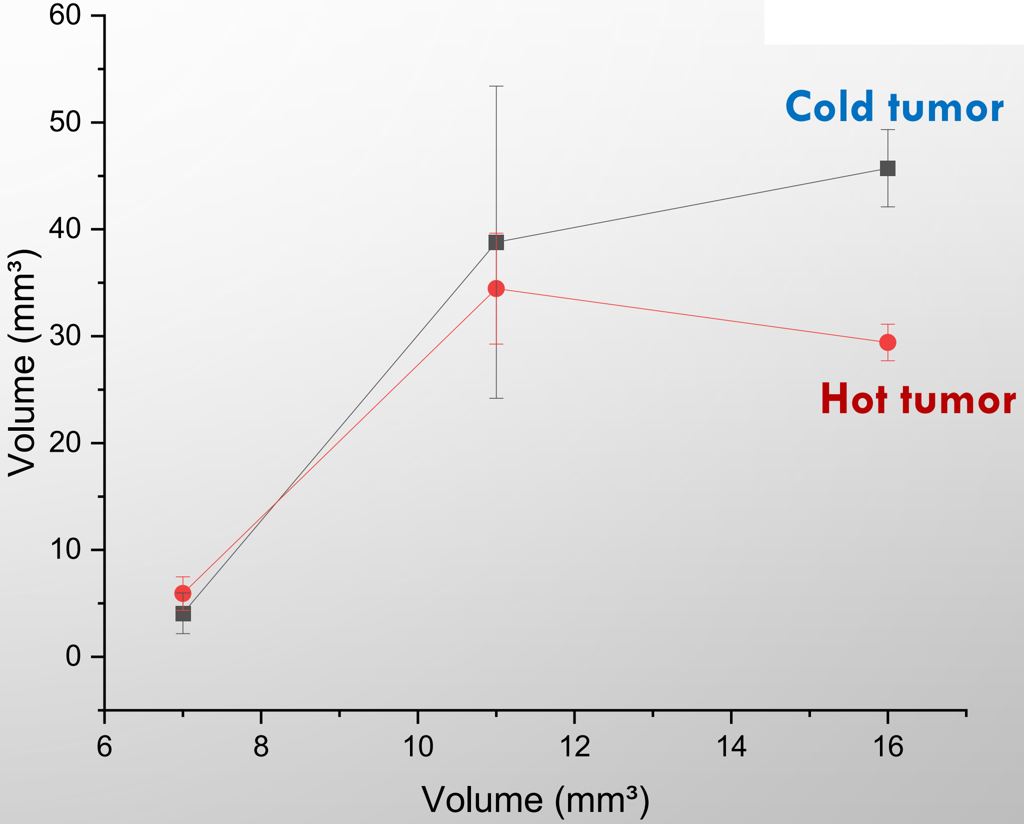
Hot tumor — w/ Tamoxifen tumor

Day 07

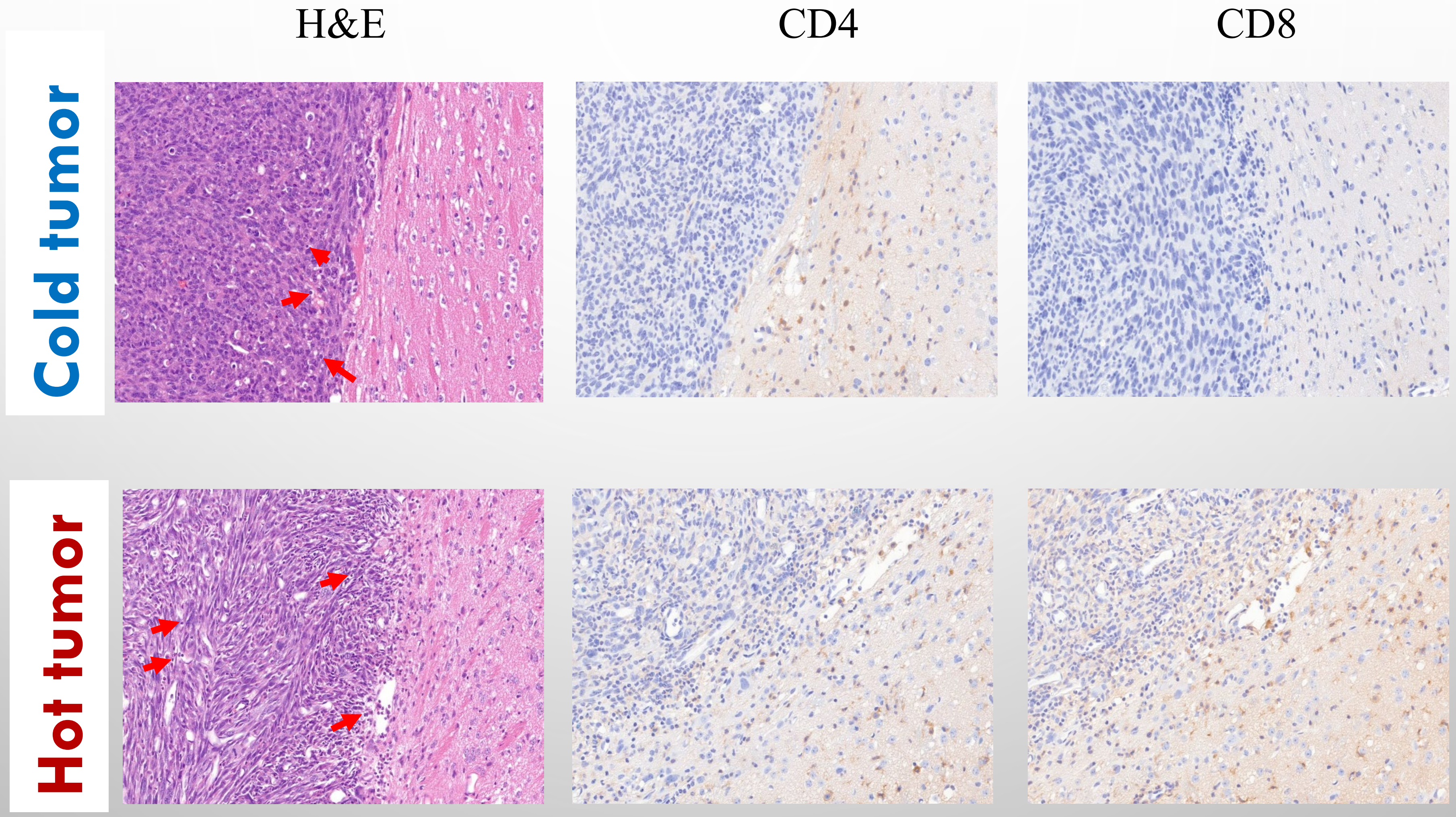
Day 11

Day 16





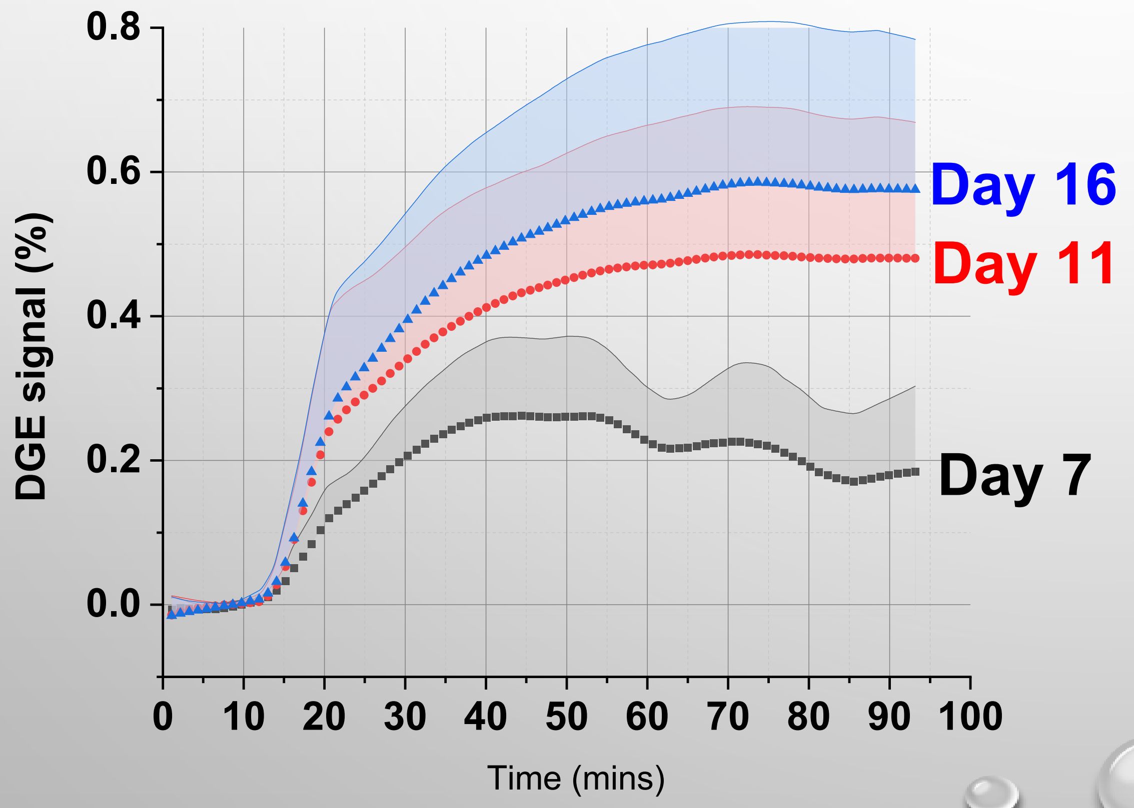
Pathology of Hot and Cold Tumor



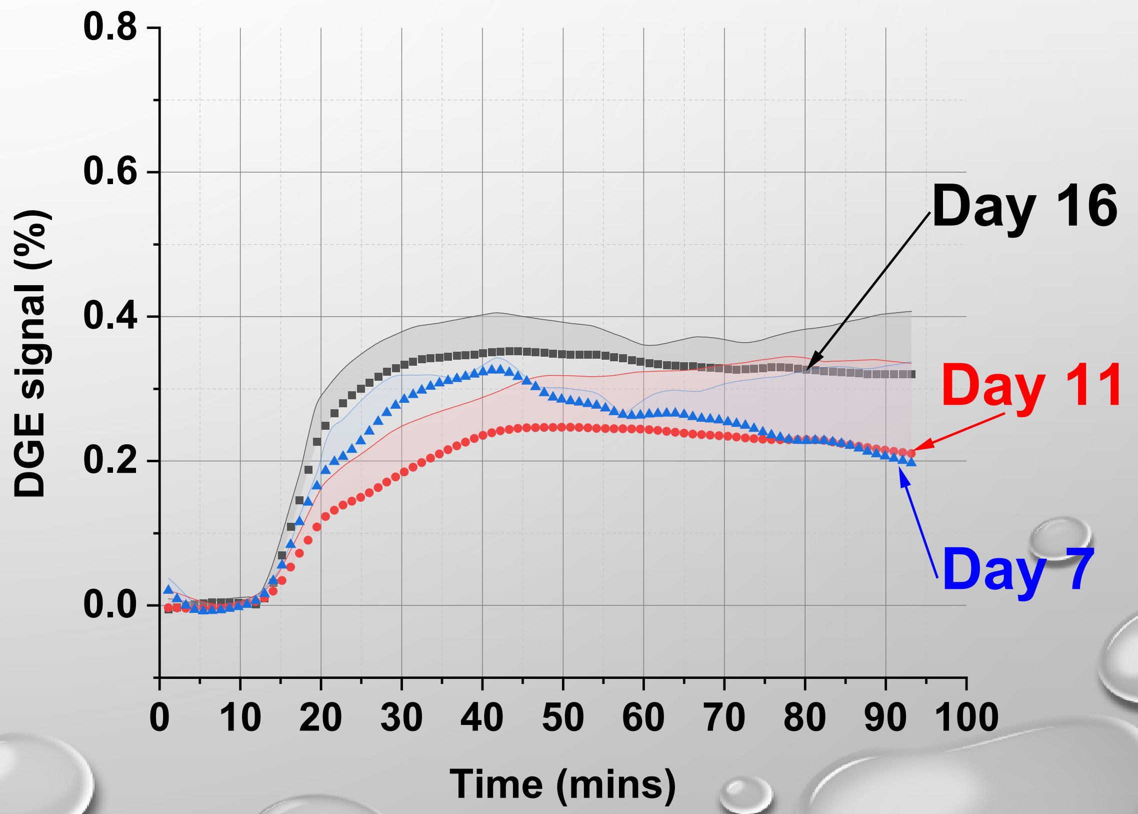
Application: Tumor Immune Responses

Glucose Uptaking of Hot and Cold Tumor

Hot tumor



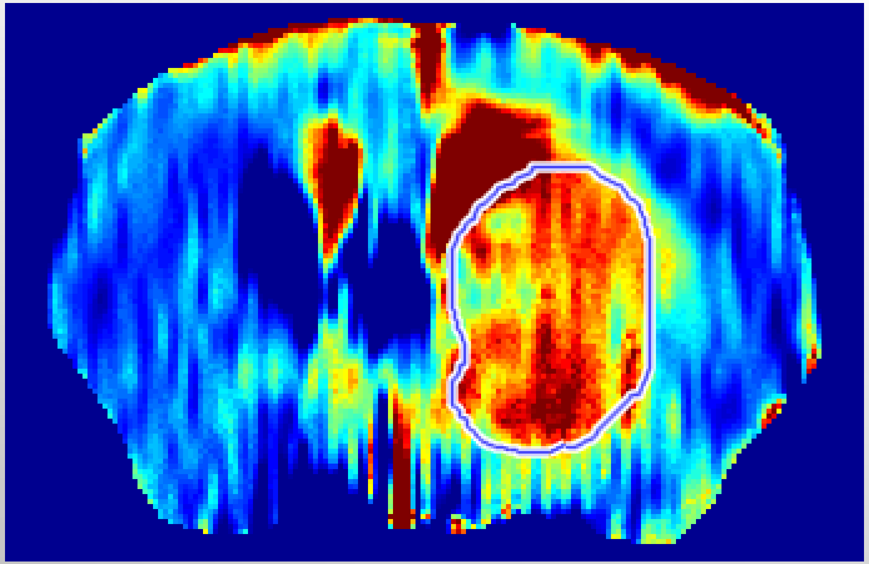
Cold tumor

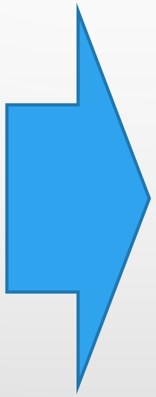


Application: Tumor Immune Responses

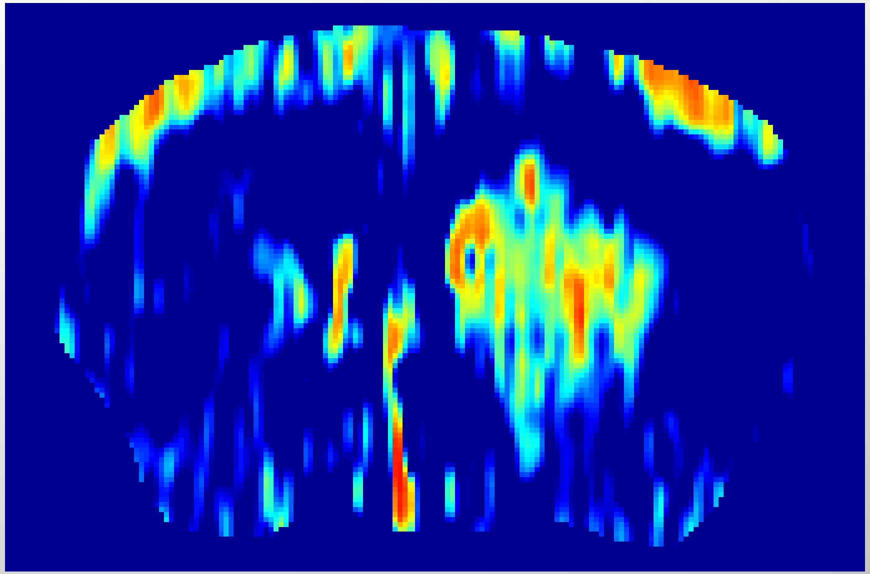
Correlation Map

Allocate the tumor by AUC map





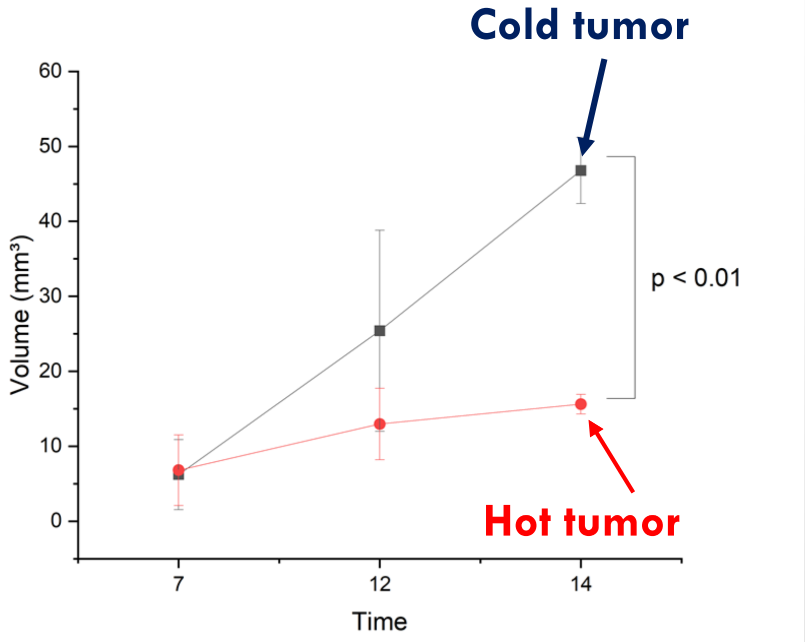
Check the correlation between the average and local DGE signal of tumor

