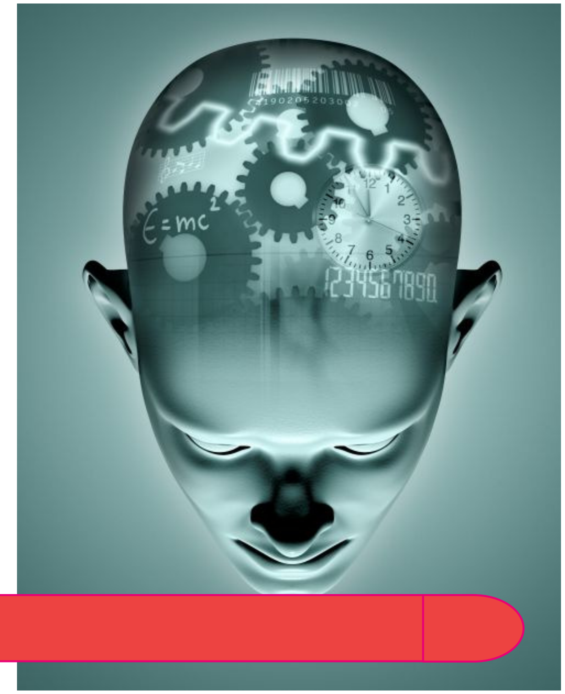
Neuroeconomics :