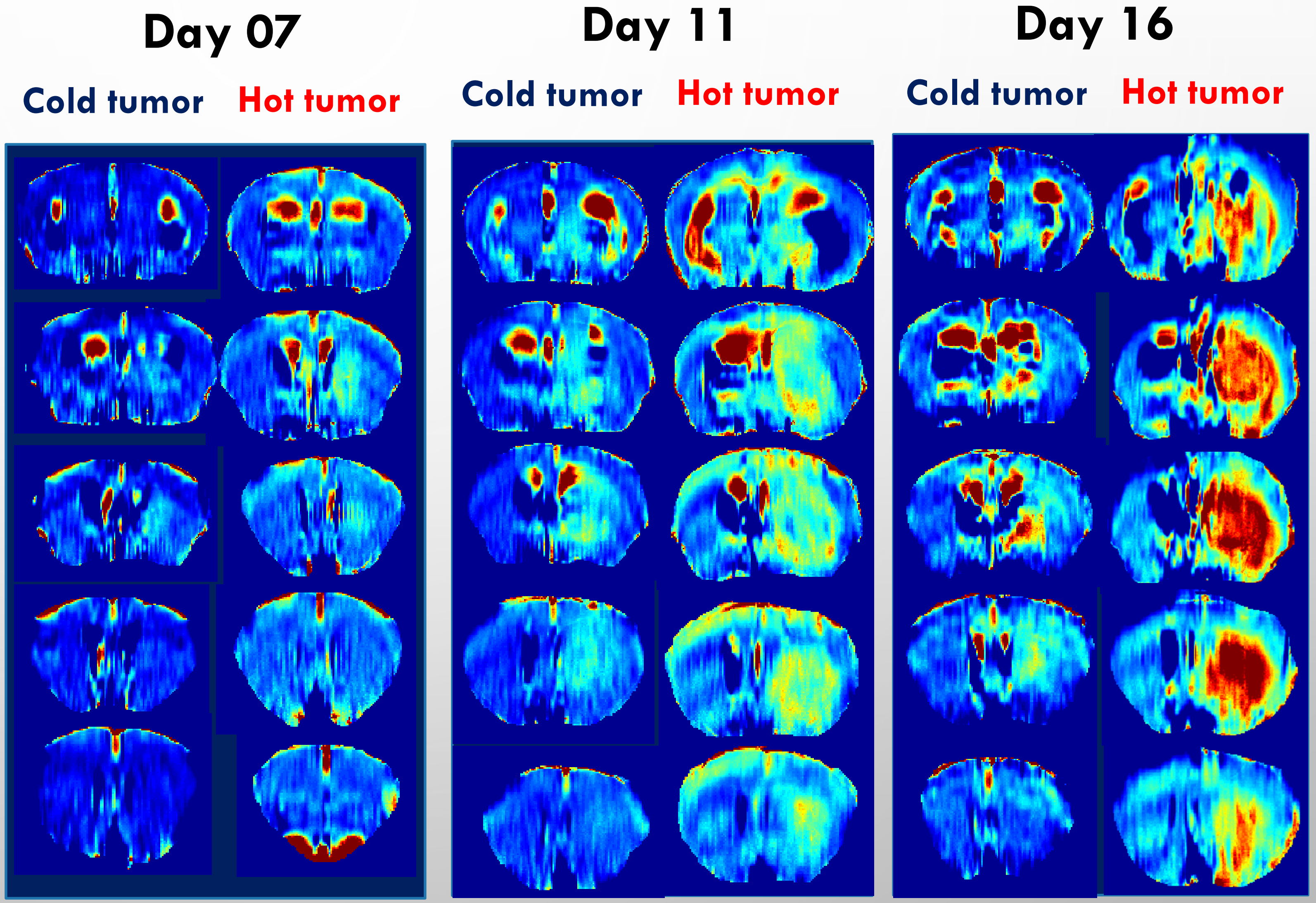


Application: Tumor Immune Responses

Correlation Map

Tumor Size



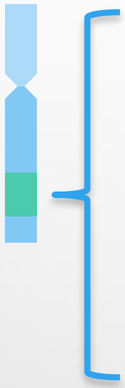


Application: Huntington's Disease Mice

Application: Huntington's Disease Mice

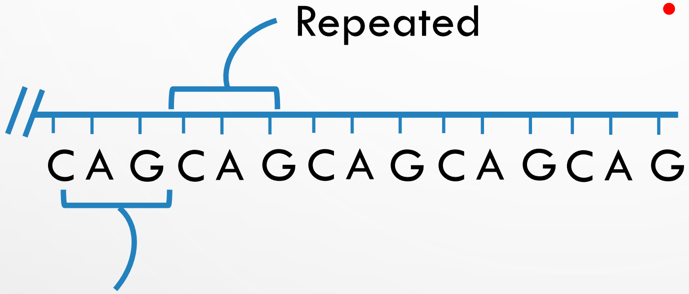
What Causes Huntington's Disease (HD)?

Chromsome 4

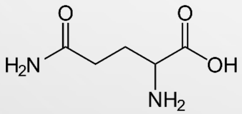


Huntingtin (HTT)

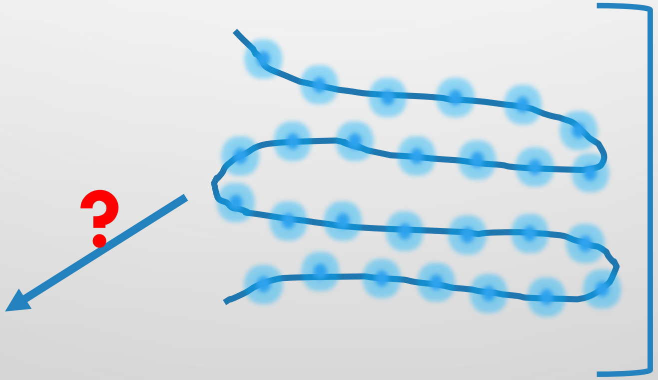
- Contains triplet repeat



- Normal : 10-35 times
- Huntington disease : >36 times



Glutamine



symptoms

Mutated Huntingtin protein

36 or more

Glutamines

↓

Polyglutamine Disease

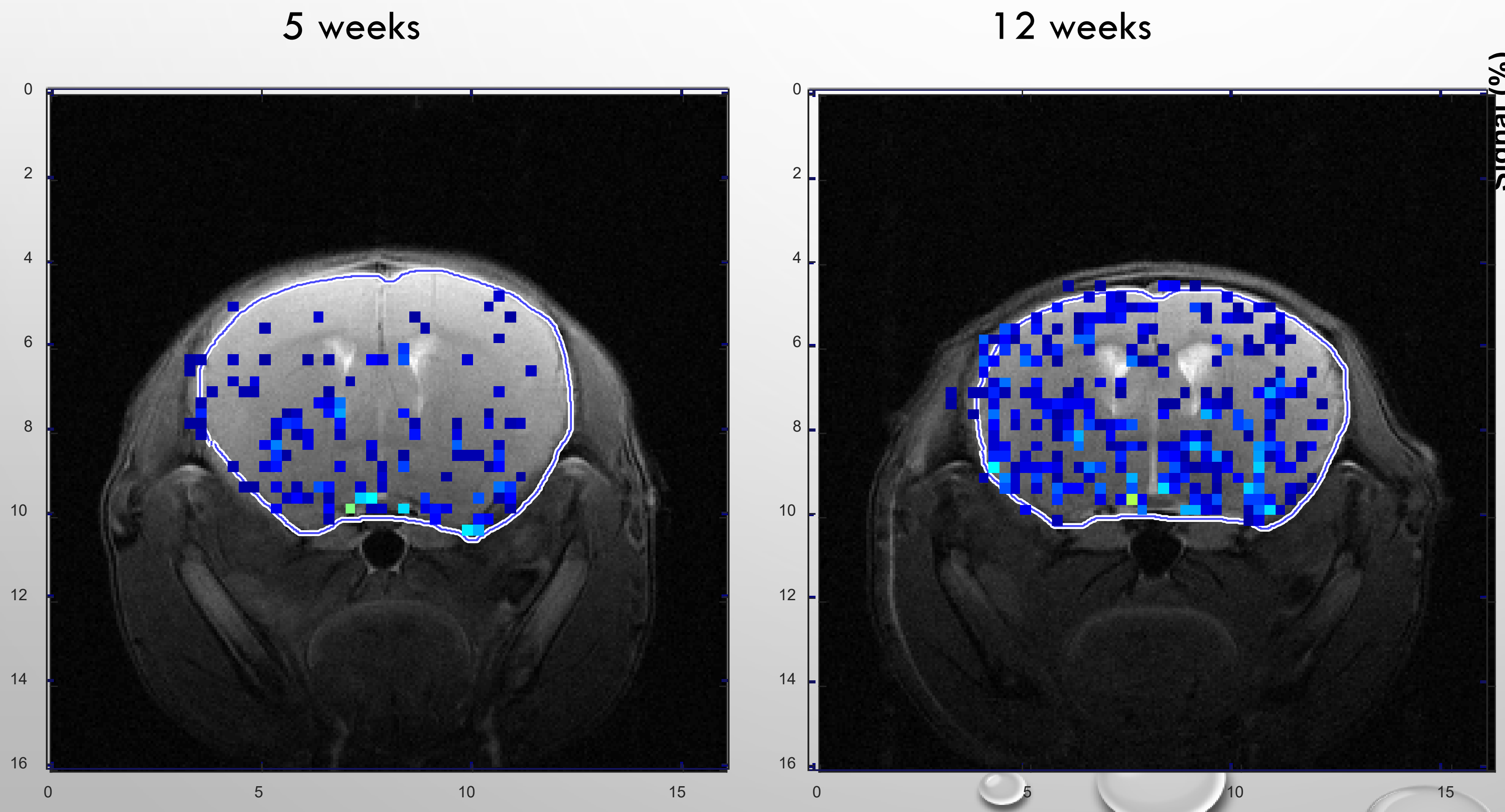
↓

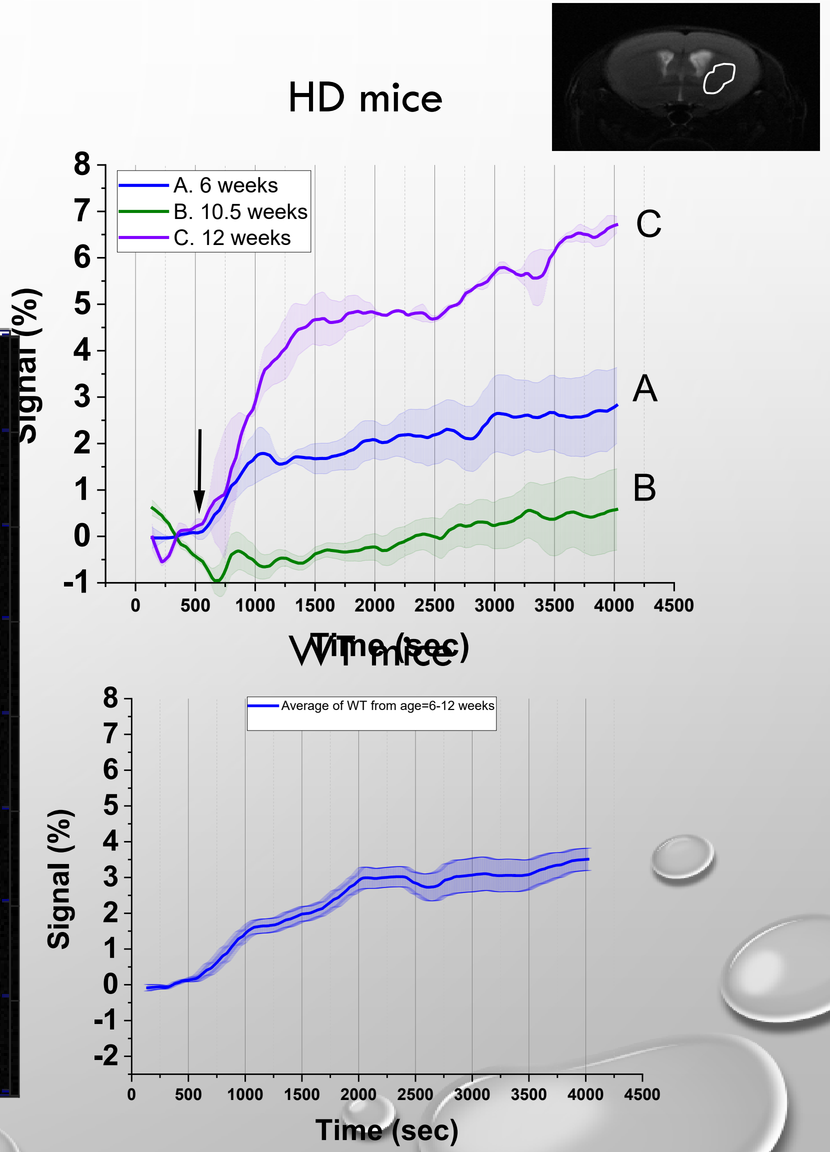
Abnormal or degenerated neuron

Application: Huntington's Disease Mice

Disease Progress

Huntington Disease Mice



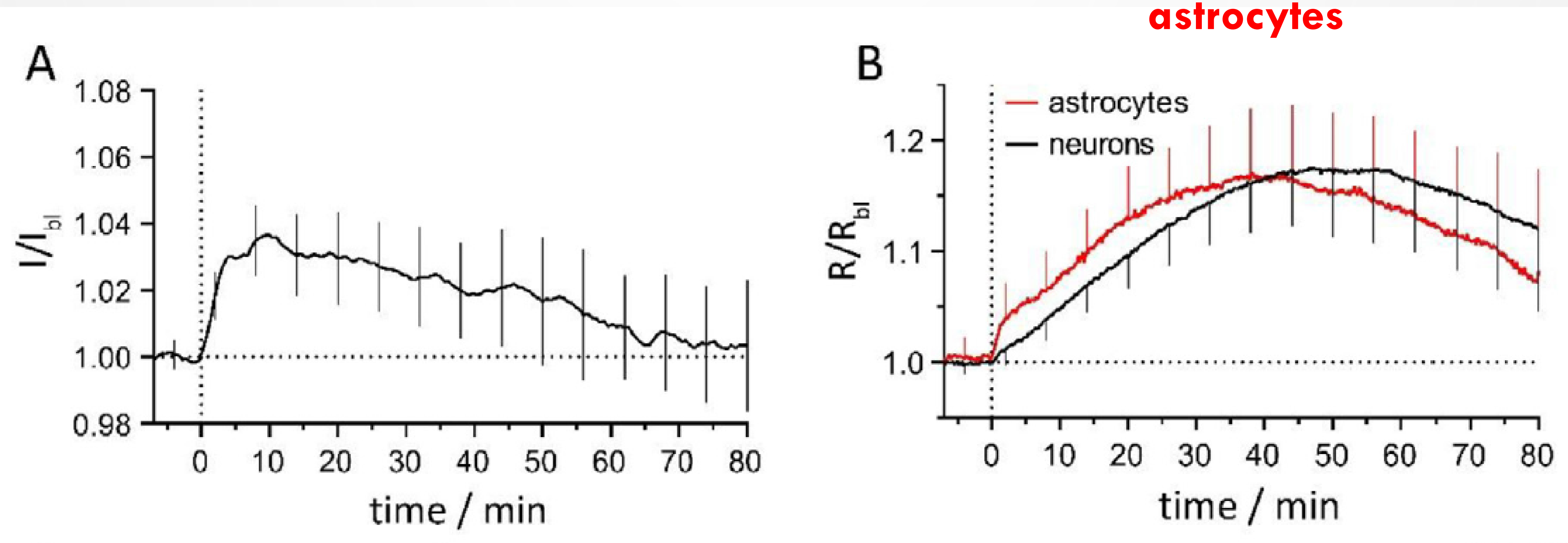


Application: Huntington's Disease Mice

Functional Analysis of HD Mice by DGE

DGE

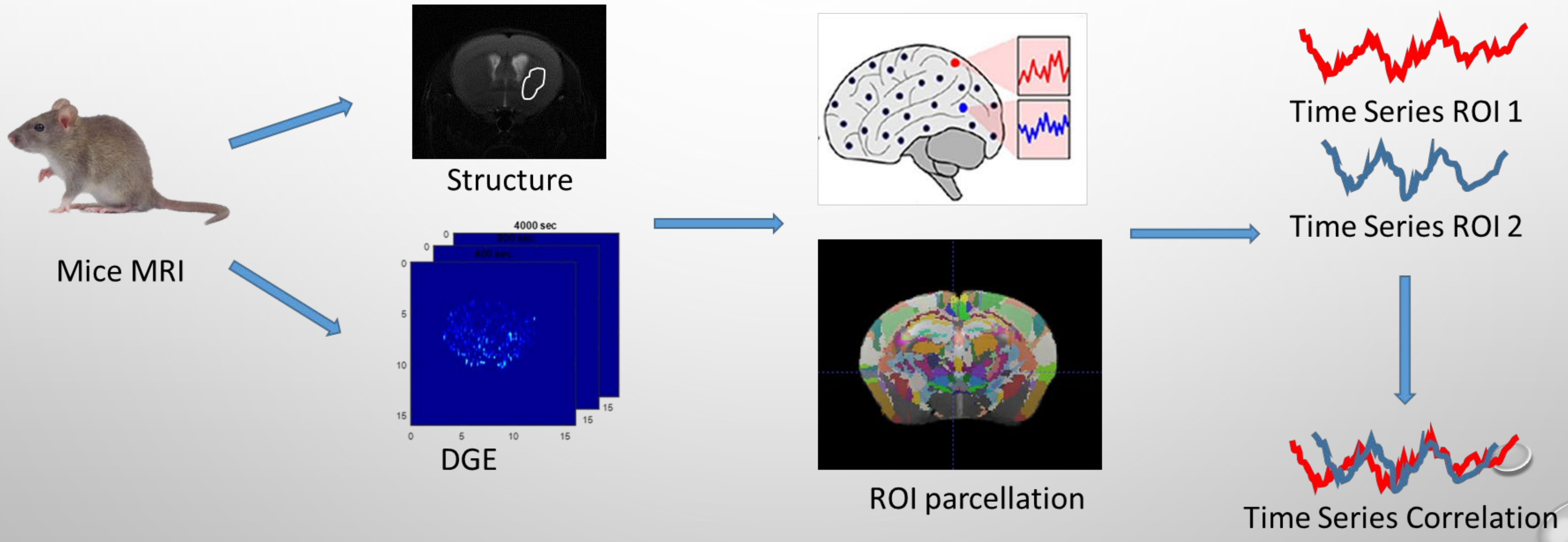
Fiber photometry in neurons and astrocytes



A. Eleftheriou, L. Ravotto, M.T. Wyss et al. NeuroImage 265 (2023) 119762

Application: Huntington's Disease Mice

Functional Analysis of HD Mice by DGE



Connectivity Analysis

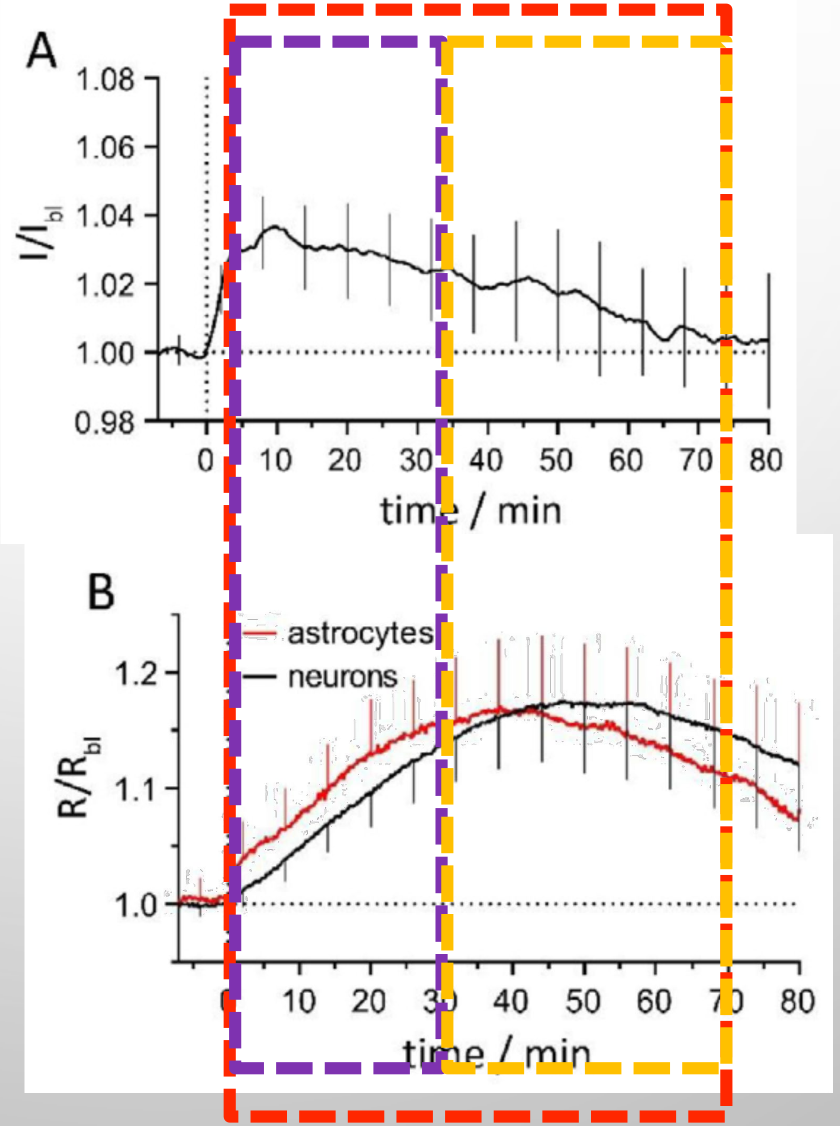
- Pearson Correlation
- Fisher z-transformation (inverse hyperbolic tangent, artanh)
- Two Sample T-Test
- Chosen brain regions: ACA, RSP, S1, S2, M1, M2, Ins, TeA, DG, Ce, CPu, Thalamus
- Data interval:
    - 21-90 mins (from post-glucose injection to end of session)
    - 21-50 mins (from post-glucose injection to 30 mins after injection)
    - 51-90 mins (from 30 mins after injection to end of session

Chuang KH, Lee HL, Li Z, et al. Evaluation of nuisance removal for functional MRI of rodent brain. Neuroimage. 2019;188:694-709. doi:10.1016/j.neuroimage.2018.12.048

Functional Analysis of HD Mice by DGE with Different Time Interval

DGE

Fiber photometry in neurons and astrocytes

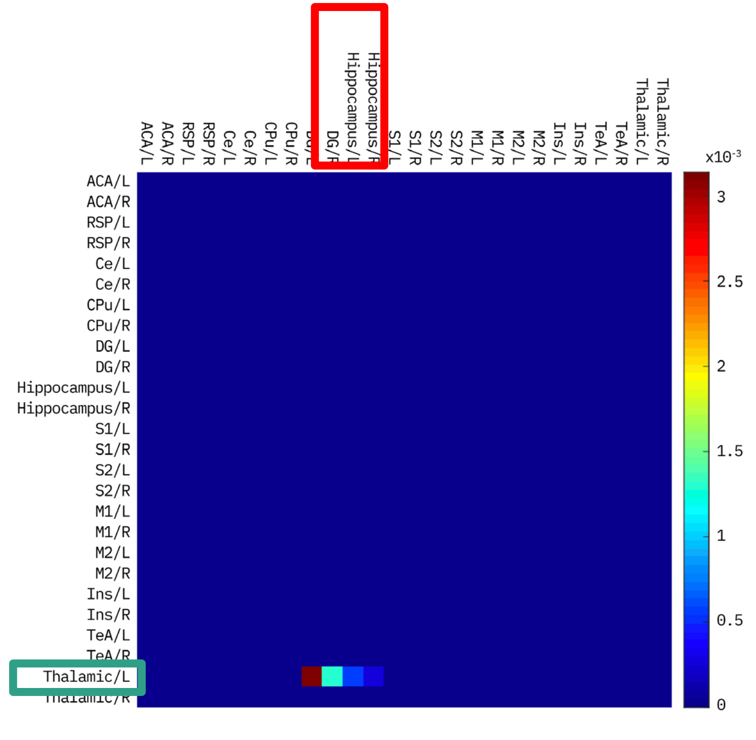


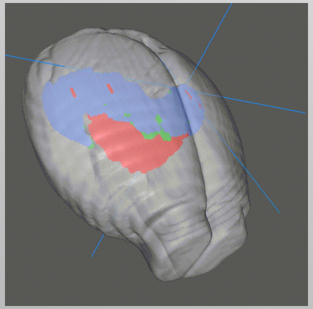
A. Eleftheriou, L. Ravotto, M.T. Wyss et al. NeuroImage 265 (2023) 119762

Application: Huntington's Disease Mice

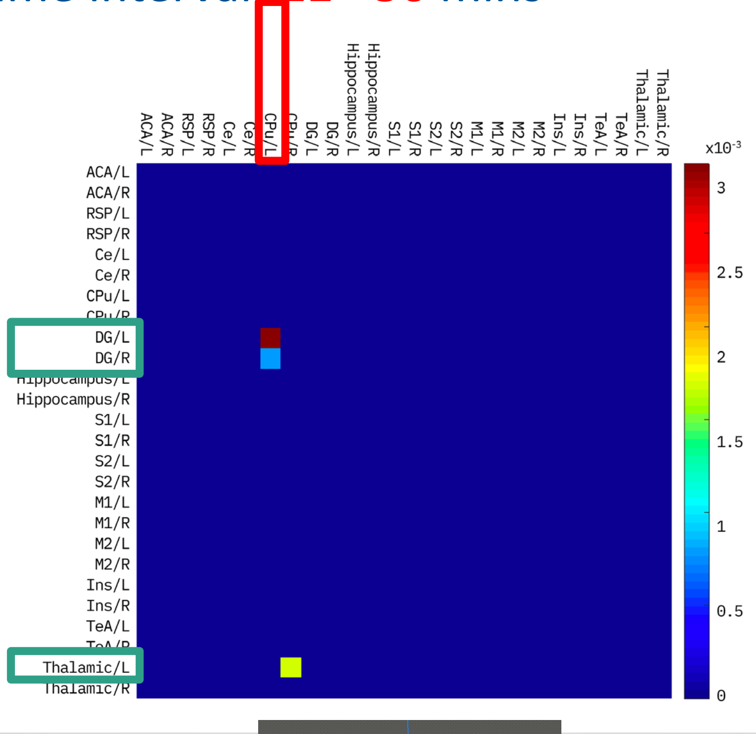
WT (15 m.o.) v.s. zQ175 KI (15 m.o.)

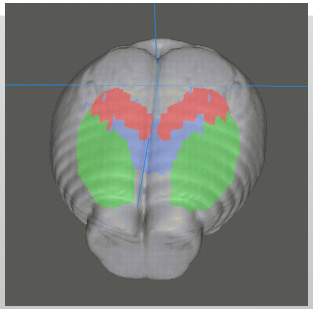
Time interval: **21 - 90** mins



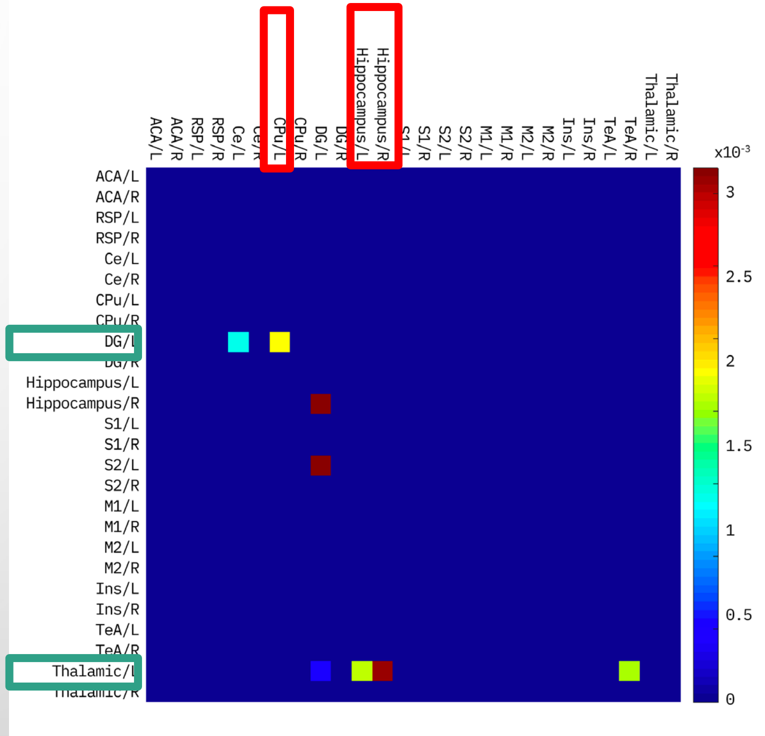


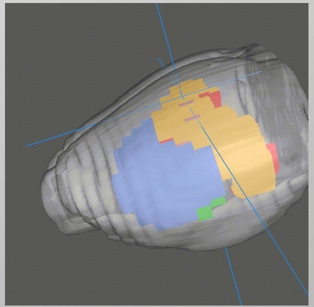
Time interval: **21 - 50** mins





Time interval: **51 - 90** mins

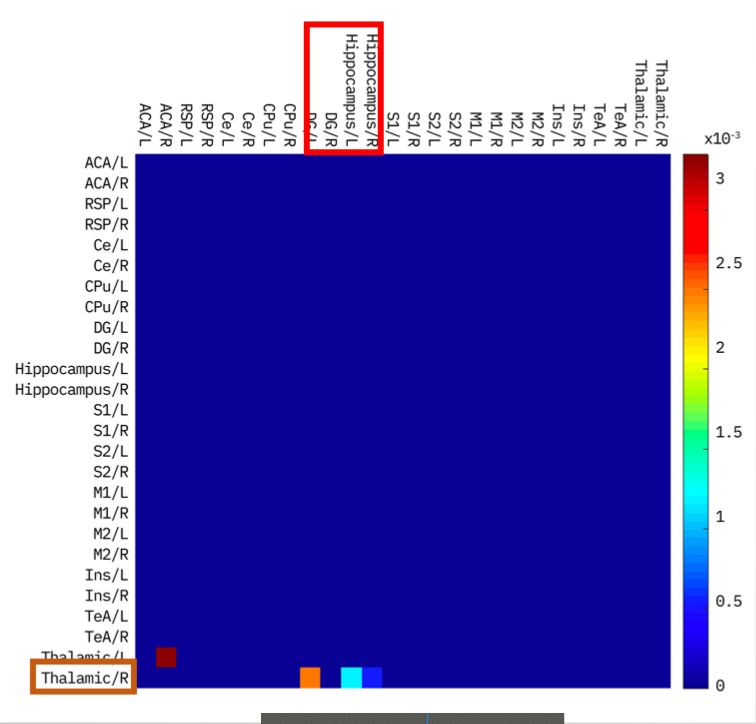


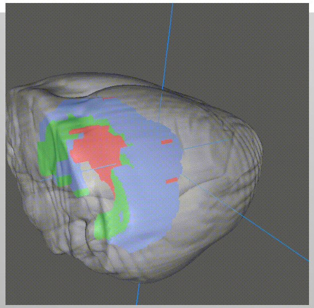


Application: Huntington's Disease Mice

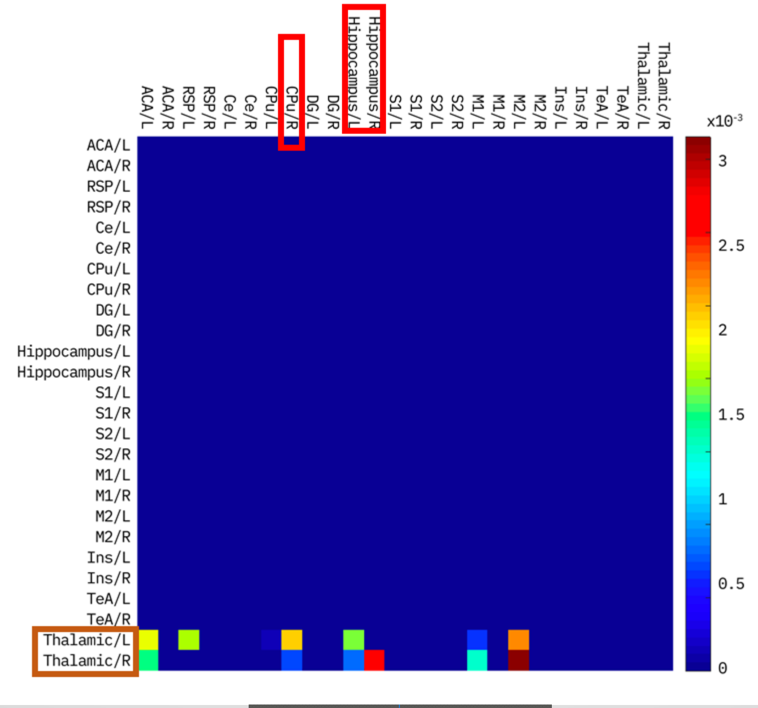
WT (12W) v.s. R6/2 KI (12W)

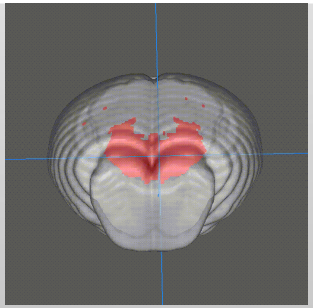
Time interval: **21 - 90** mins



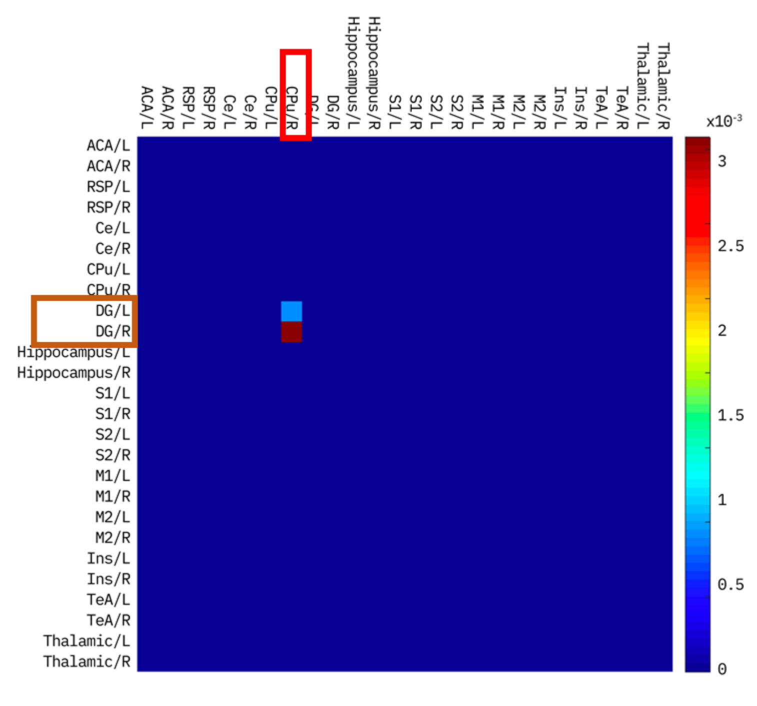


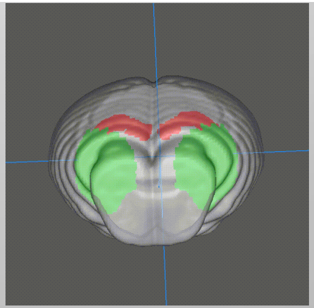
Time interval: **21 - 50** mins





Time interval: **51 - 90** mins





APPLICATIONS

FUNCTIONAL MRI
功能性磁振造影

FUNCTIONAL MRI (FMRI, 功能性磁振造影)

Using MRI to understand the brain's responses to cognition, behavior, and other activities
利用MRI來瞭解有關大腦對於認知、行為等反應的活動區

Applications of fMRI

- Brain tumors.
- Drug abuse.
- Neuropsychiatric diseases.
- Growth and aging.
- ……………………………………