Neuroscience of decision making

Lecture N2

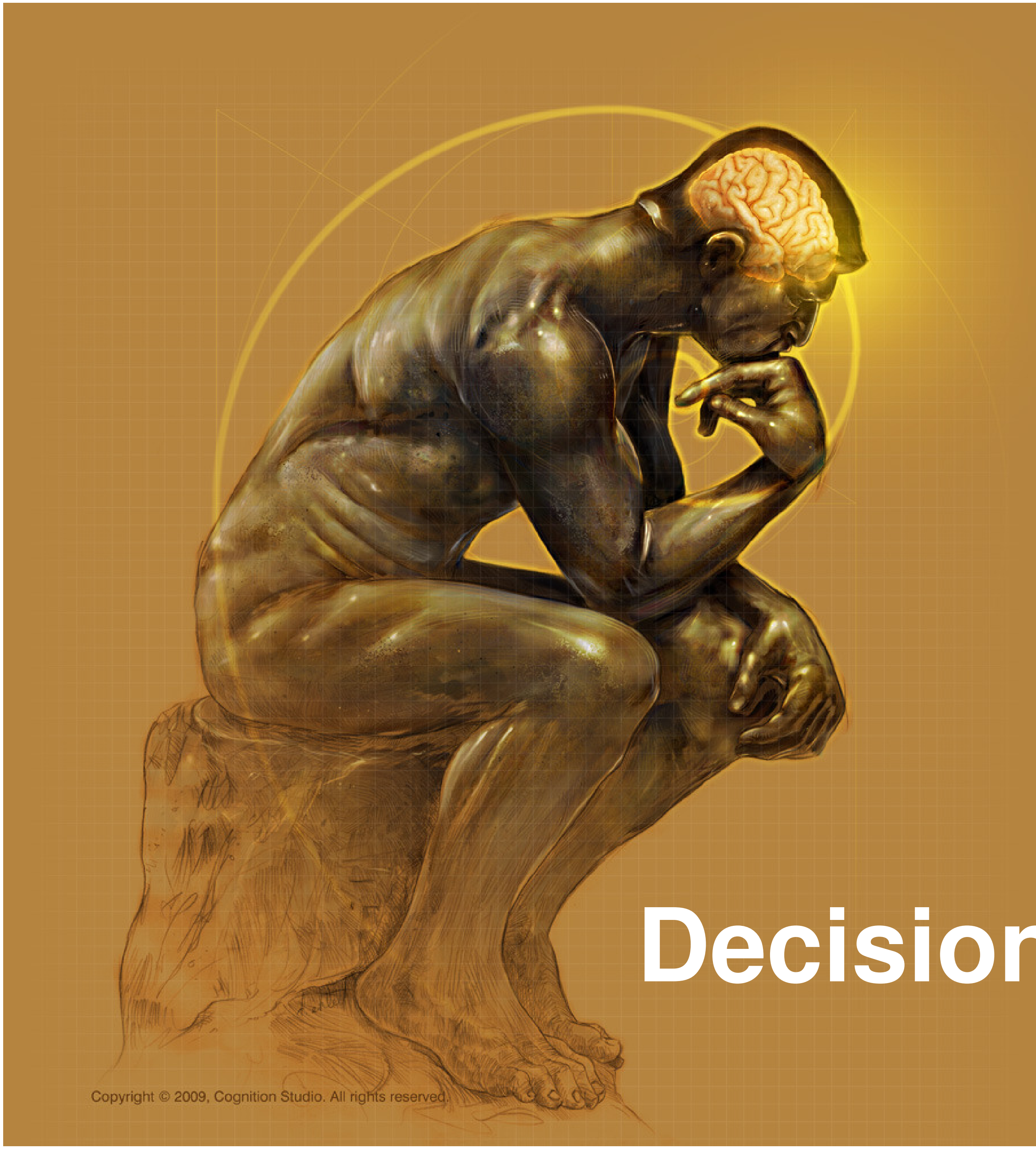


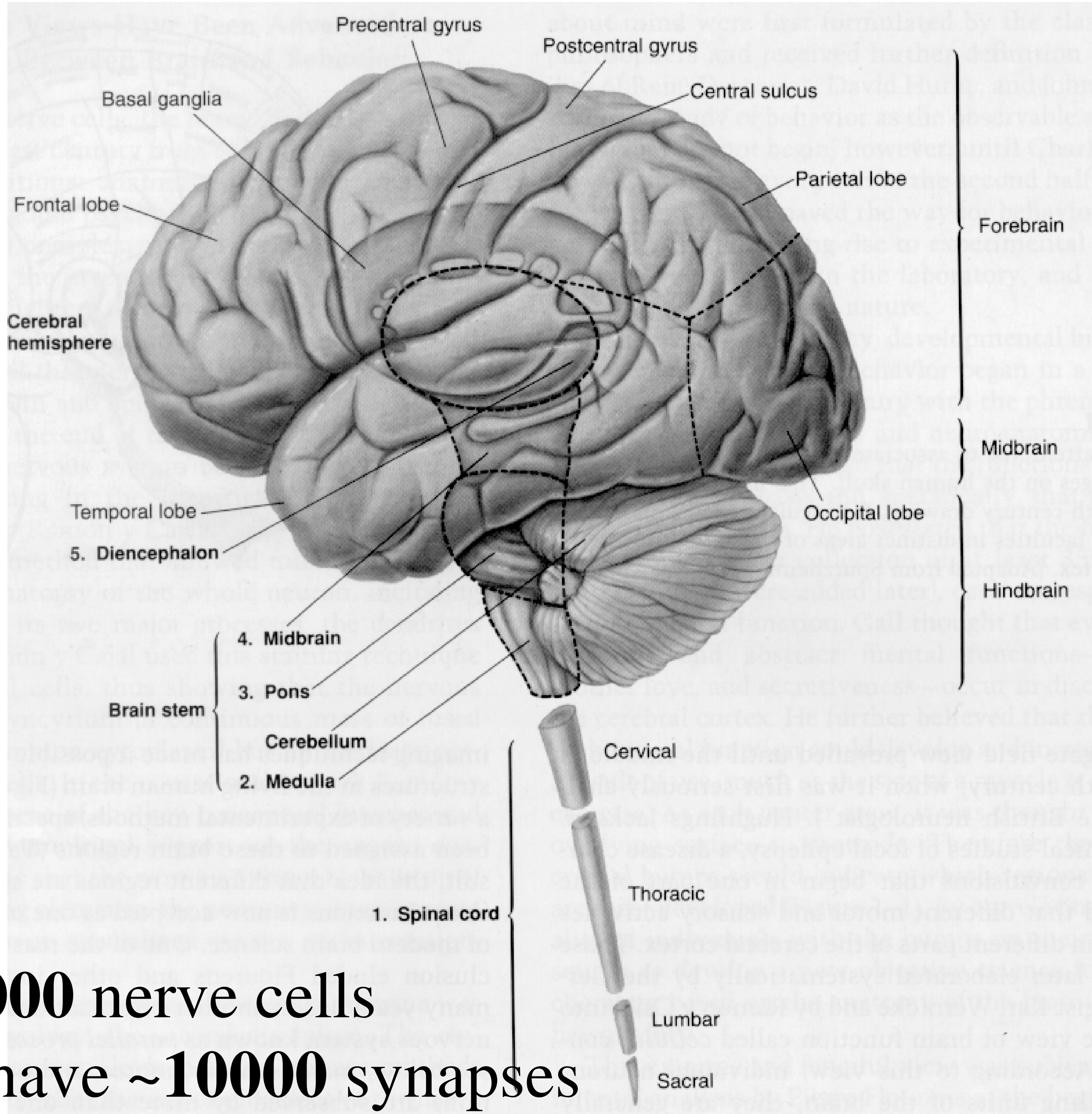
Brain Anatomy and Functions…

Vasily Klucharev

- Higher School of Economics

Decision making



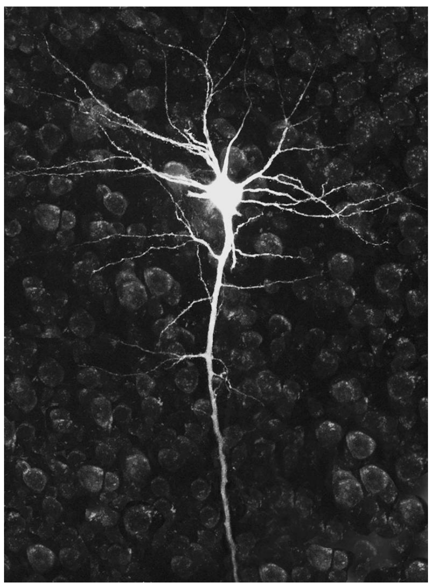


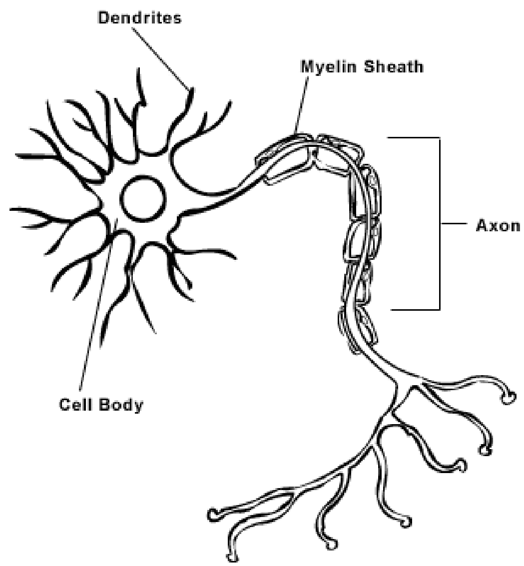
100,000,000,000 nerve cells

Typical cells have **~10000** synapses