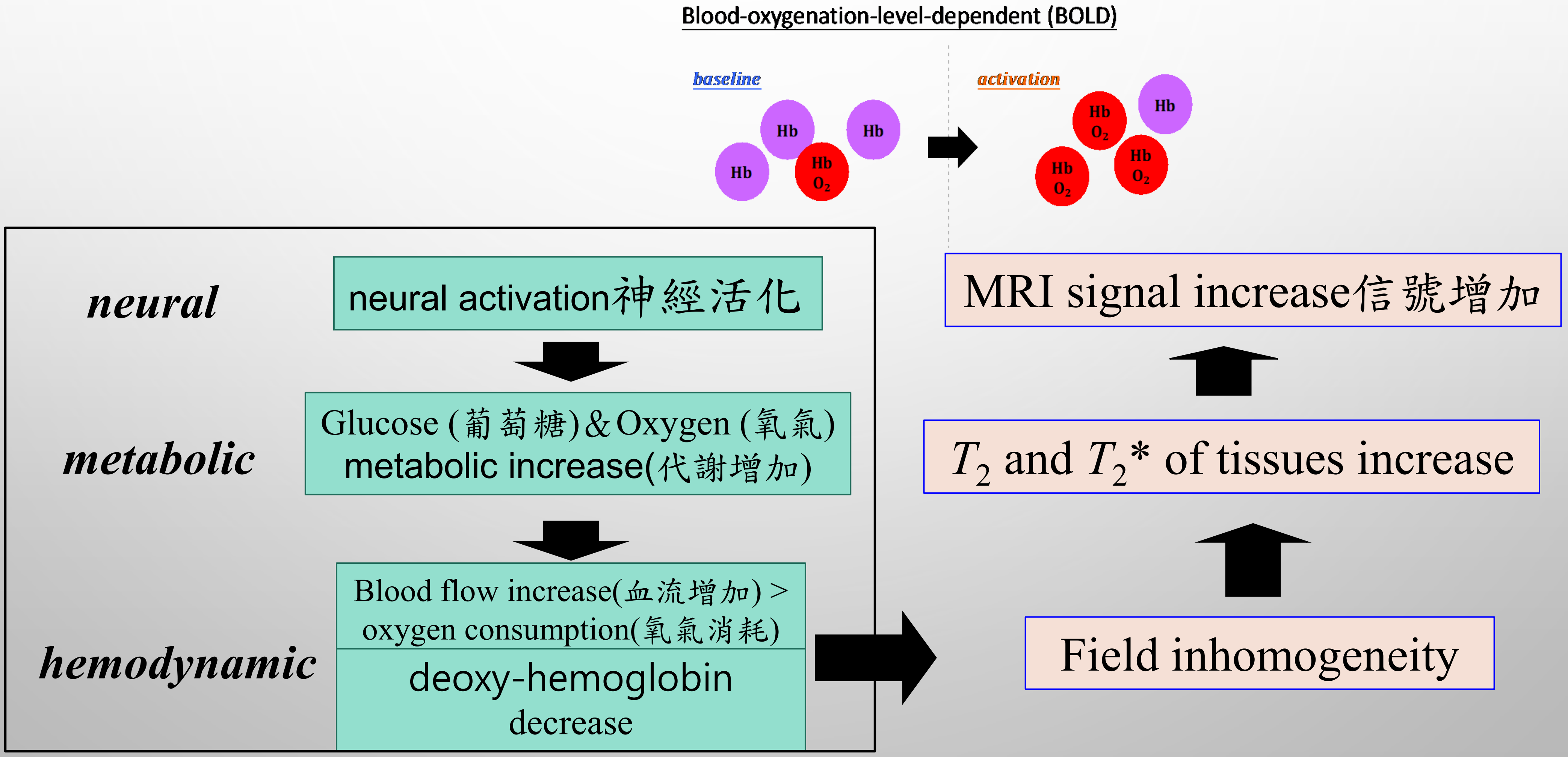
How it works?

By detecting Blood Oxygen Level Dependent (BOLD) contrast images, changes in brain signals are observed.
透過偵測BOLD對比的影像，來觀察大腦訊號變化

BOLD (BLOOD OXYGENATION LEVEL DEPENDENT)

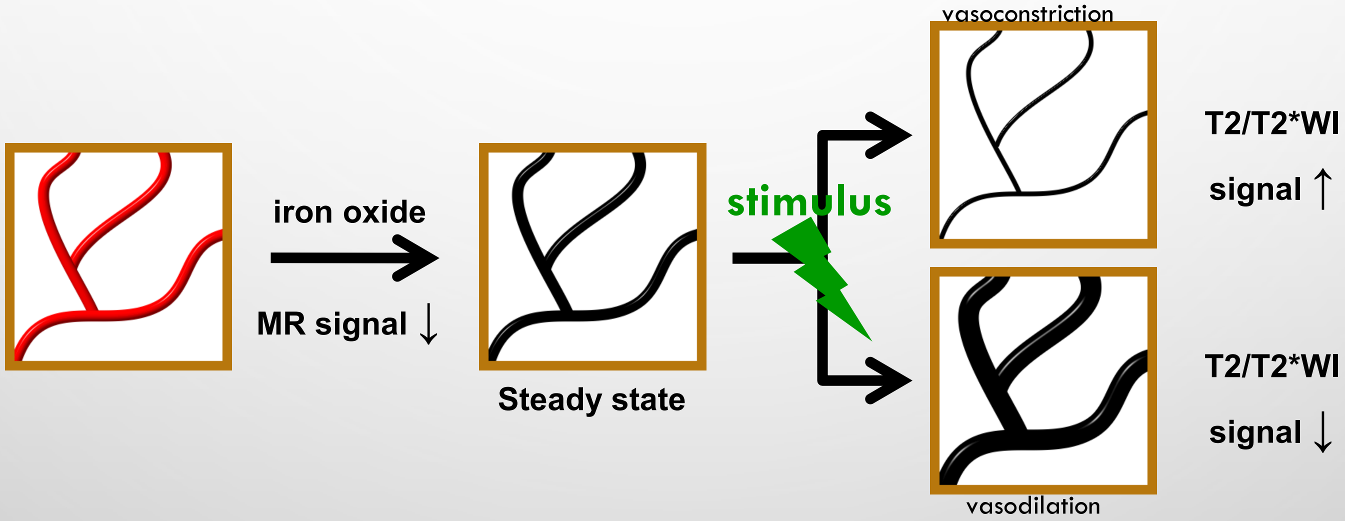
- 帶氧血紅素(OXY-HEMOGLOBIN):抗磁性(DIAMAGNETISM)
- 去氧血紅素(DEOXY-HEMOGLOBIN):順磁性 (PARAMAGNETISM)

造成局部磁場不均勻
(Cause local magnet field inhomogeneity)

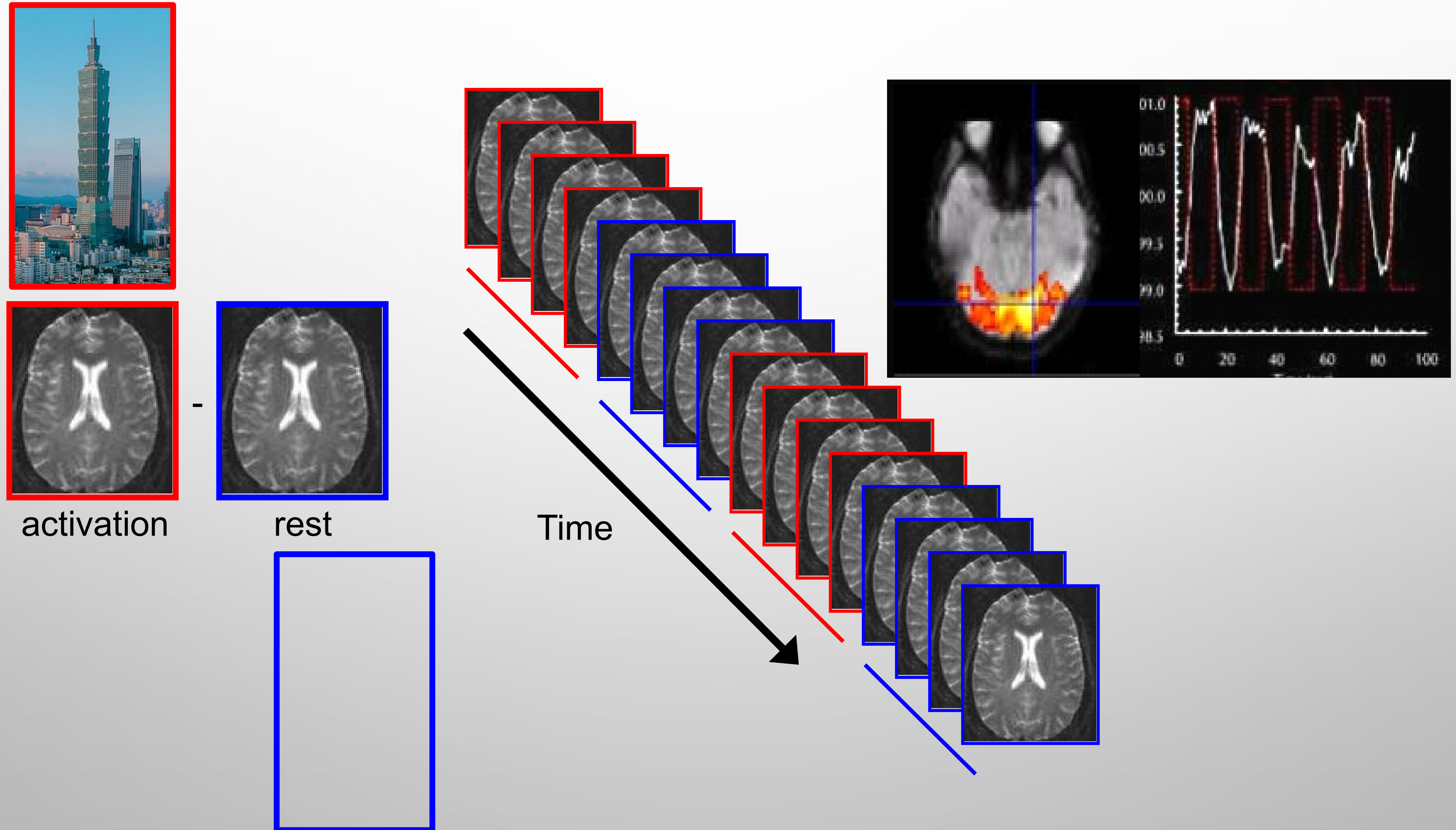


What is Cerebral Blood Volume fMRI?

> Application of contrast agent (iron oxide particles, T2/T2* shortening), providing better image contrast.

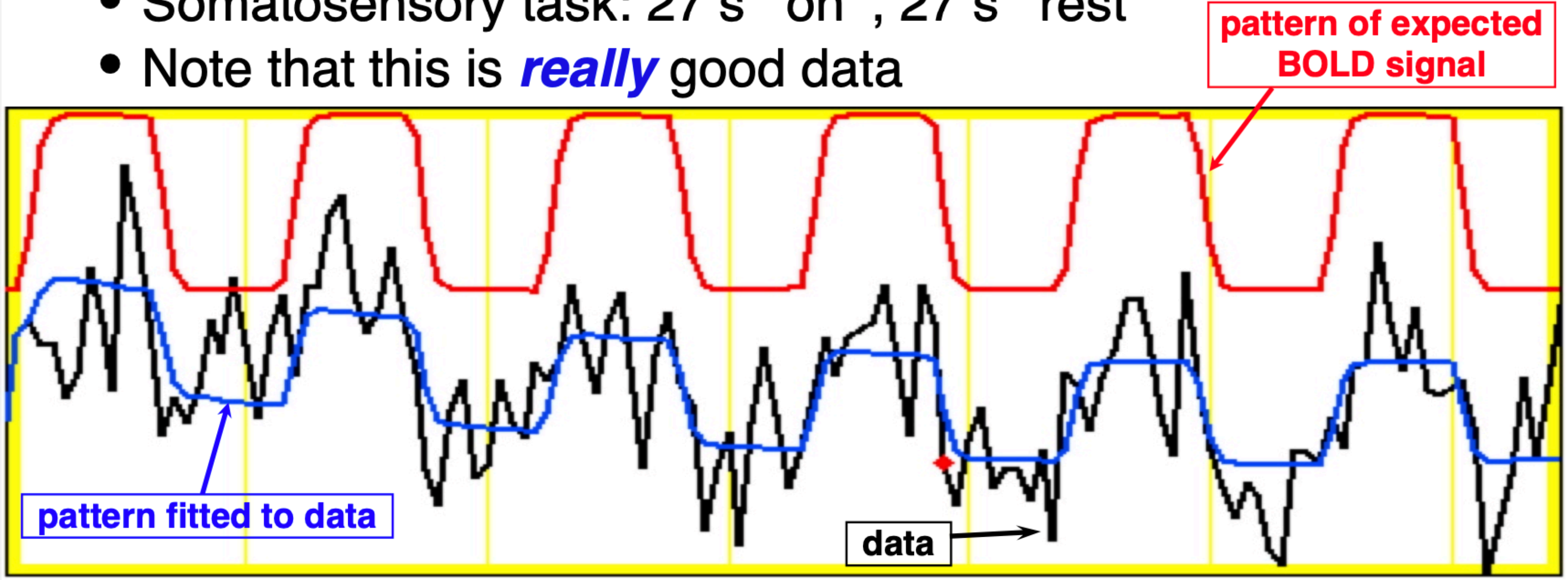


FUNCTIONAL MRI (FMRI, 功能性磁振造影)



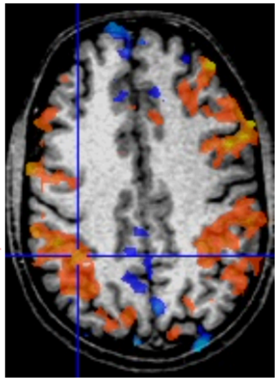
Sample Data Time Series

- 64 × 64 matrix (TR=2.5 s; 130 time points per imaging run)
- Somatosensory task: 27 s "on", 27 s "rest"
- Note that this is ***really*** good data



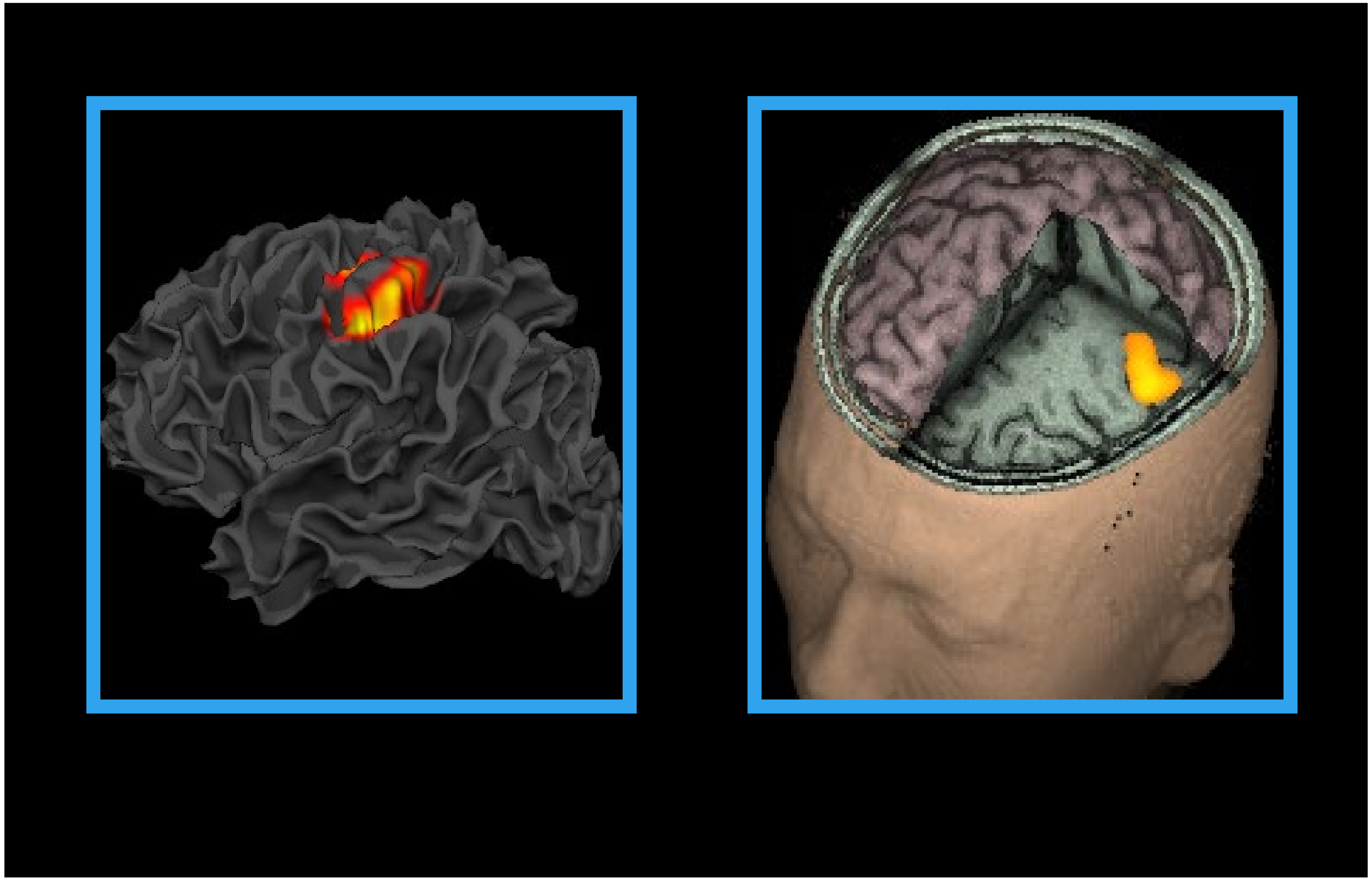
One echo-planar image

One anatomical image, with voxels that match the pattern given a color overlay



https://afni.nimh.nih.gov/class_handouts

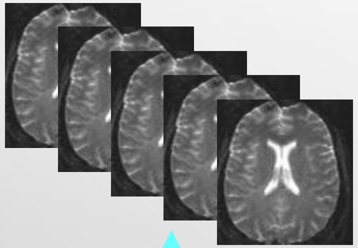
RIGHT FINGER TAPPING



Preprocessing

Motion correction

Normalization



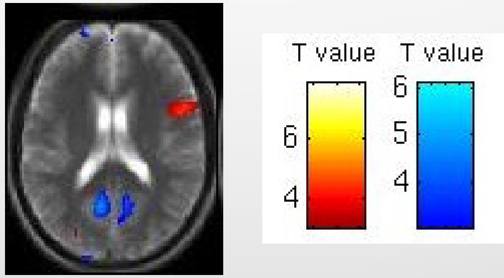
Group analysis

Statistical analysis

資料分析

Model-based / Model-free

Statistical analysis



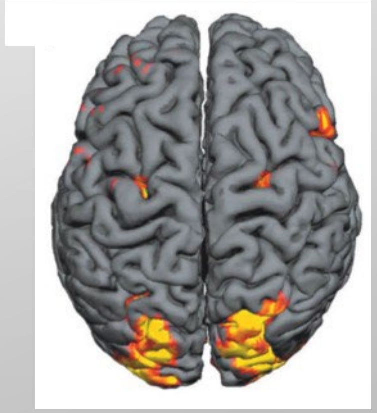
2nd level analysis

Visualization

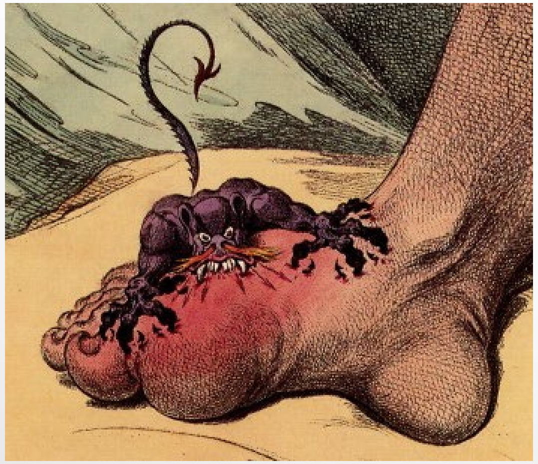
Co-registration with anatomy

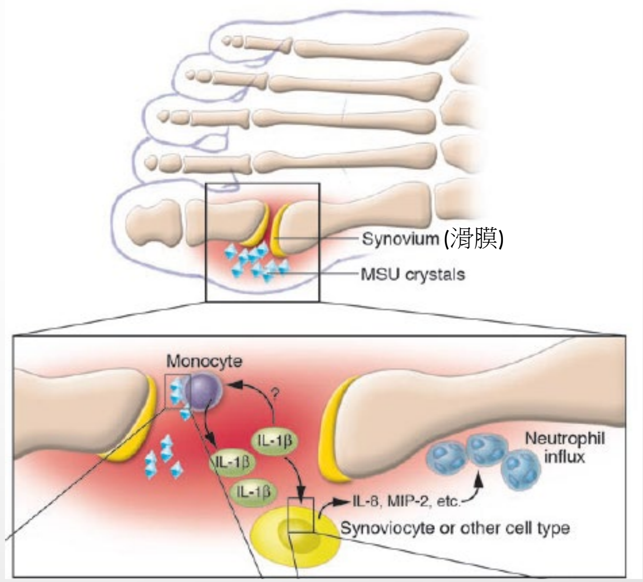
Talairach coordinate

2D or 3D Rendering



What is "Gout"? 痛風





> Gout is one of the most painful acute conditions that human can experience.