Cellular components of the nervous system

Neurons: Fundamental units of the brain, spinal cord and peripheral nerves





Dendrite

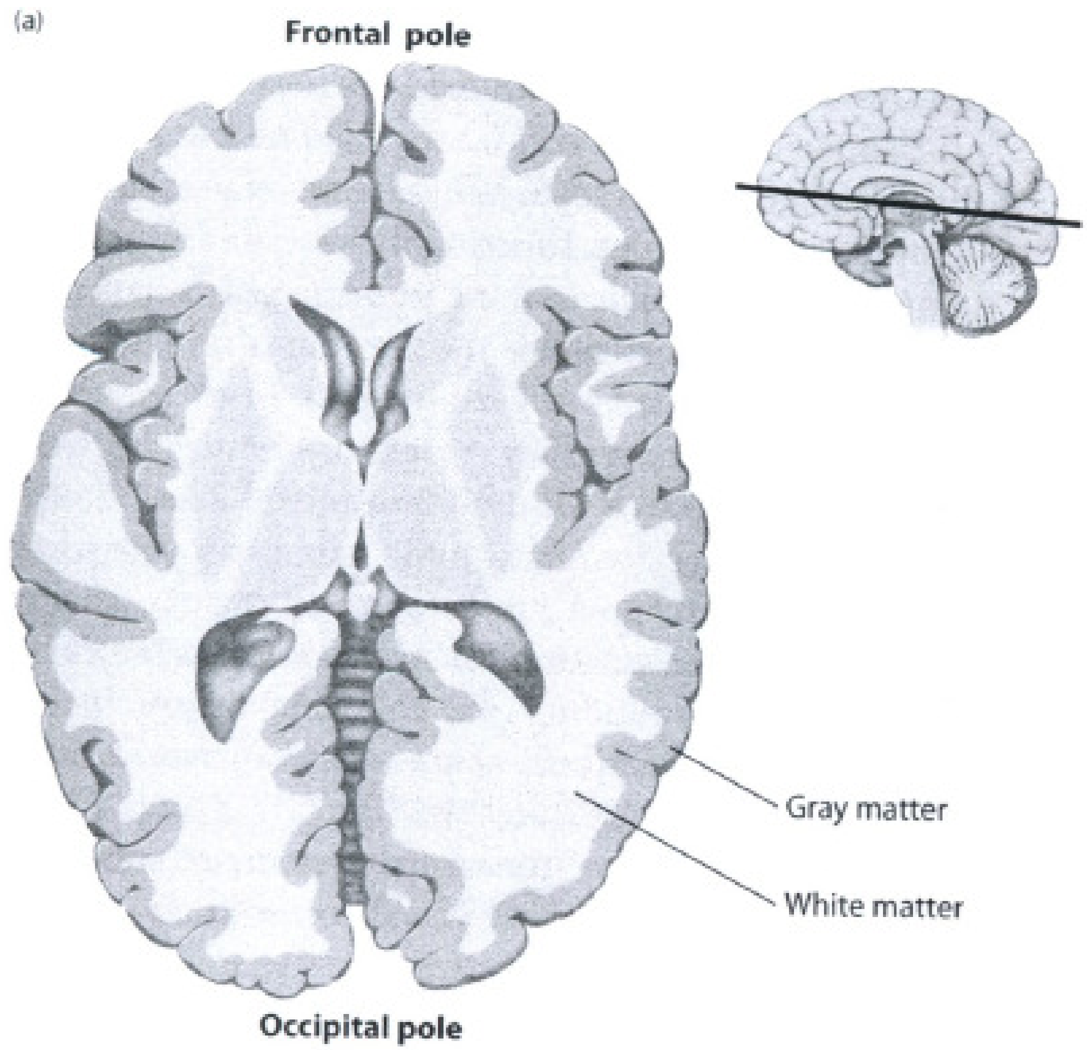
- Target for synaptic input from other neurons

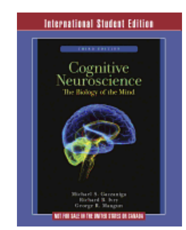
Axon:

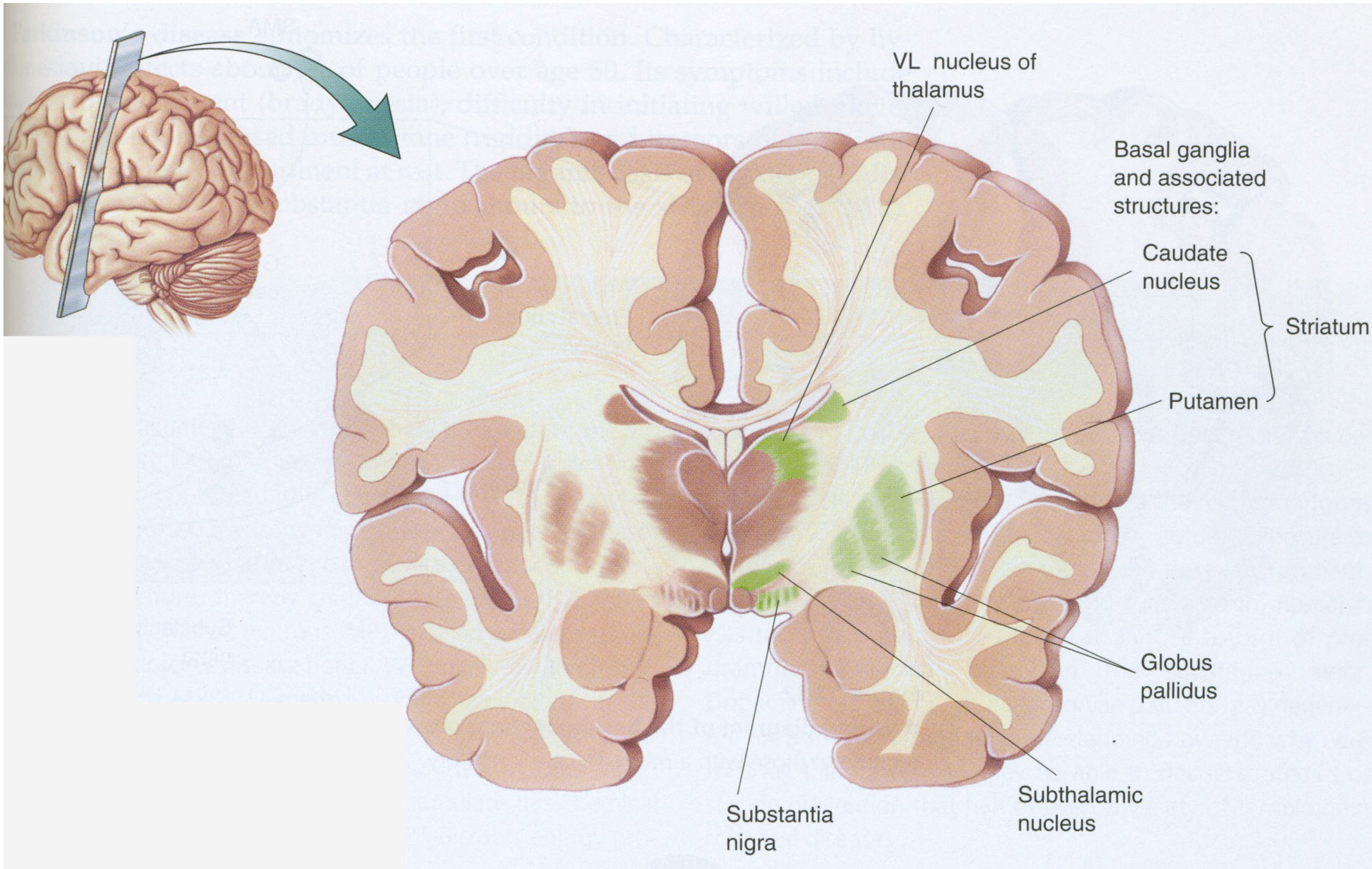
- Transmission of electrical signal from cell body to other neuron

Myelin:

- Substance that insulates axon

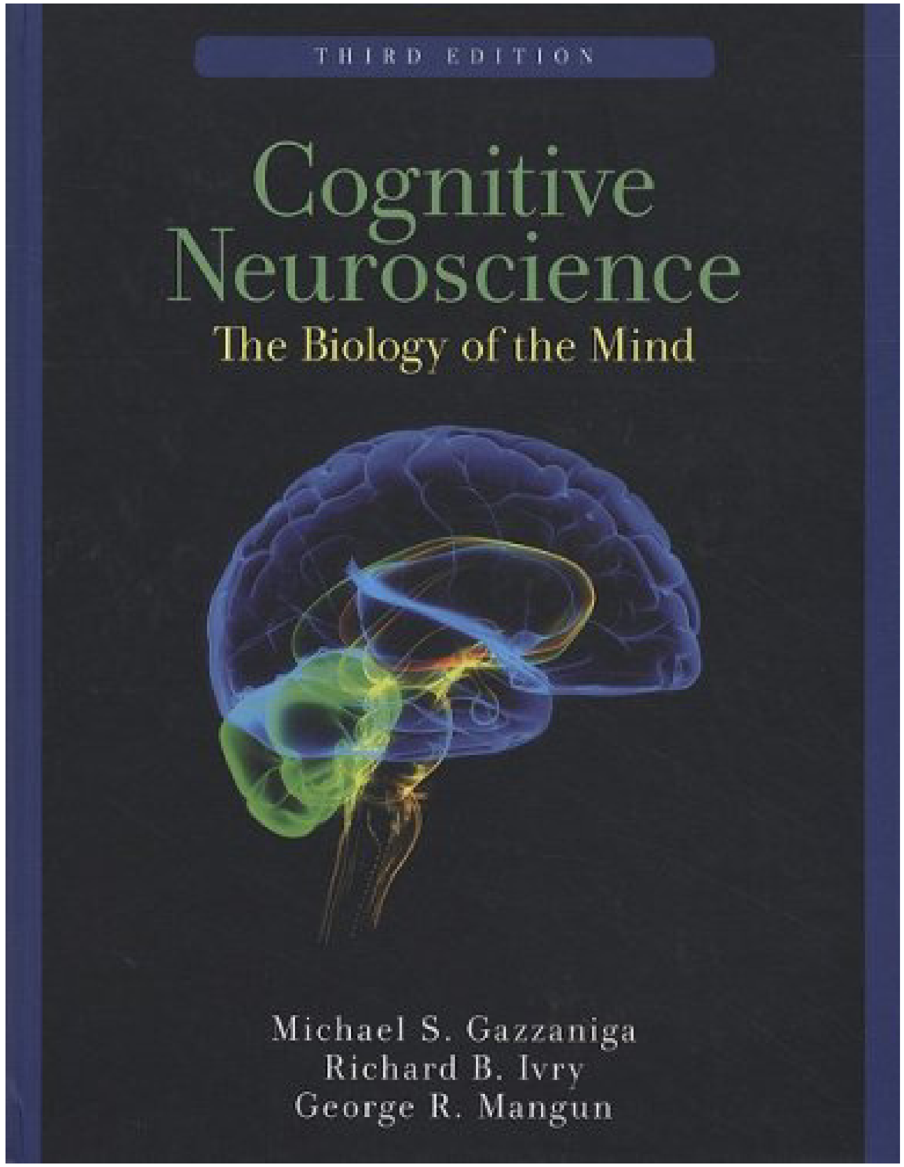

(a)
Frontal pole
Gray matter
White matter
Occipital pole


International Student Edition
Cognitive
Neuroscience
The Biology of the Mind



VL nucleus of thalamus
Basal ganglia and associated structures:
Caudate nucleus
Striatum
Putamen
Globus pallidus
Subthalamic nucleus
Substantia nigra

A bit of Anatomy


THIRD EDITION
Cognitive Neuroscience
The Biology of the Mind
Michael S. Gazzaniga
Richard B. Ivry
George R. Mangun