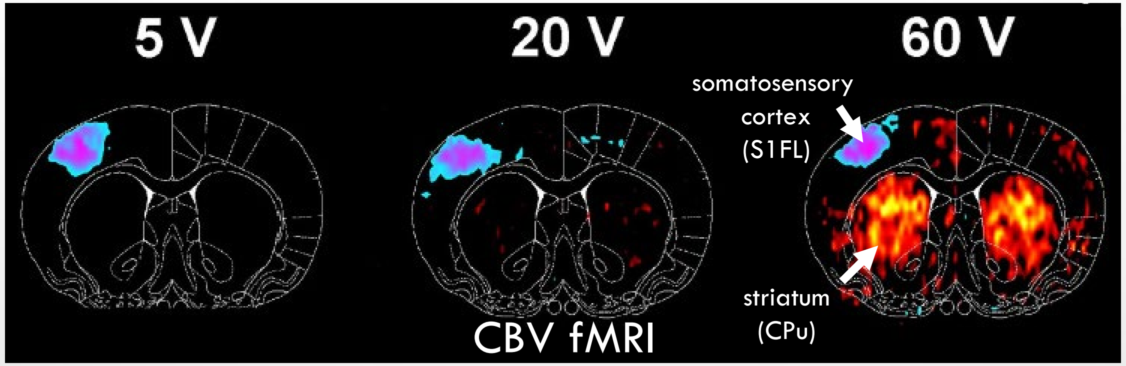
> Gout is initiated with the deposition of monosodium urate (MSU) crystals in joints and periarticular tissues.

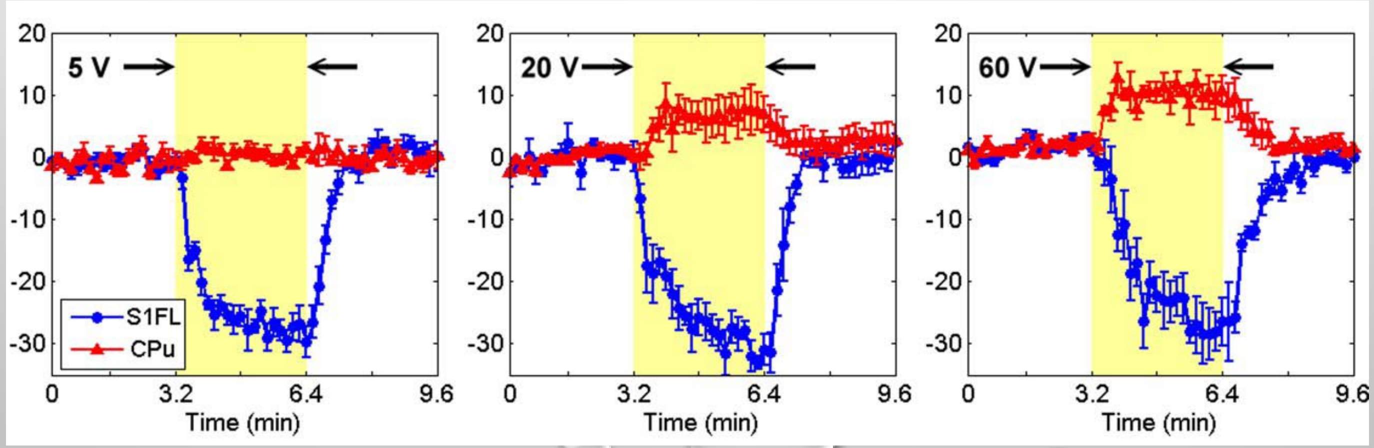
> MSU crystals activate the immune system to drive inflammation.

Martinon F, Glimcher LH. (2006) Gout: new insights into an old disease. *J Clin Invest.* 116:2073.

Electrical stimulation induced CBV changes

electrical stimulation on the rat forepaw





Shih YY. et al. (2009) A new scenario for negative functional magnetic resonance imaging signals: endogenous neurotransmission.
J Neurosci. 29:3036.

Experiment design

MSU injection (1.2 mg / 50uL / left wrist)
Behavioral observation: Gait, Swelling
Behavioral observation: Gait, Swelling
Killed for other analyses

CBV fMRI (3 hr)
CBV fMRI (24 hr)

Tues. 9:30 (12:30)
Tues. 12:30 (15:30)
Tues. 15:30 (18:30)
Wed. 9:30 (12:30)
Wed. 12:30 (15:30)

< 4.7 T scanner>
TR / TE = 150 ms / 15 ms
Angle = 22.5'
NEX = 1
FOV / Matrix = 2.56 cm / 128x64 → 128x128
Slice number / thickness = 5 / 1.5 mm
Repetition = 60

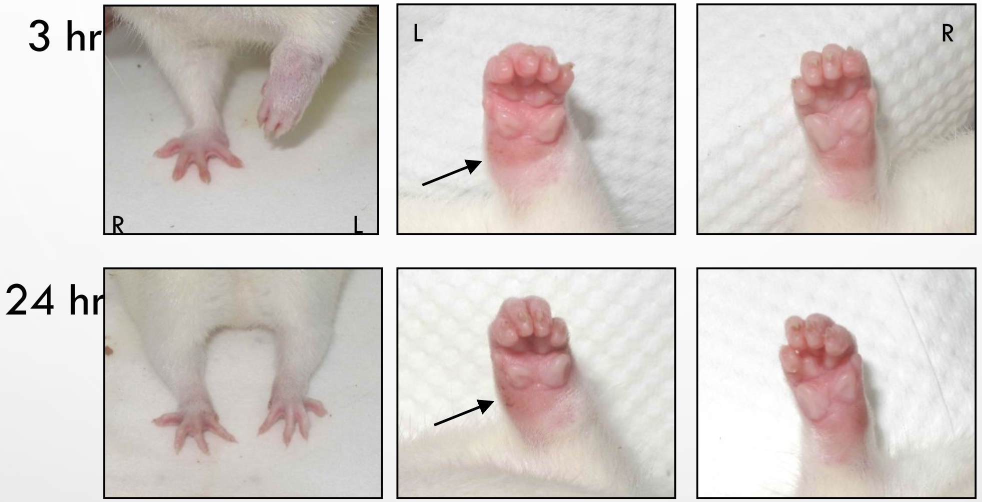
3 mA   3 mA

normal right leg (as control)

→ MSU-injected left leg

1. Histological analysis
a. H&E
b. IHC ...... COX-2, iNOS, IL-1beta, CD45, CD68

Representative behavioral observation

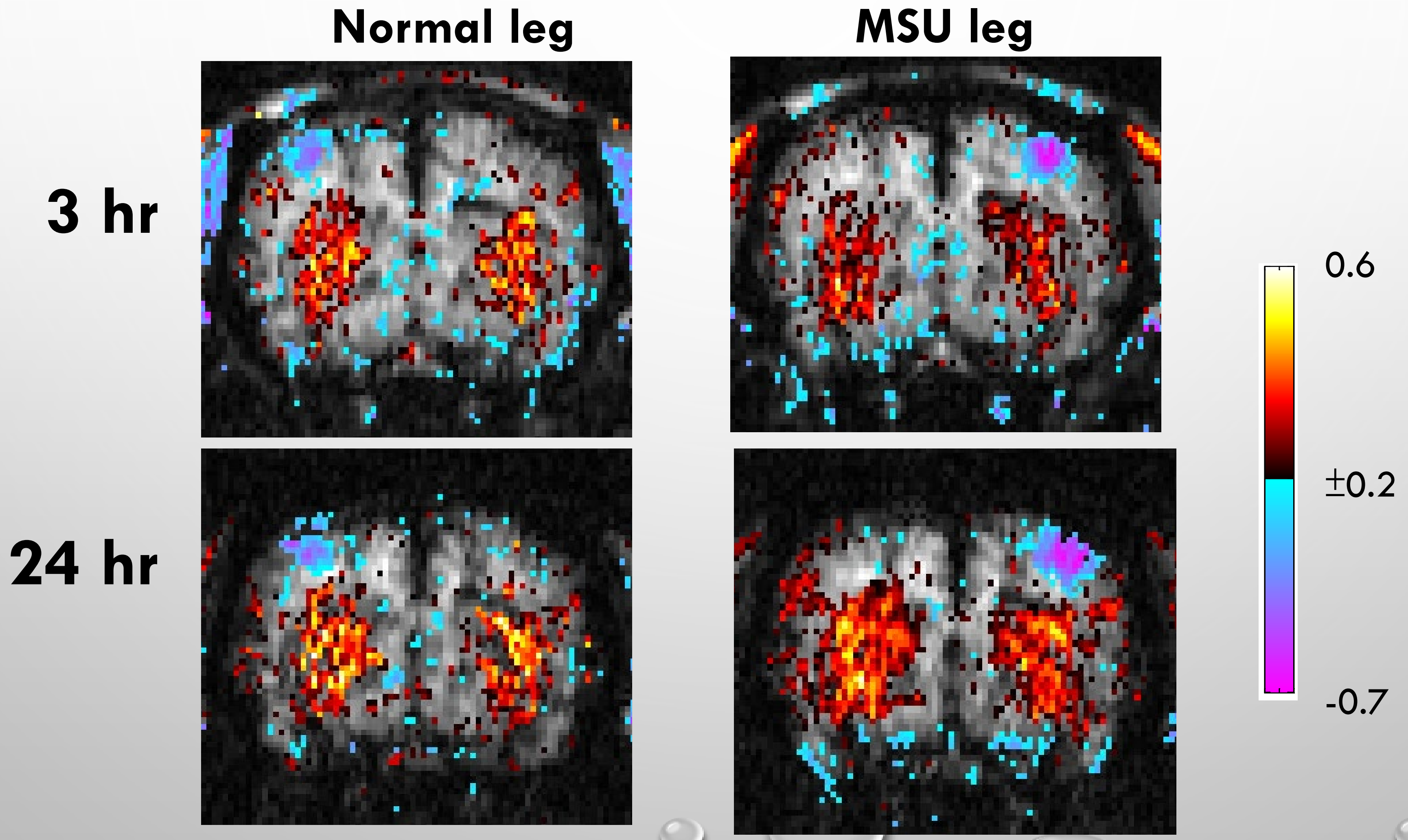


Position	Condition	
Standing	S0	Normal
	S1	Complete touch of foot pads with closed fingers
	S2	Partial touch of foot pads
	S3	One foot stand
Walking	W0	Normal
	W1	Slight limping
	W2	Severe limping
	W3	One foot gait

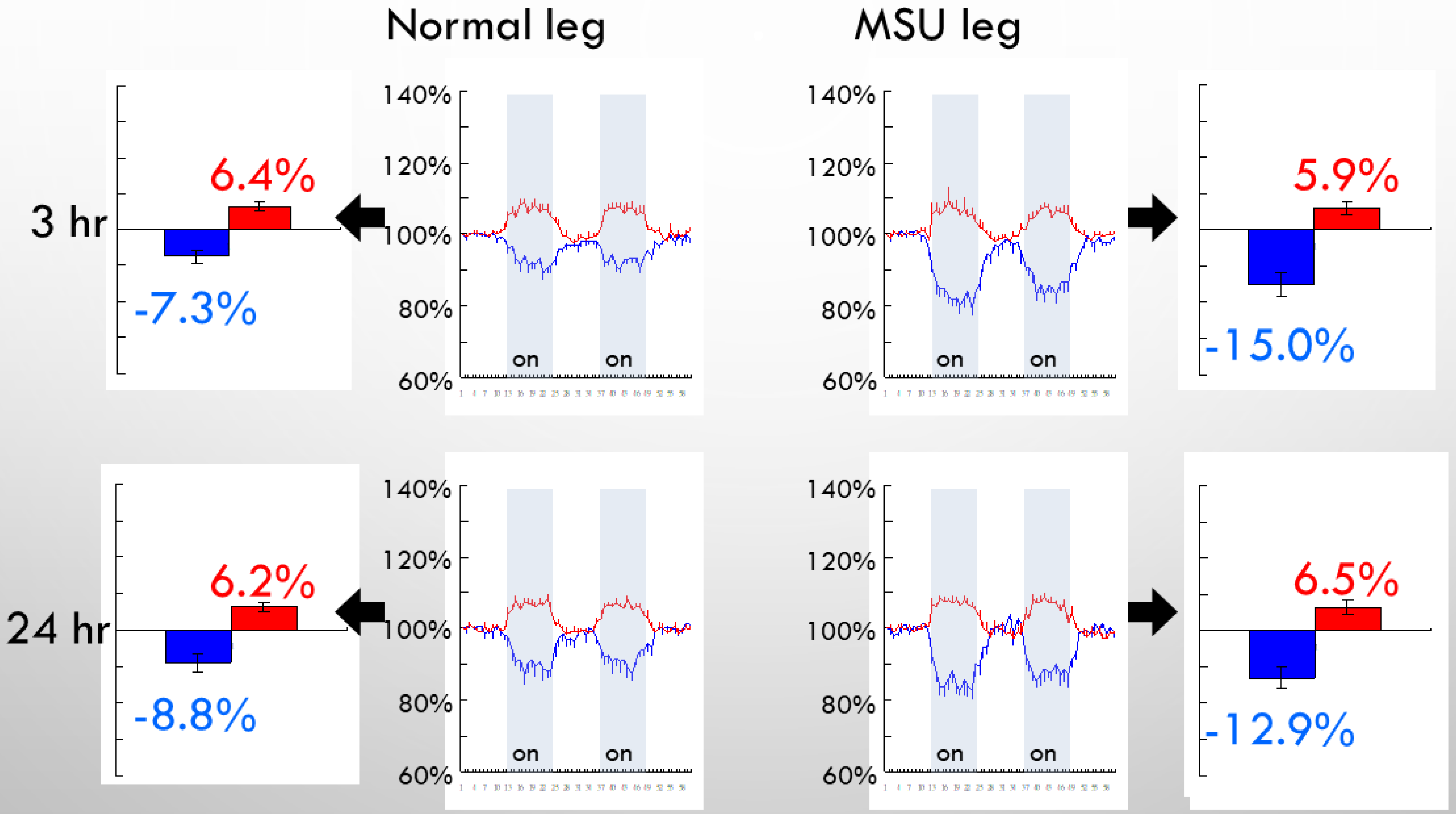
Brain Research, 365 (1986) 235–240

	standing	**walking**	**Swelling**
	3hr→24hr	3hr→24hr	3hr→24hr
No1	3→0	3→1	O→O
No2	3→0	3→1	O→O
No3	3→0	3→1	O→O
No4	3→0	3→0	O→X
No5	3→0	3→0	O→O
No6	3→0	3→0	O→X

Representative CBV-weighted fMRI (3-1)



Representative CBV-weighted fMRI (3-2)



averaged (n=6)

IN ADDITION TO TASK-GIVEN/STIMULATED TASK-FMRI
除了給予任務/刺激的TASK-FMRI以外…

還有一種是BASELINE狀態下的FMRI：

RESTING STATE FUNCTIONAL MRI
靜息態功能性磁振造影

- BRAIN IS ALWAYS WORKING EVEN DURING REST

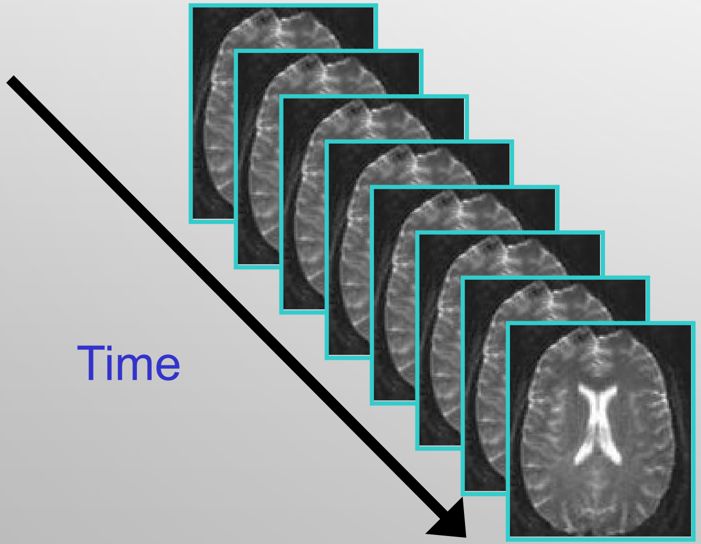
→ RESTING STATE ACTIVITY (SPONTANEOUS LOW FREQUENCY FLUCTUATIONS)

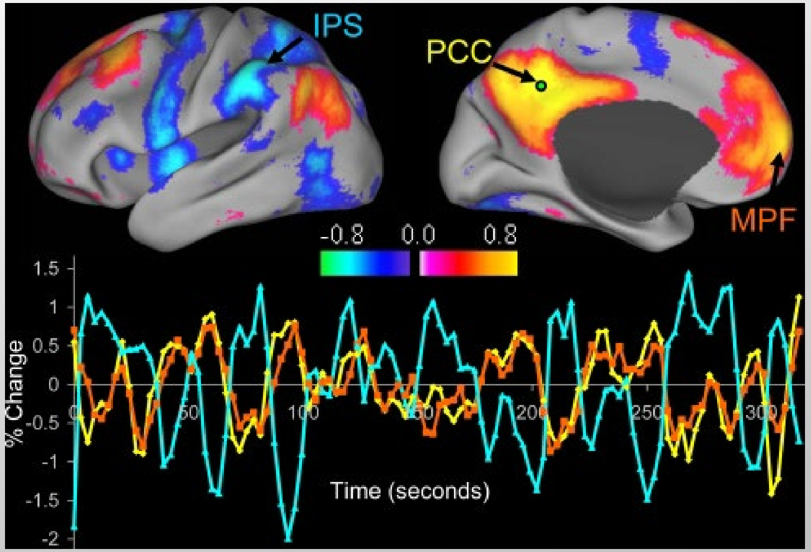
→ READY TO RESPONSE TO ANY INTERNAL OR EXTERNAL CHANGES

→ ENERGY CONSUMING !

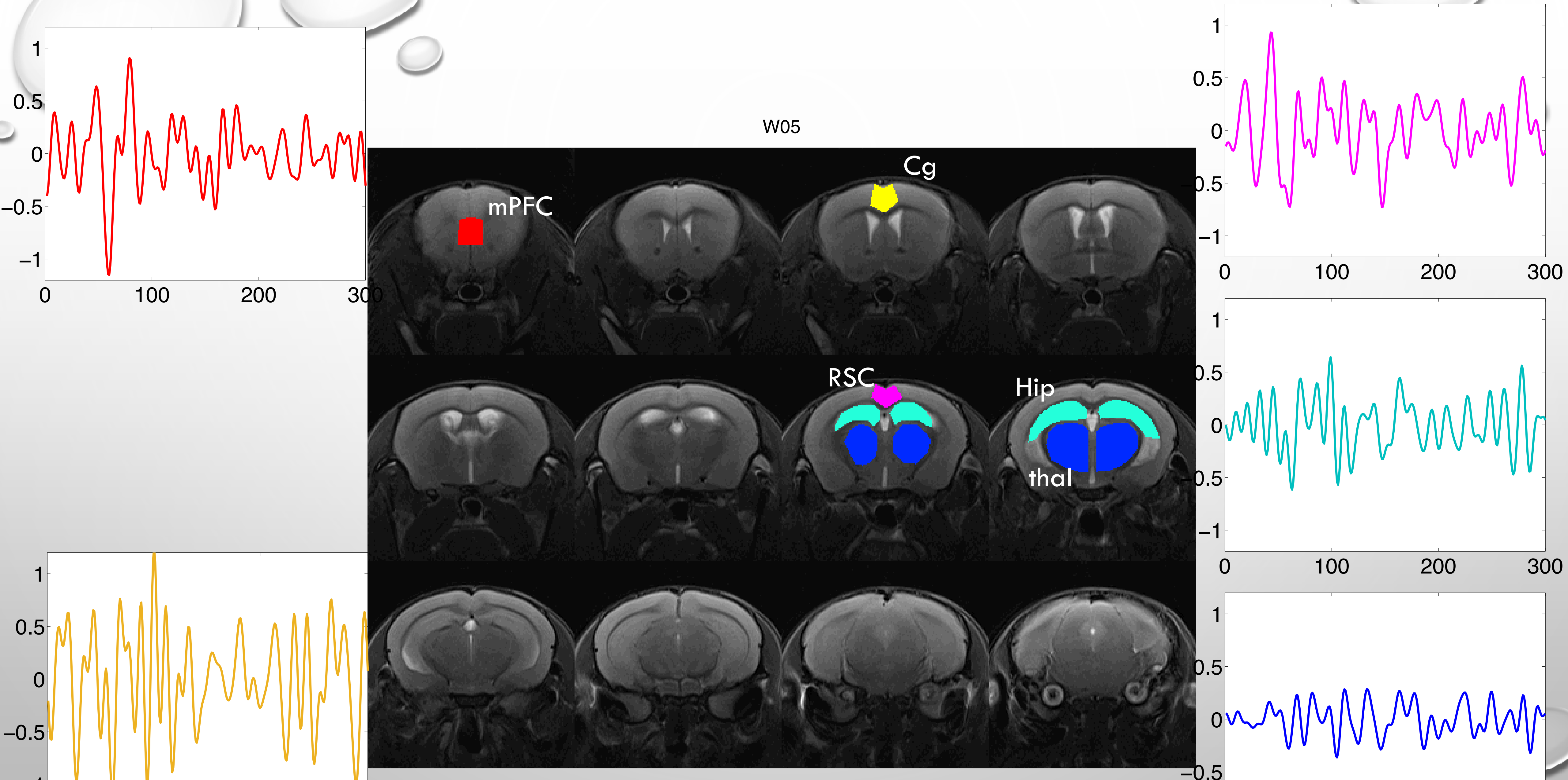
靜息態大腦功能性磁振造影(RESTING STATE FUNCTIONAL MRI)

- 量測原理: 一樣透過血氧濃度相依對比(BOLD CONTRAST)，分析與判斷各個腦區之間的基頻運作連結程度 (E.G. 相關性)。
- 分析目標: 低頻訊號 (LOW FREQUENCY FLUCTUATIONS) (< 0.1 HZ)





Fox MD and Greicius M. *Front Syst Neurosci*. 2010;4:19



mPFC: medial prefrontal cortex **Hip:** hippocampus

Cg: cingulate cortex **thal:** thalamus

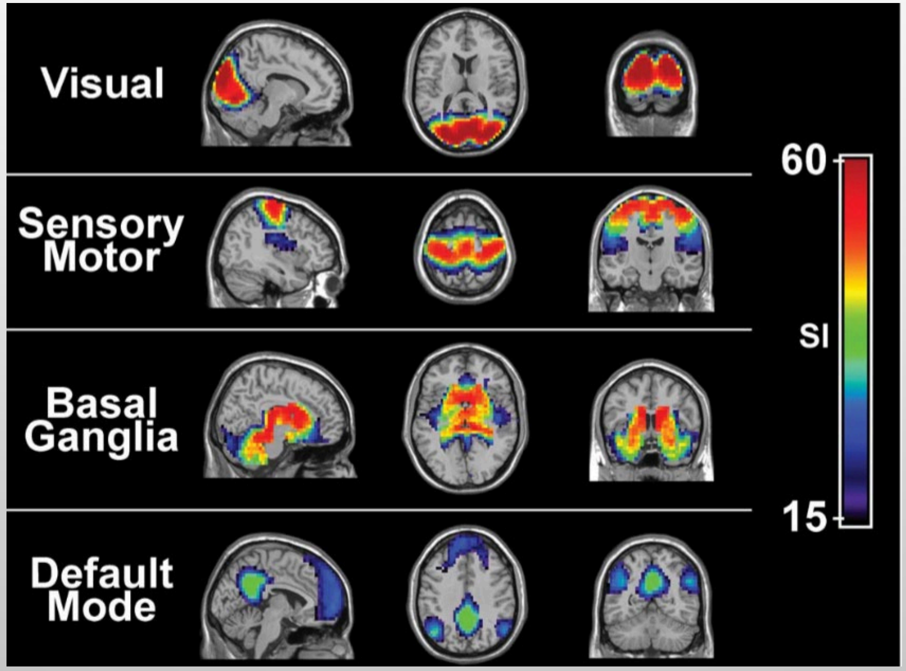
RSC: retrosplenial cortex

RESTING STATE FUNCTIONAL MRI

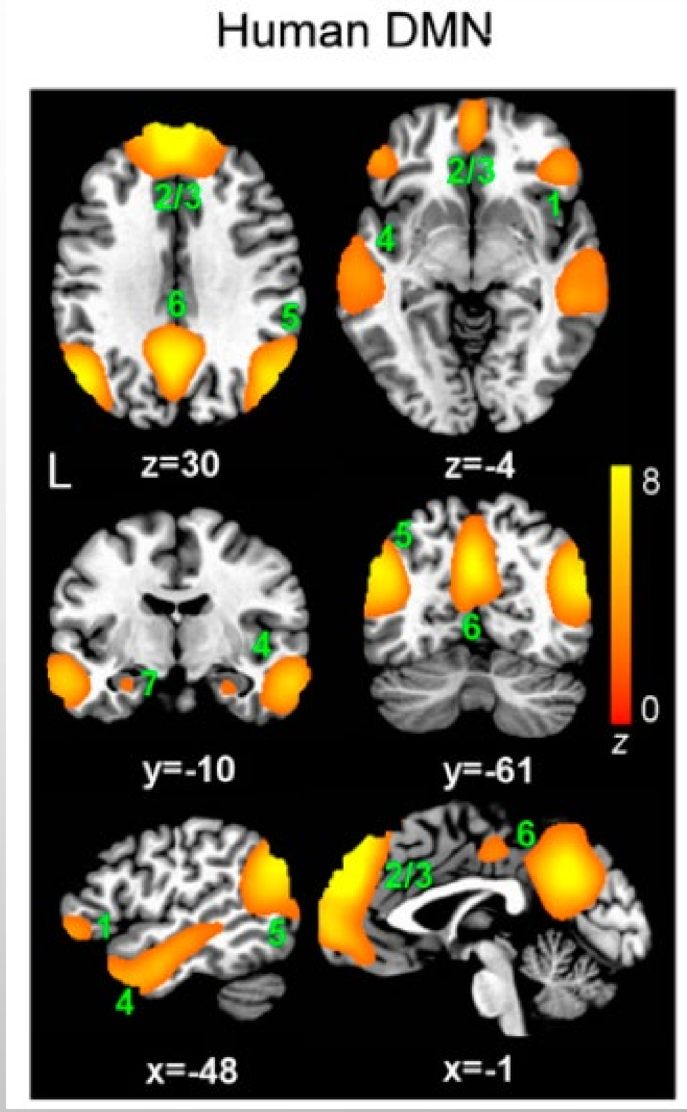
- RESTING STATE NETWORKS
  - DEFAULT MODE NETWORKS
  - SENSORY/MOTOR
  - VISUAL
  - BASAL GANGLIA
  - SALIENCE
  - ATTENTION