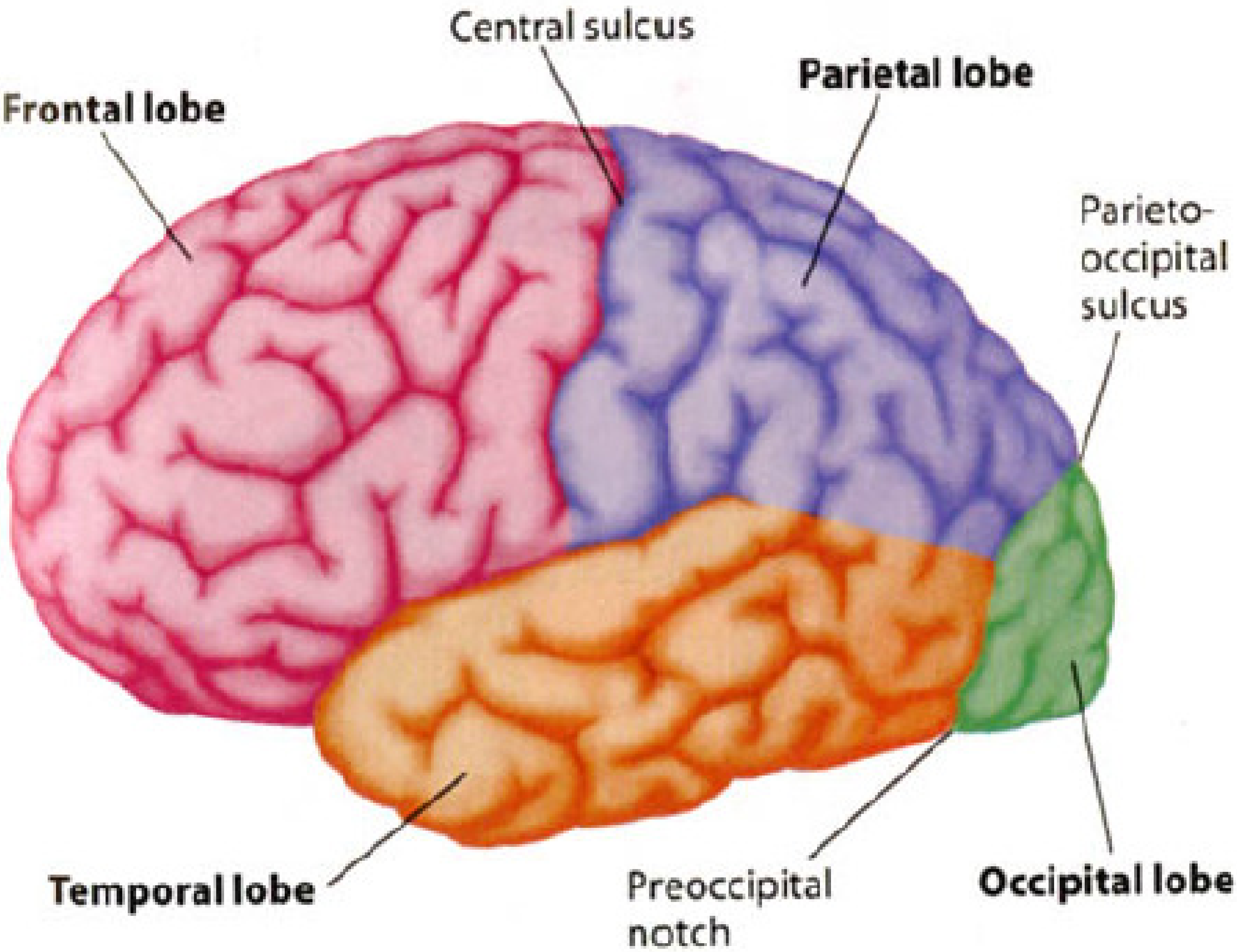
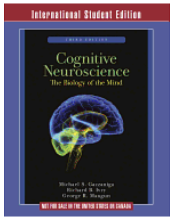
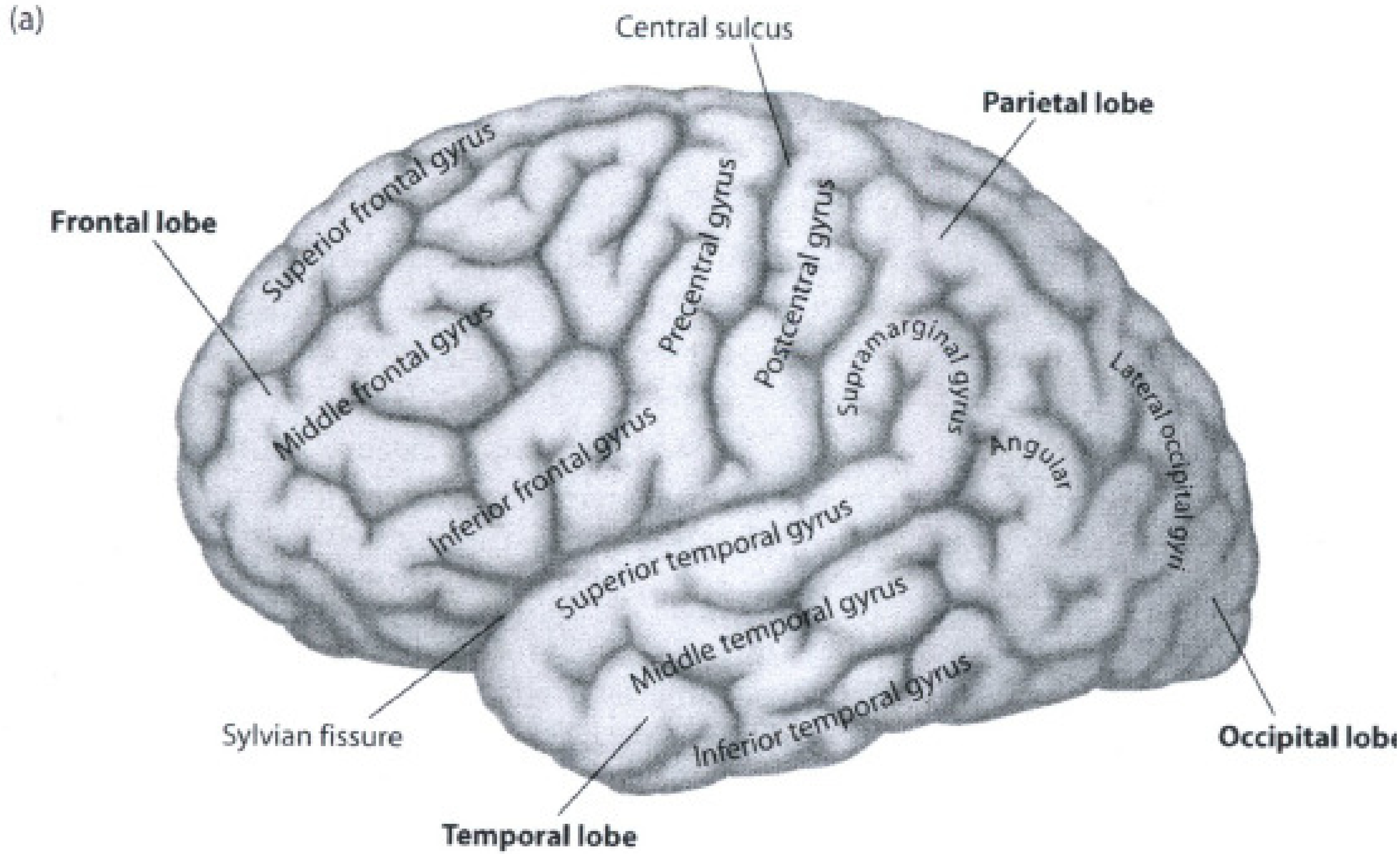


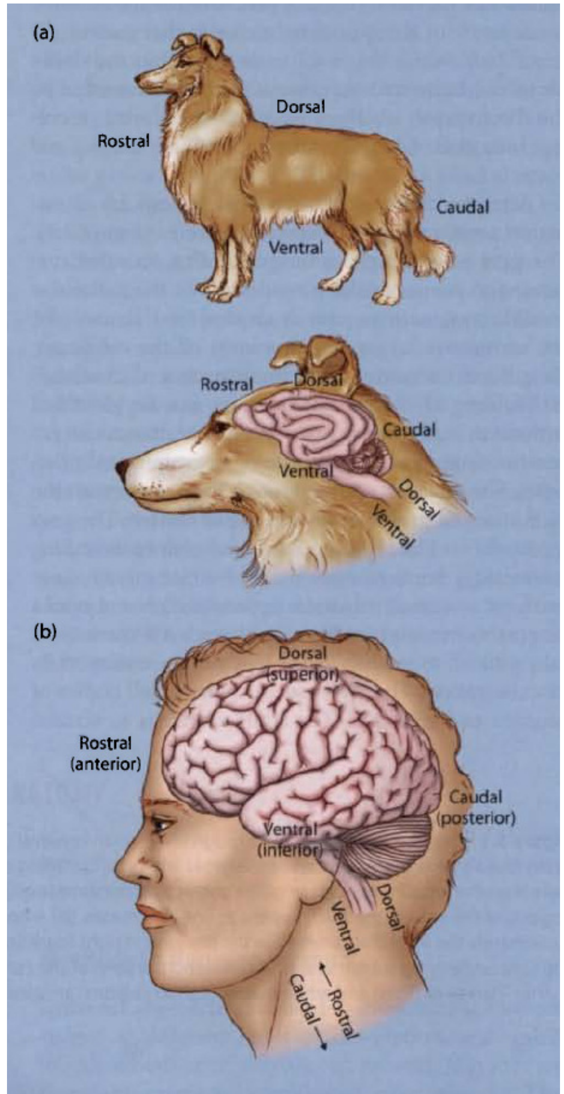
Figure 3.10 Four lobes of the cerebral cortex, in lateral view of the left hemisphere. See text for details.