  ……

  …

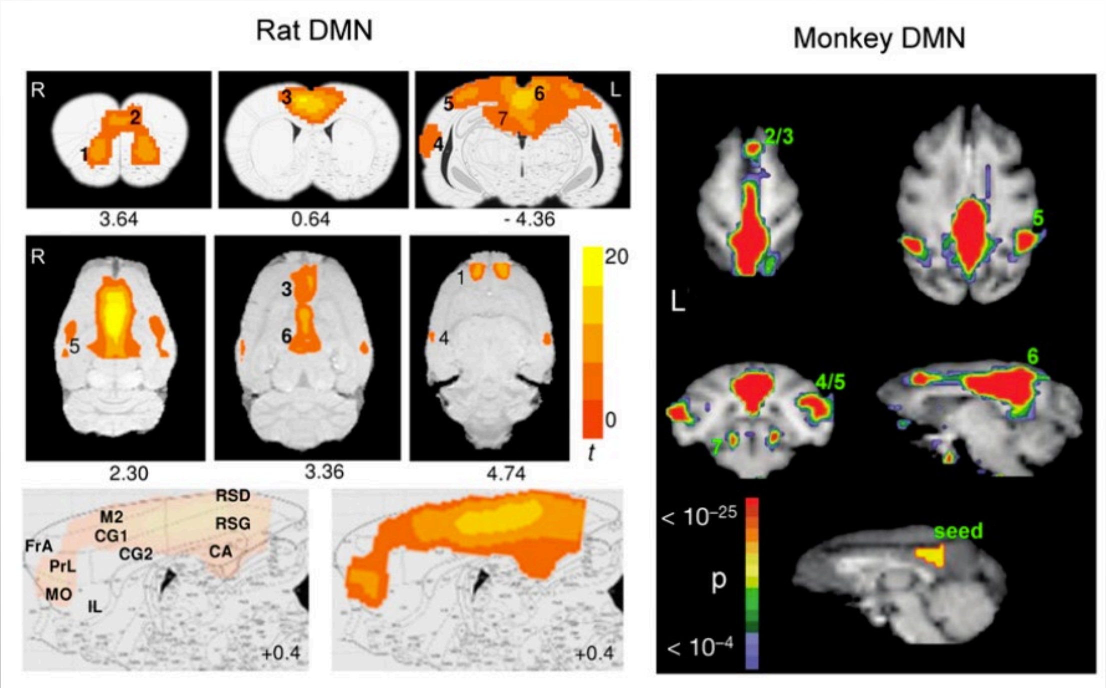


Moussa MN et al., (2012) PLoS ONE 7(8): e44428

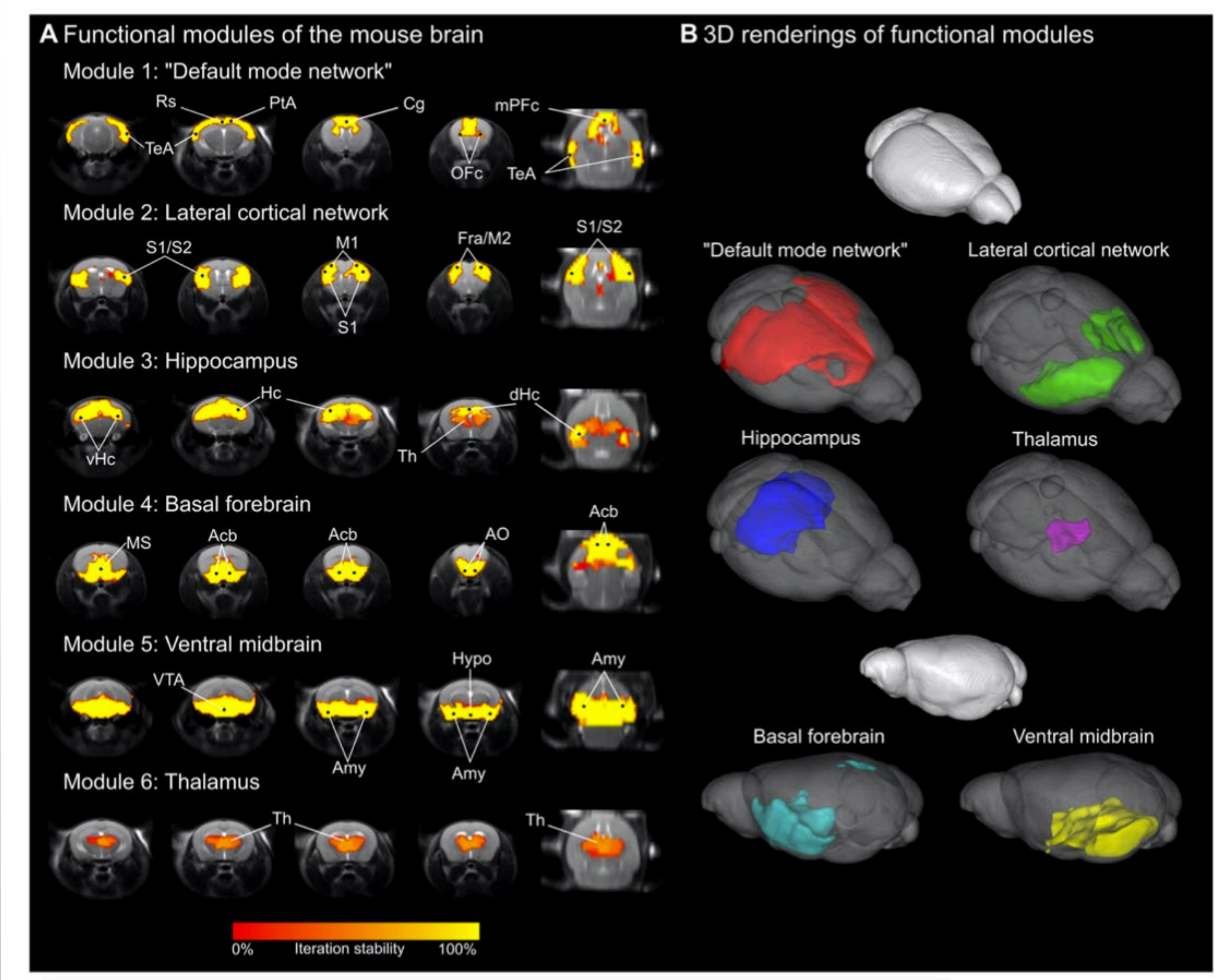


Lu H et al. (2012) PNAS USA 109(10):3979-3984

RESTING STATE FU

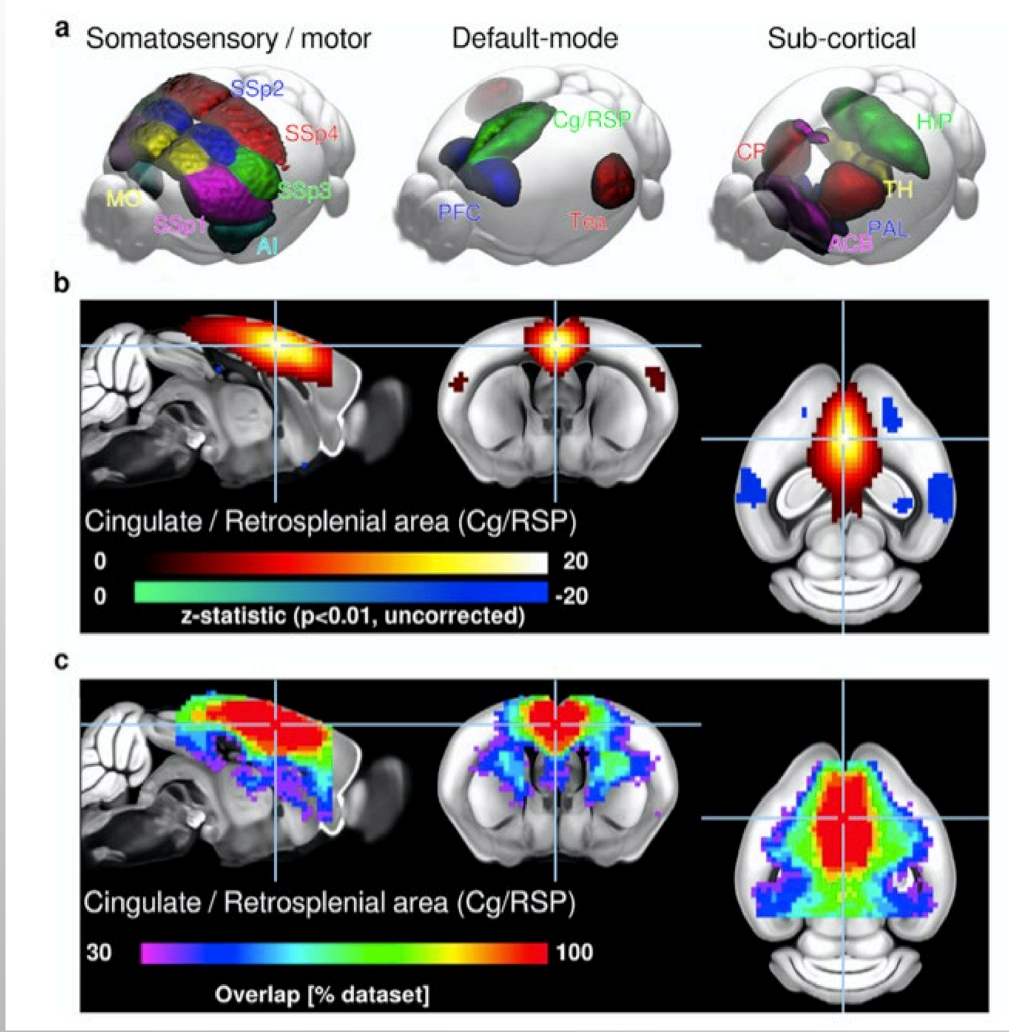


Lu H et al. (2012) PNAS USA 109(10):3979-3984

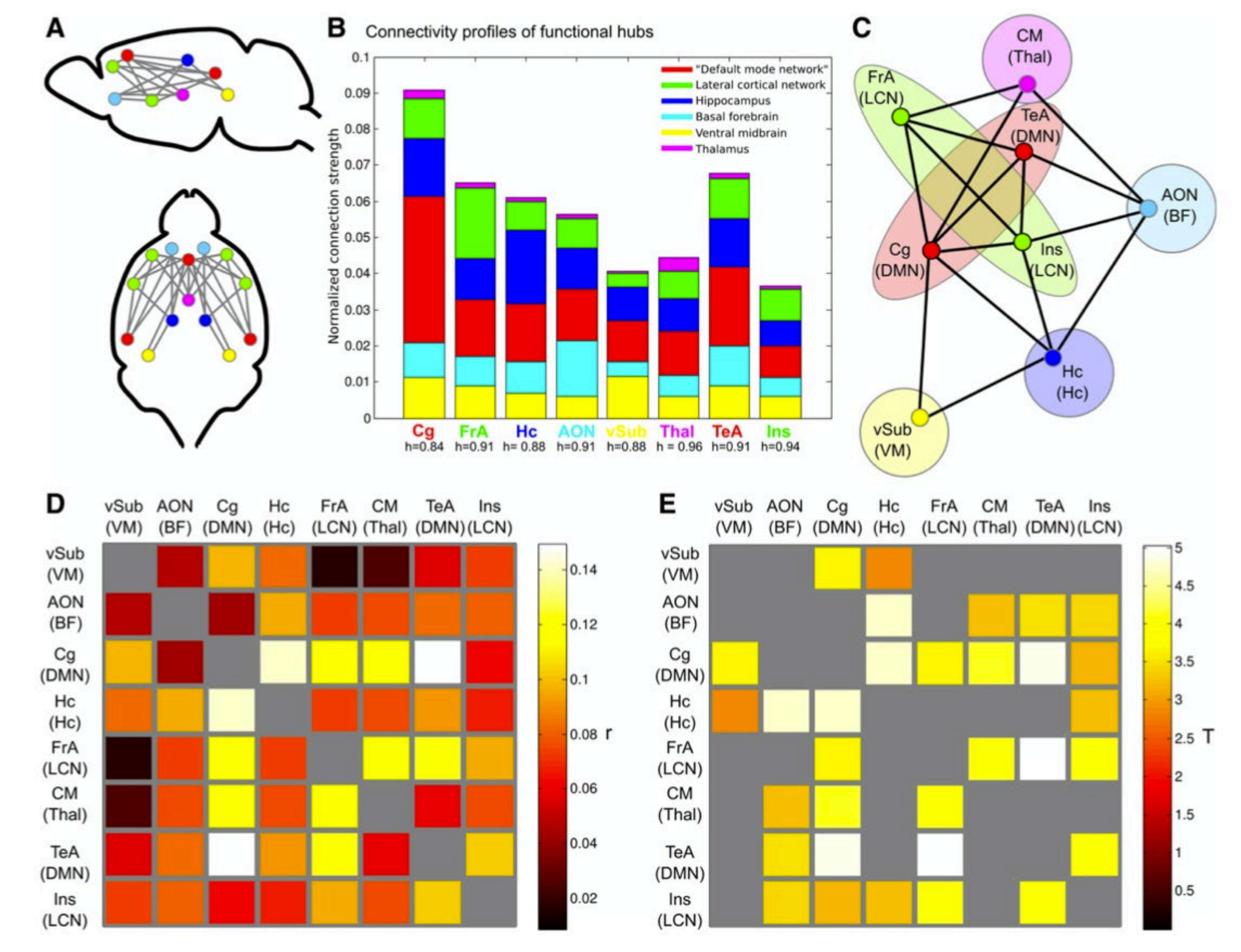


Liska A et al. (2015) NeuroImage 115:281–291

RESTING STATE FUNCTIONAL MRI (ANIMALS)



Grandjean J et al. (2020) NeuroImage 205:116278

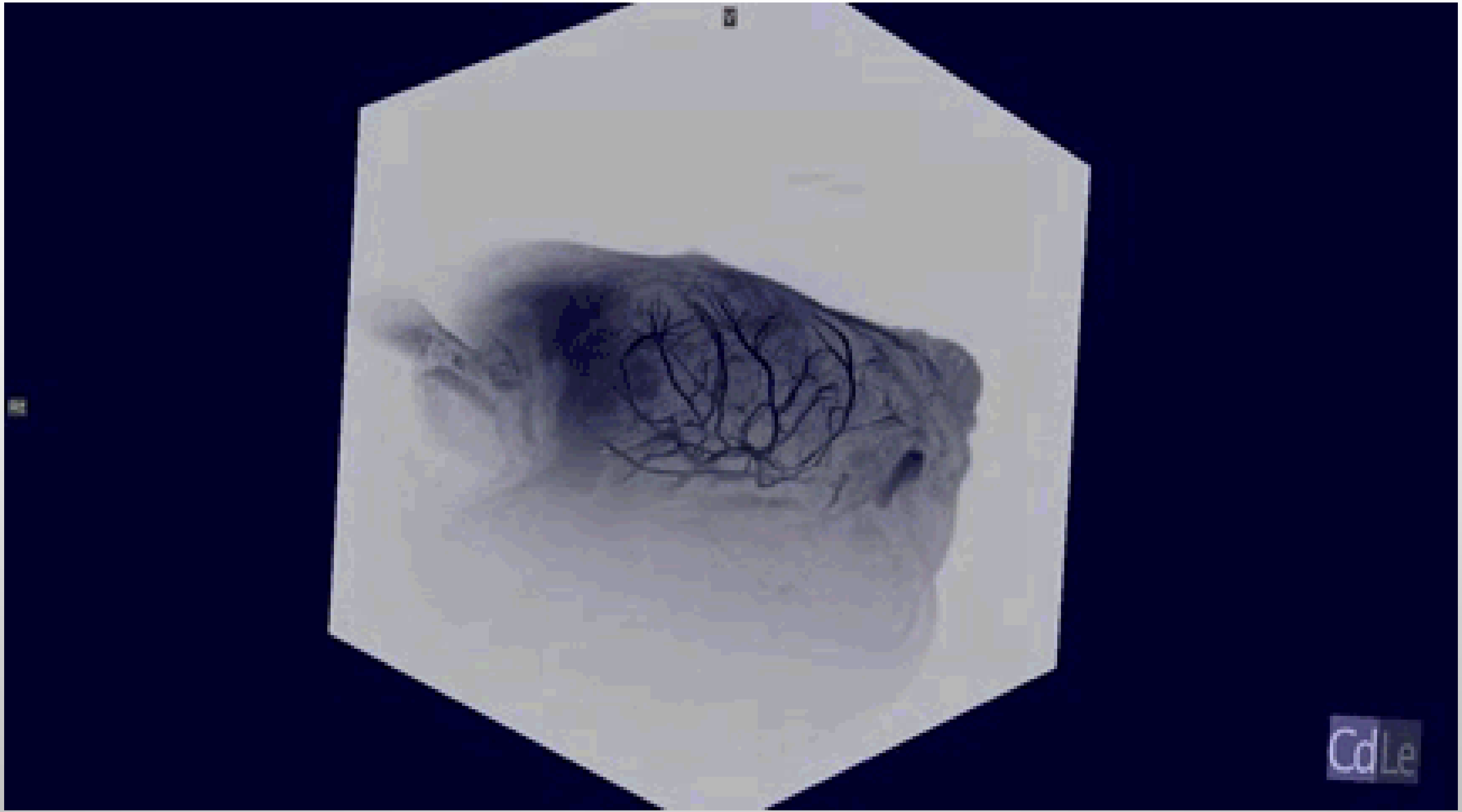


Liska A et al. (2015) NeuroImage 115:281–291

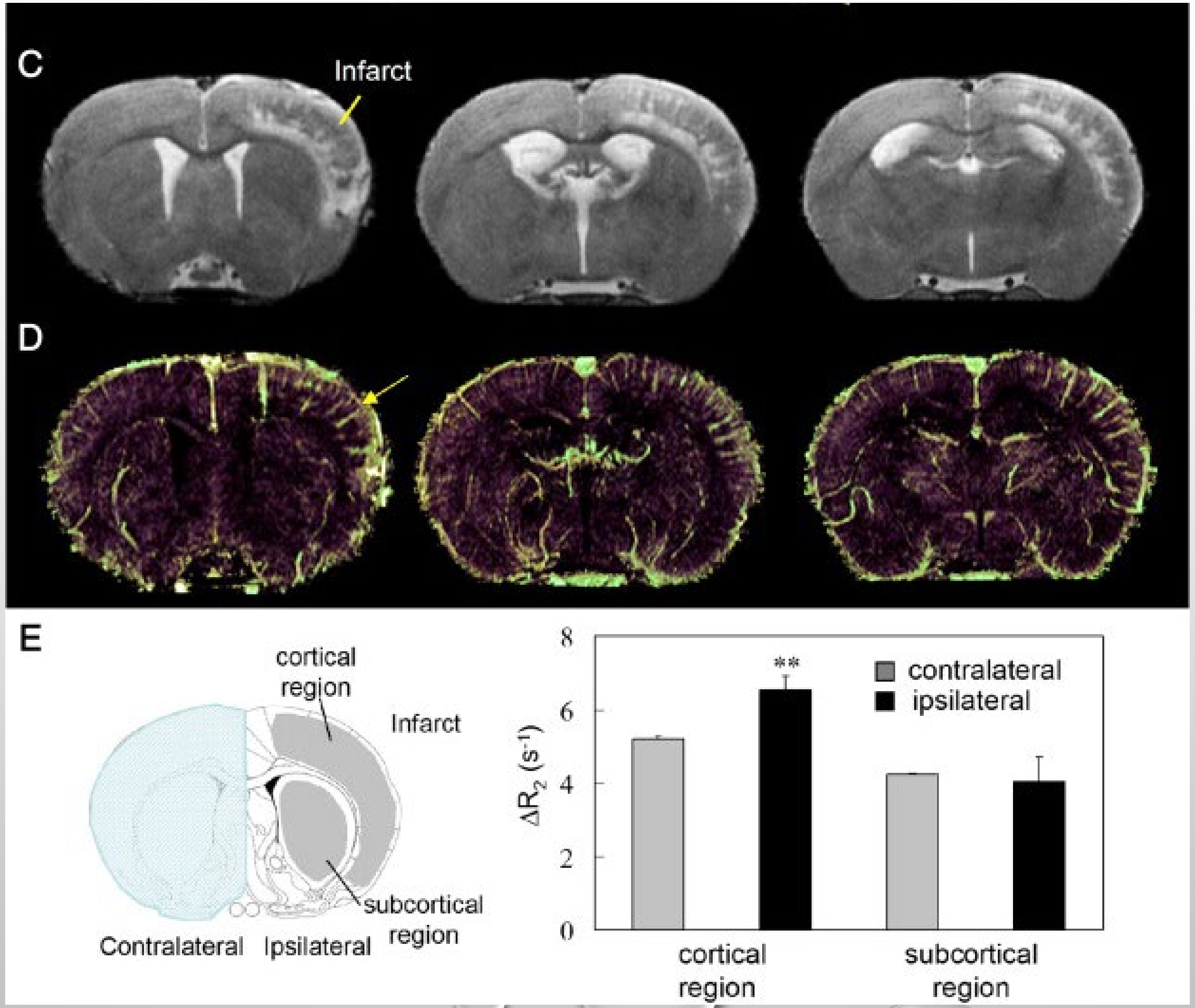
APPLICATIONS

MR ANGIOGRAPHY
磁振血管攝影

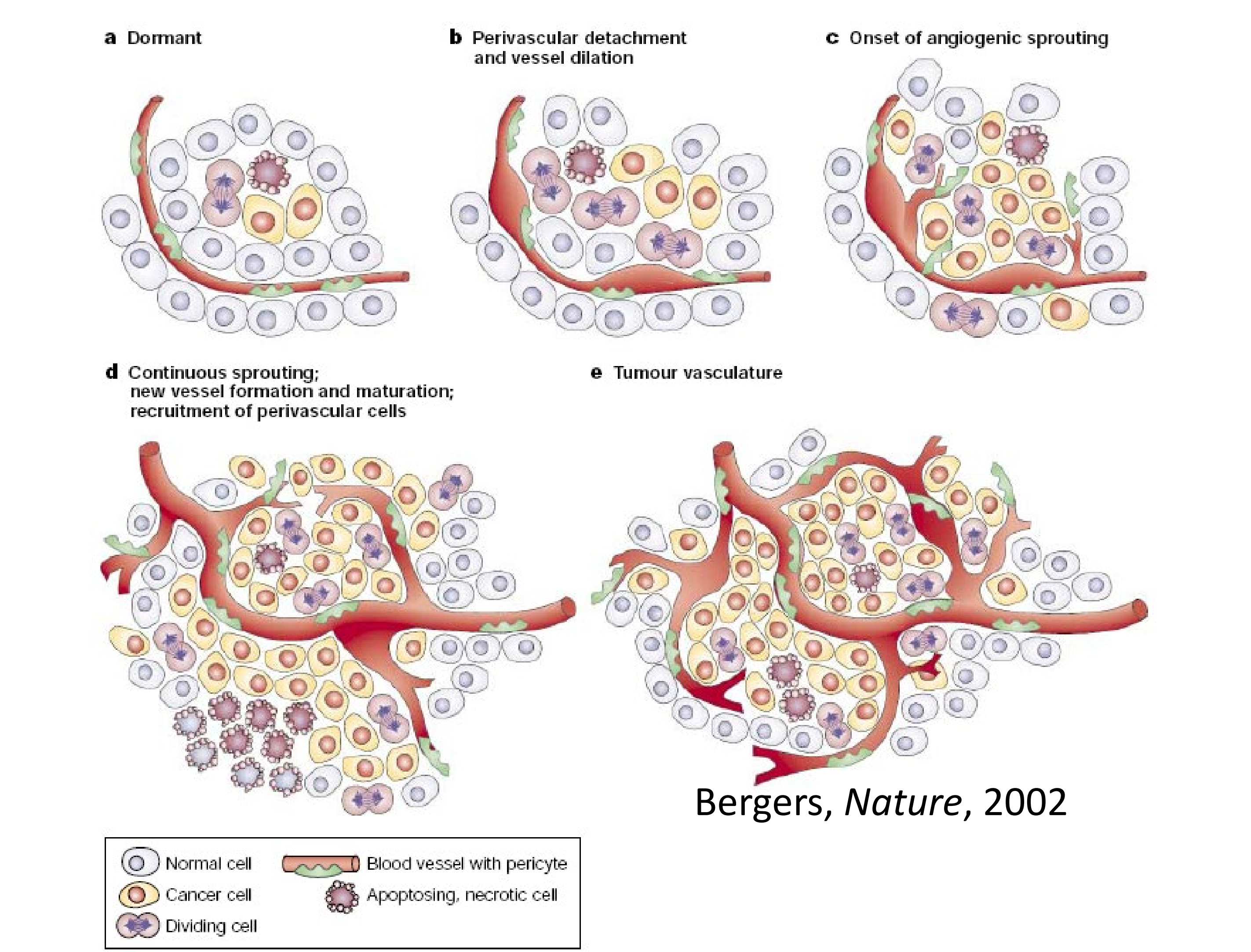
MR ANGIOGRAPHY



VASCULAR REMODELING AFTER ISCHEMIC STROKE REVEALED BY 3DΔR_2 MMRA

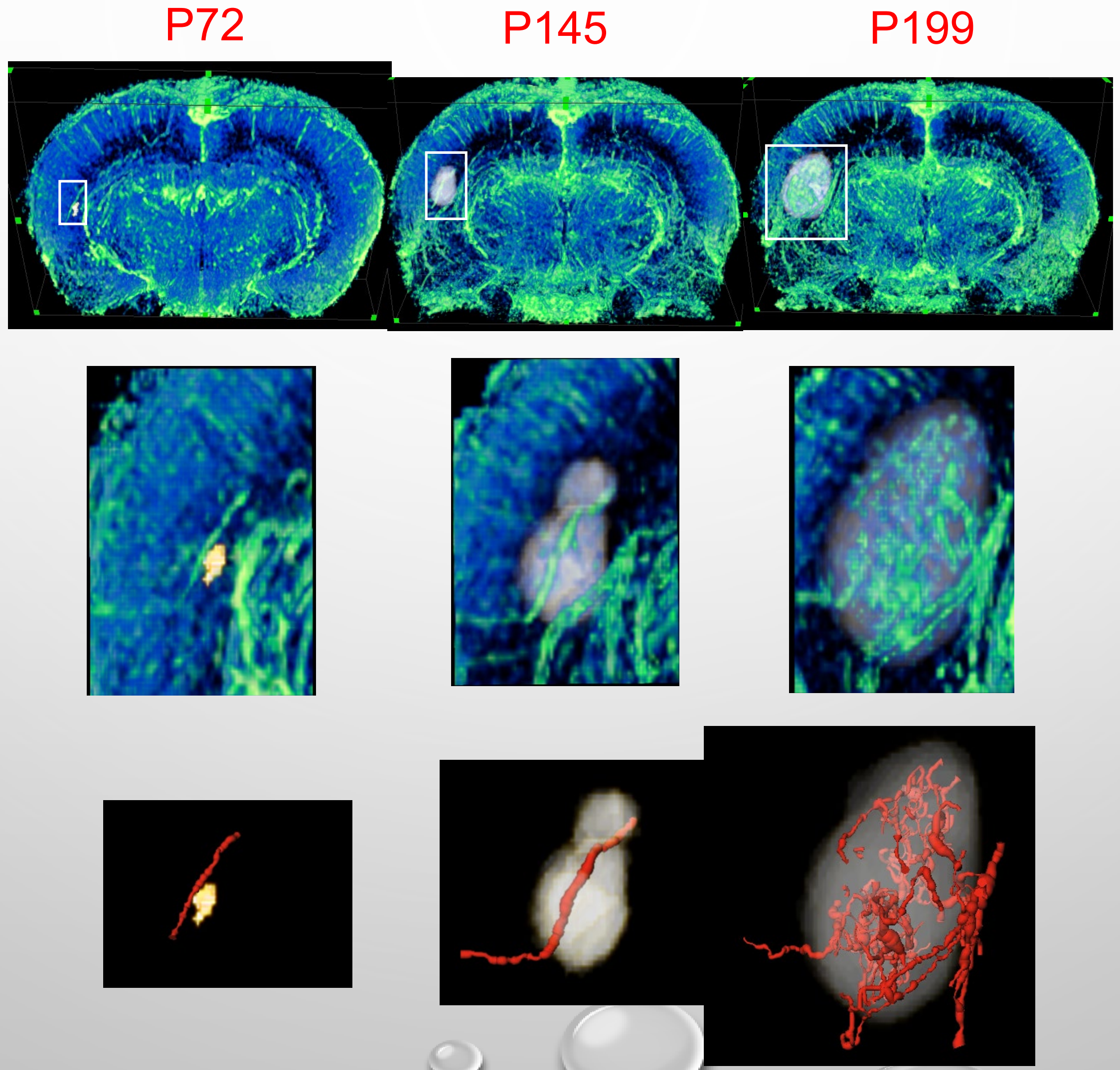


TUMOR ANGIOGENESIS

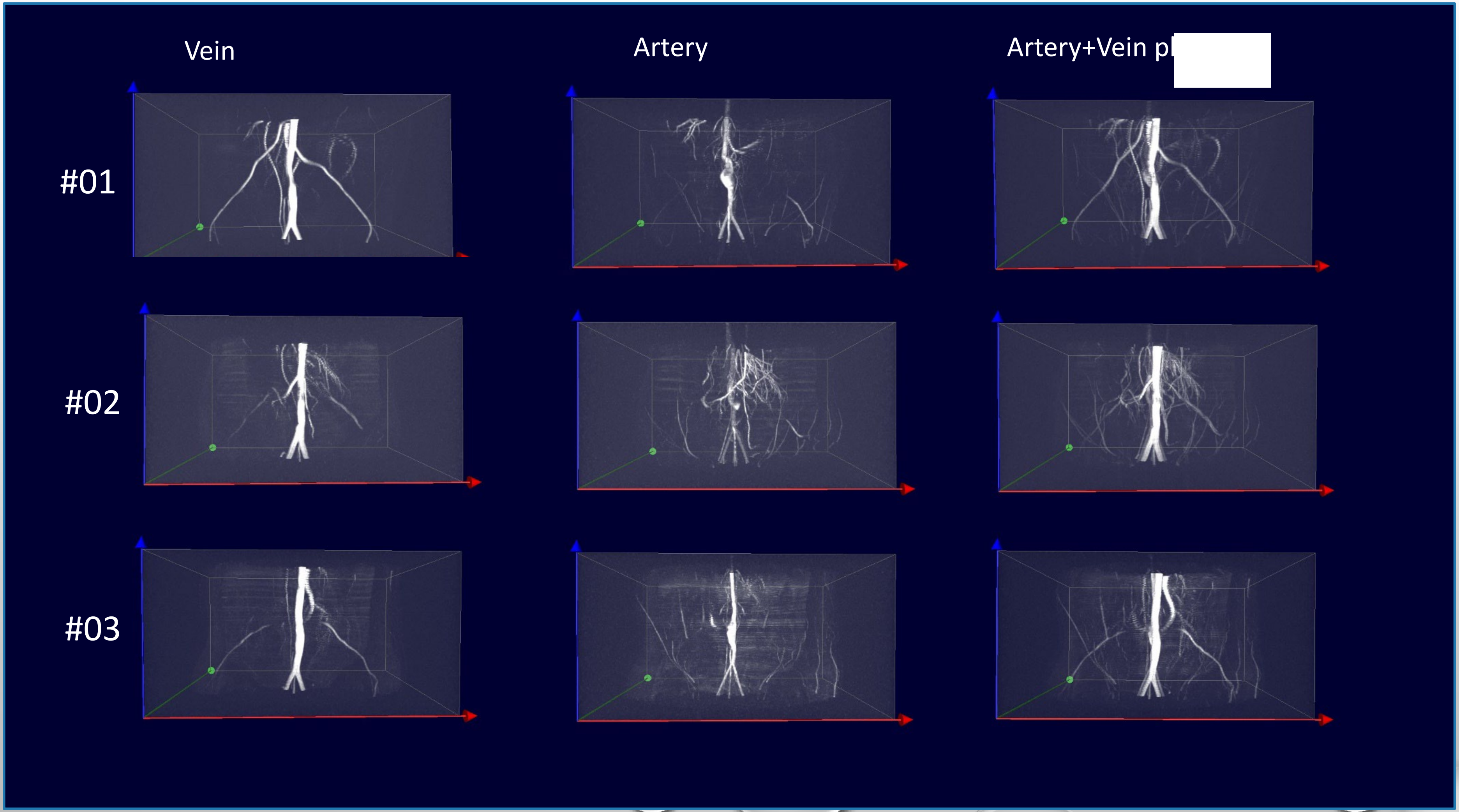


Bergers, *Nature*, 2002

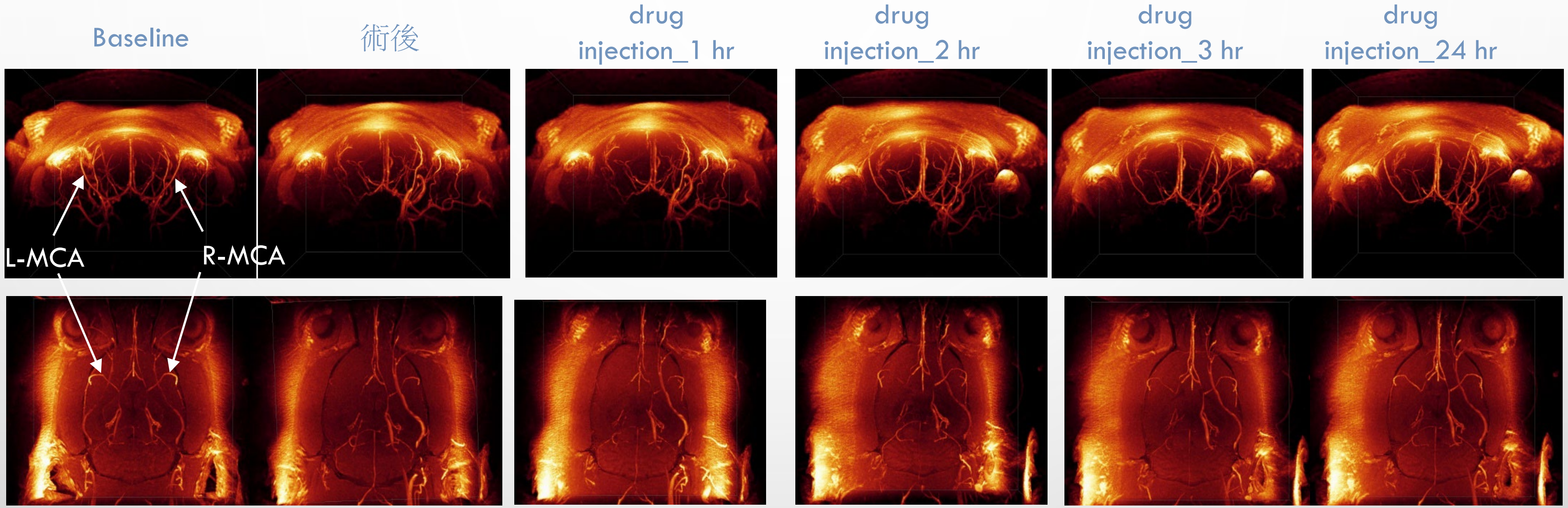
Temporal assessment of tumor microvasculature using 3D ΔR_2-mMRA



Angiography



Angiography of Stroke Model



L-MCA: 21.88 cm/s
R-MCA: 15.03 cm/s

L-MCA: N/A
R-MCA: 7.03 cm/s

L-MCA: N/A
R-MCA: 12.72 cm/s

L-MCA: N/A
R-MCA: 10.85 cm/s

L-MCA: 5.19 cm/s
R-MCA: 10.21 cm/s

L-MCA: 8.96 cm/s
R-MCA: 10.75 cm/s

L-MCA: 16.72 cm/s
R-MCA: 19.54 cm/s

L-MCA: 7.77 cm/s
R-MCA: 17.35 cm/s

L-MCA: 9.71 cm/s
R-MCA: 6.3 cm/s

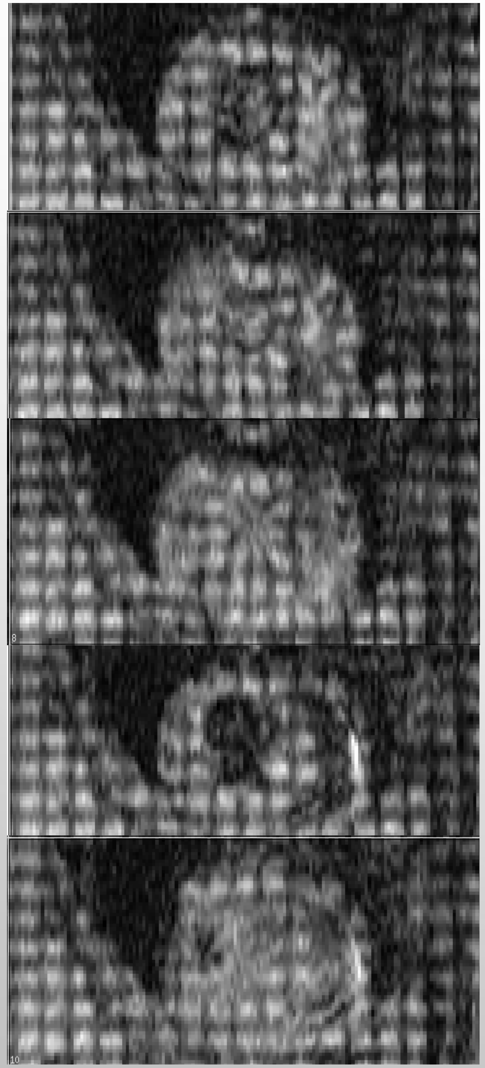
L-MCA: 9.85 cm/s
R-MCA: 12.11 cm/s

L-MCA: 9.99 cm/s
R-MCA: 11.82 cm/s

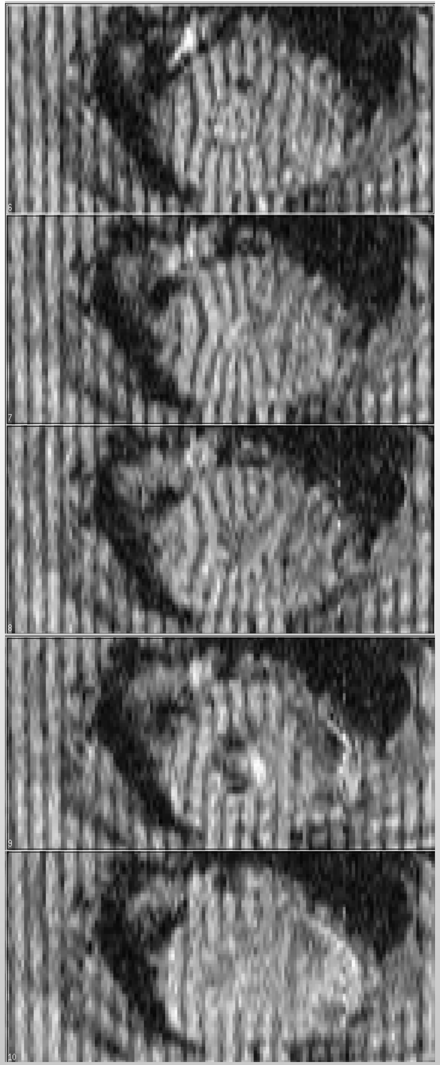
L-MCA: 12.23 cm/s
R-MCA: 17.87 cm/s

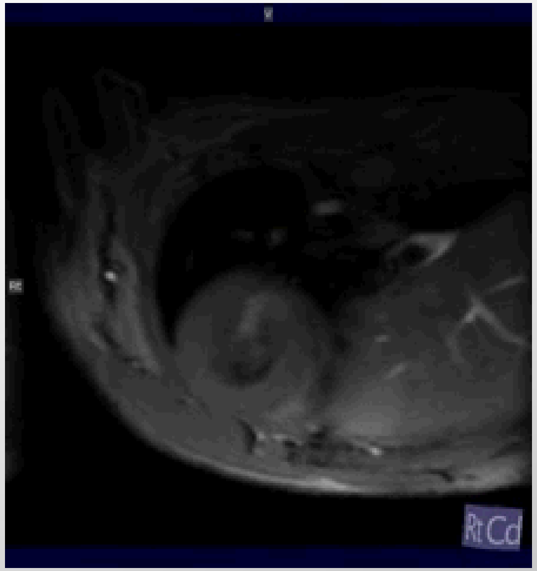
TAGGING – MYOCARDIAL MOVEMENT TRACKING

Grid mode

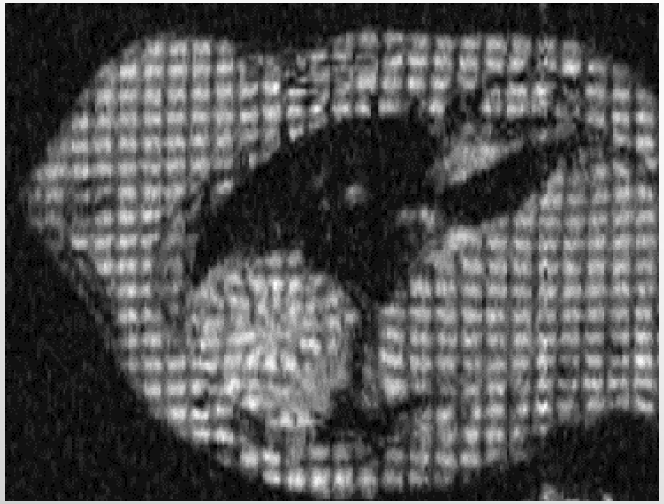


Line mode

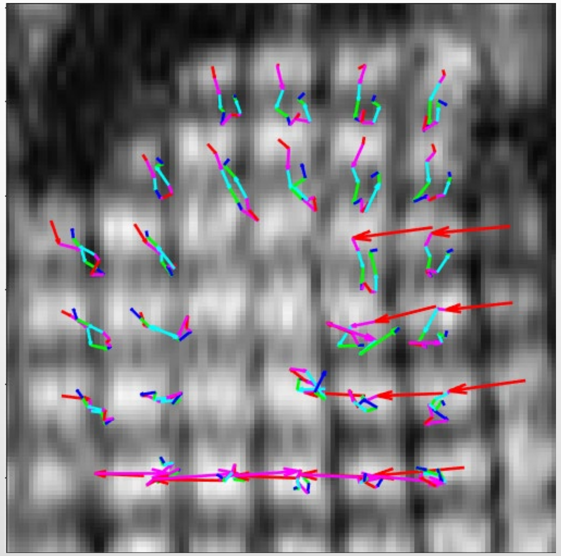




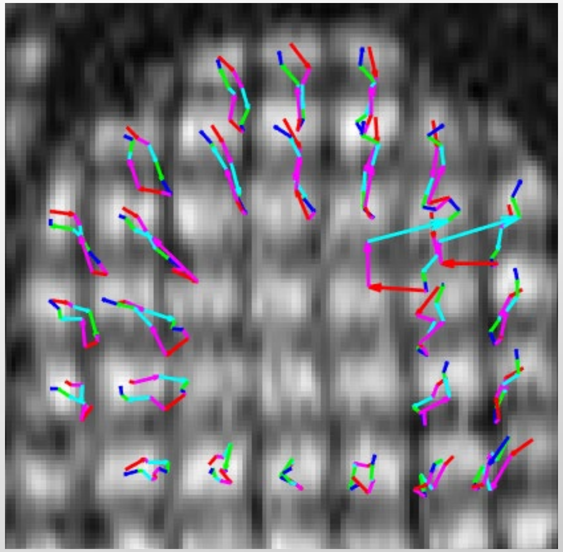
TAGGING – MYOCARDIAL MOVEMENT TRACKING



Doxorubicin induced
cardiac failure



Normal



SUMMARY

- PROVIDES A NONINVASIVE IMAGING TECHNIQUE
- PROVIDES ANATOMICAL AND FUNCTIONAL INFORMATION OF TISSUES
- *IN VIVO* STUDY