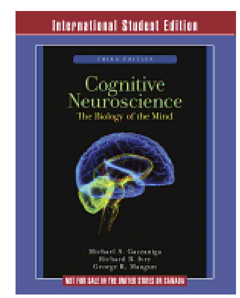

(a)
Central sulcus
Parietal lobe
Frontal lobe
Superior frontal gyrus
Precentral gyrus
Postcentral gyrus
Middle frontal gyrus
Supramarginal gyrus
Lateral occipital gyri
Angular
Inferior frontal gyrus
Superior temporal gyrus
Middle temporal gyrus
Inferior temporal gyrus
Sylvian fissure
Occipital lobe
Temporal lobe

Dorsal

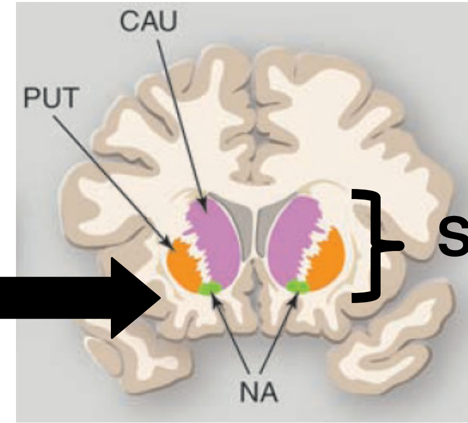
Ventral



Anatomical terms for describing various views of anatomy and sections through brain and body. The relationship between a bipedal human and quadruped animal leads to some important considerations in describing the surfaces of the brain and spinal cord.

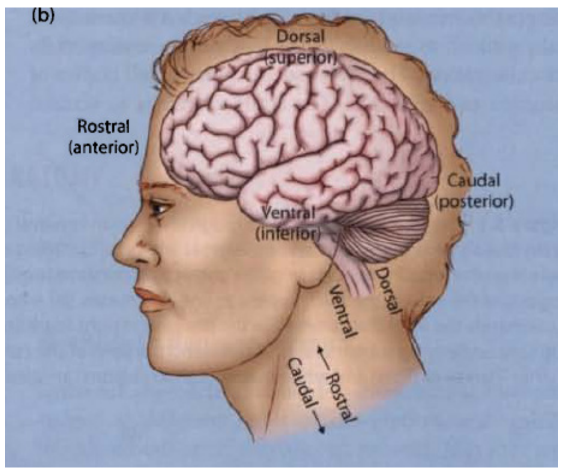


Ventral striatum (NA)

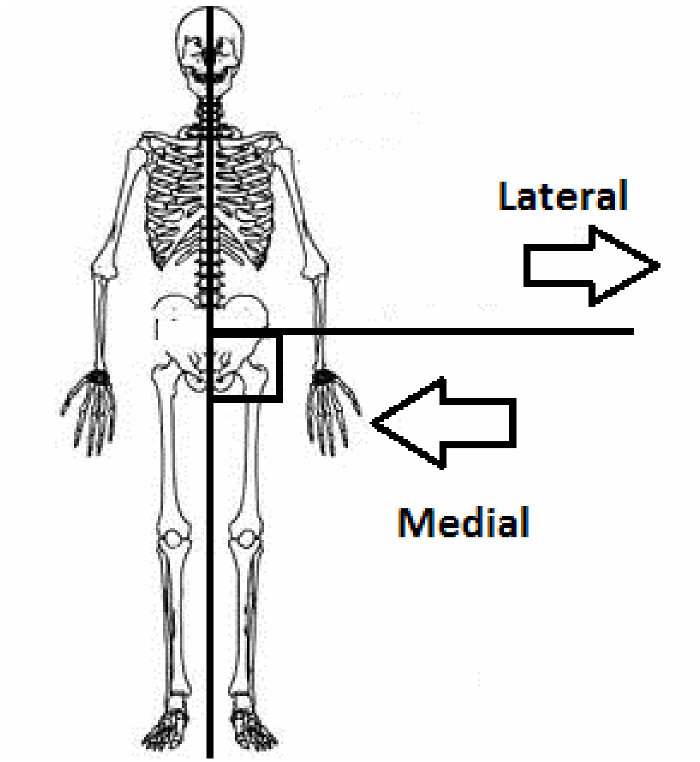


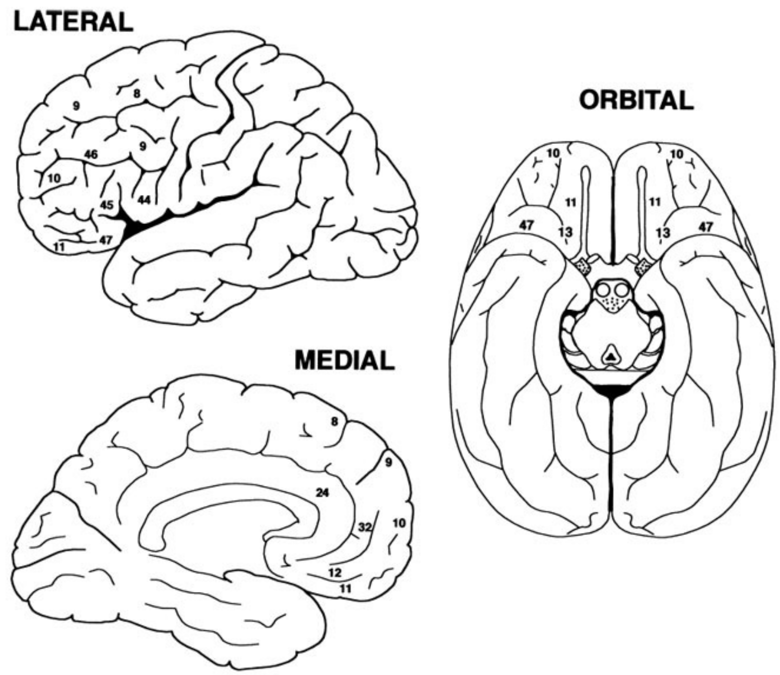
Striatum

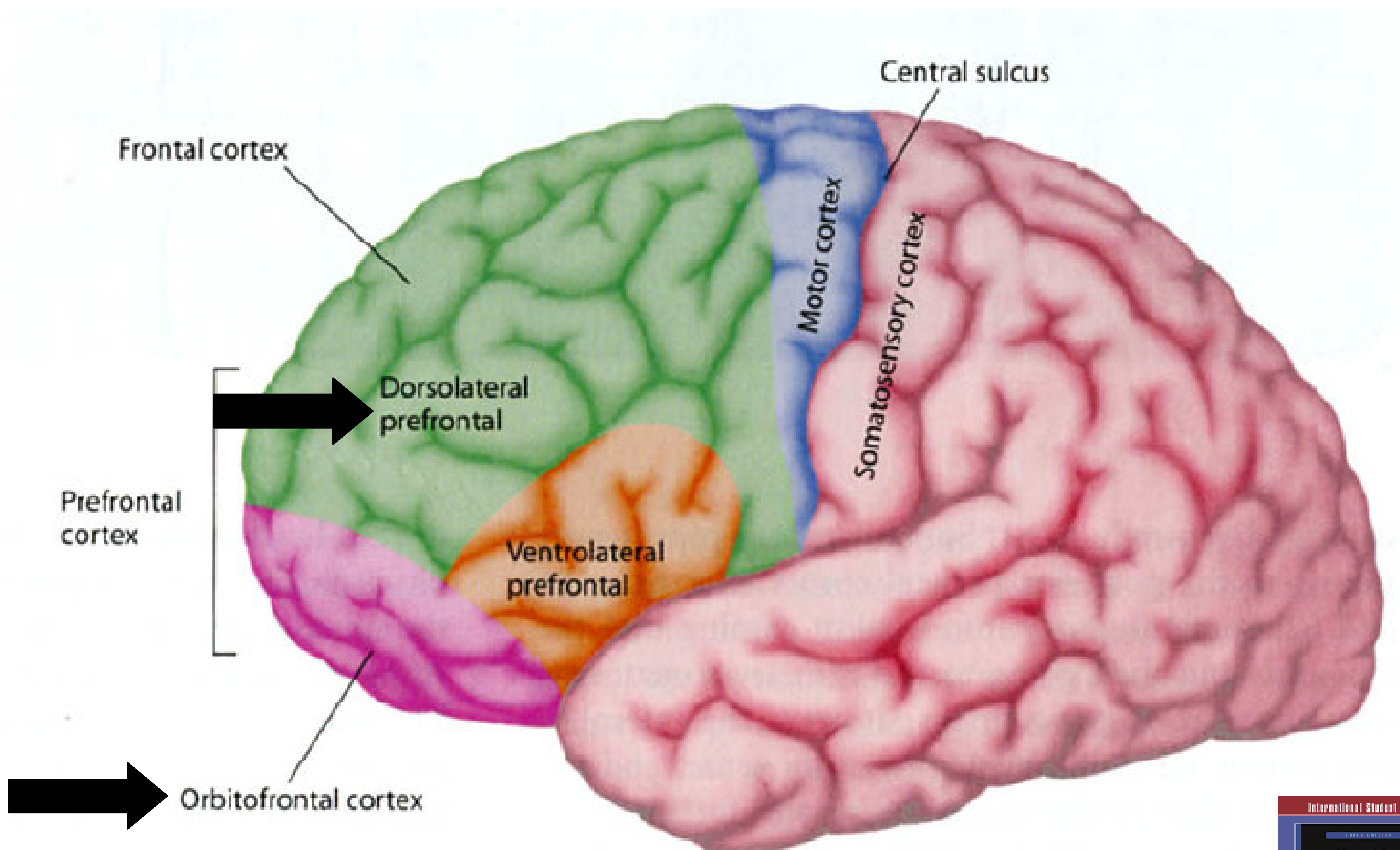
Dorsal

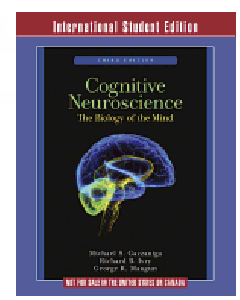


Ventral


Lateral
Medial


LATERAL
MEDIAL
ORBITAL


Central sulcus
Frontal cortex
Motor cortex
Somatosensory cortex
Dorsolateral
prefrontal
Prefrontal
cortex
Ventrolateral
prefrontal
Orbitofrontal cortex


International Student Edition
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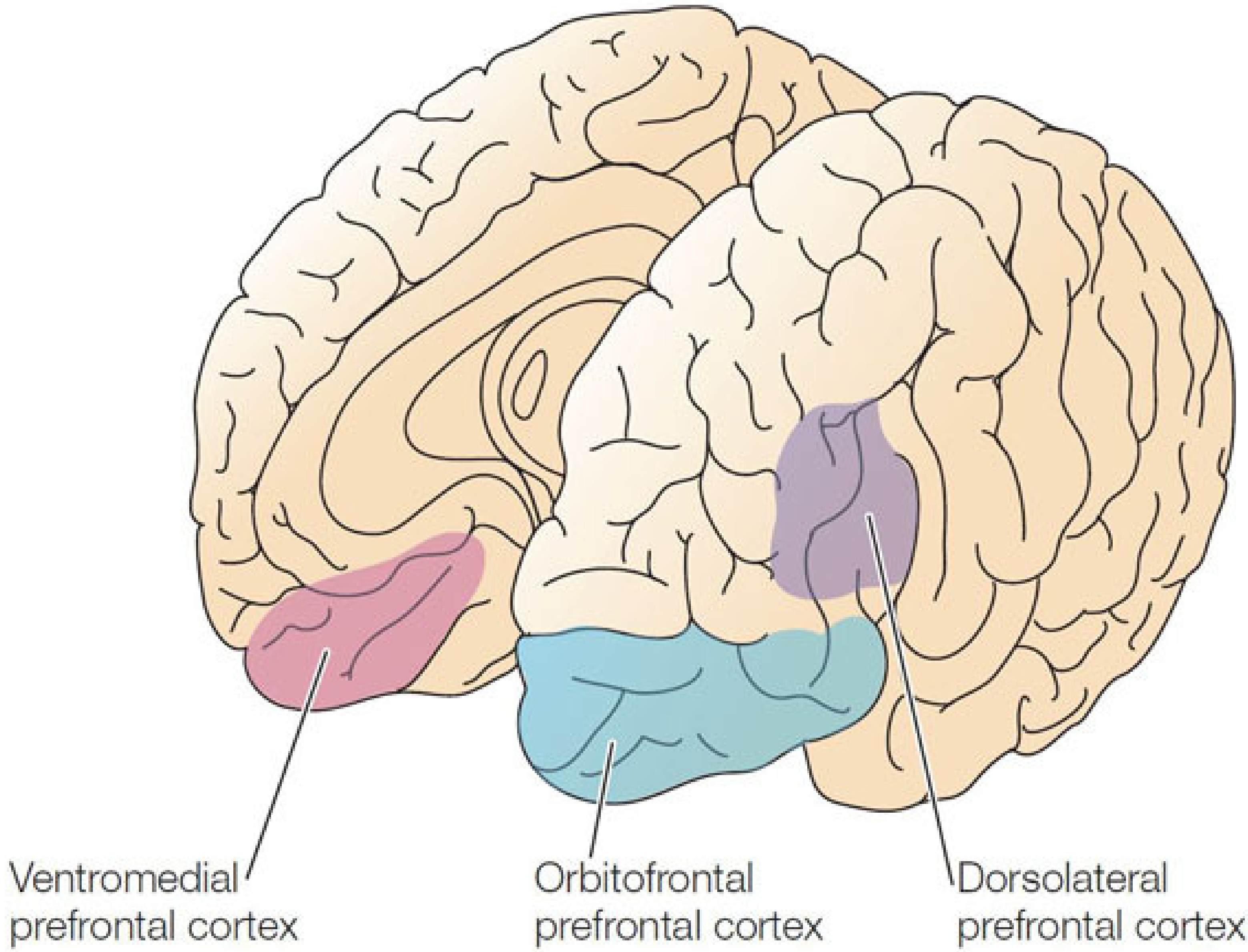

Ventromedial prefrontal cortex
Orbitofrontal prefrontal cortex
Dorsolateral prefrontal cortex

Processing of sensory information

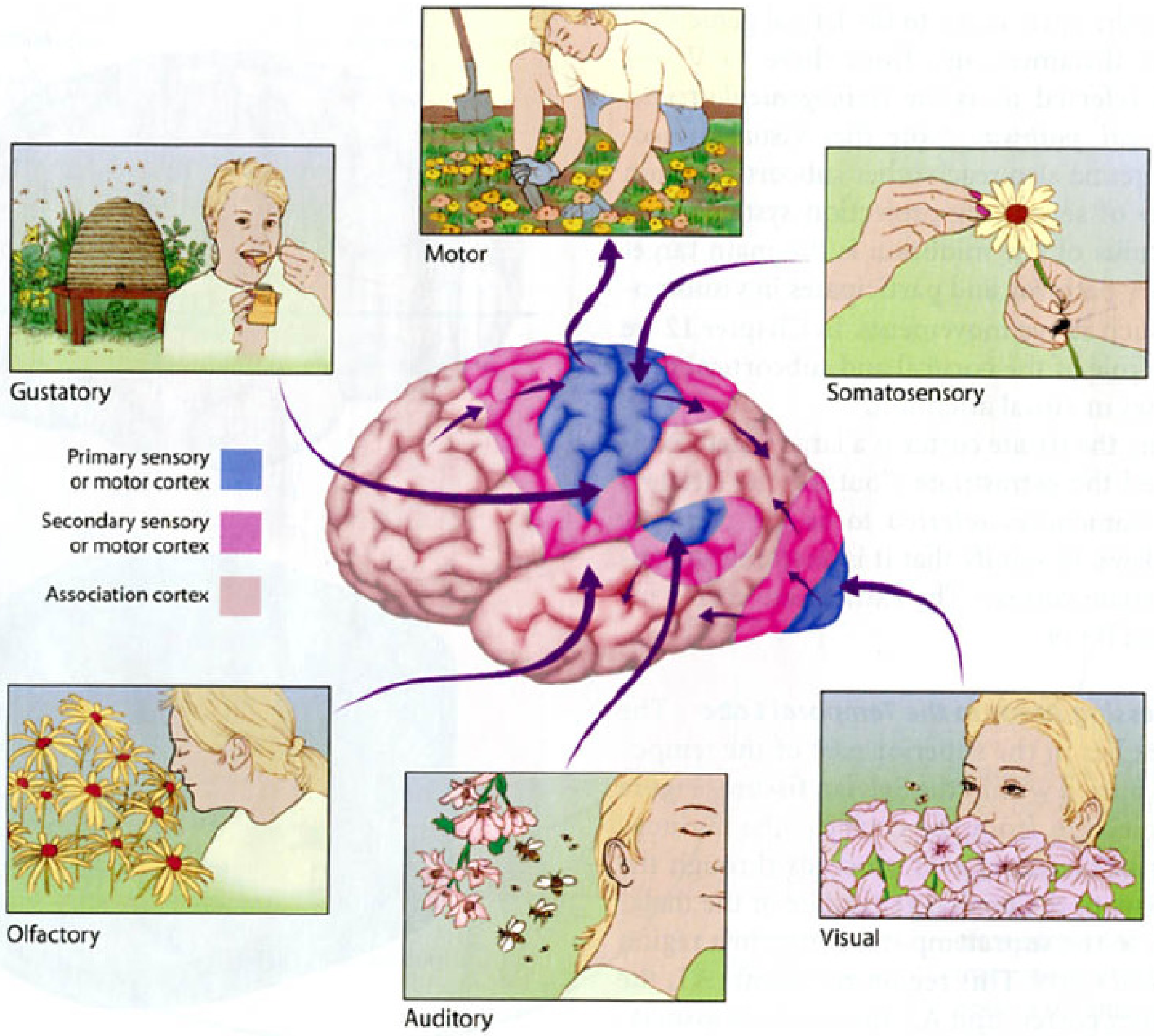
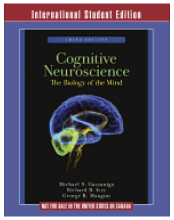
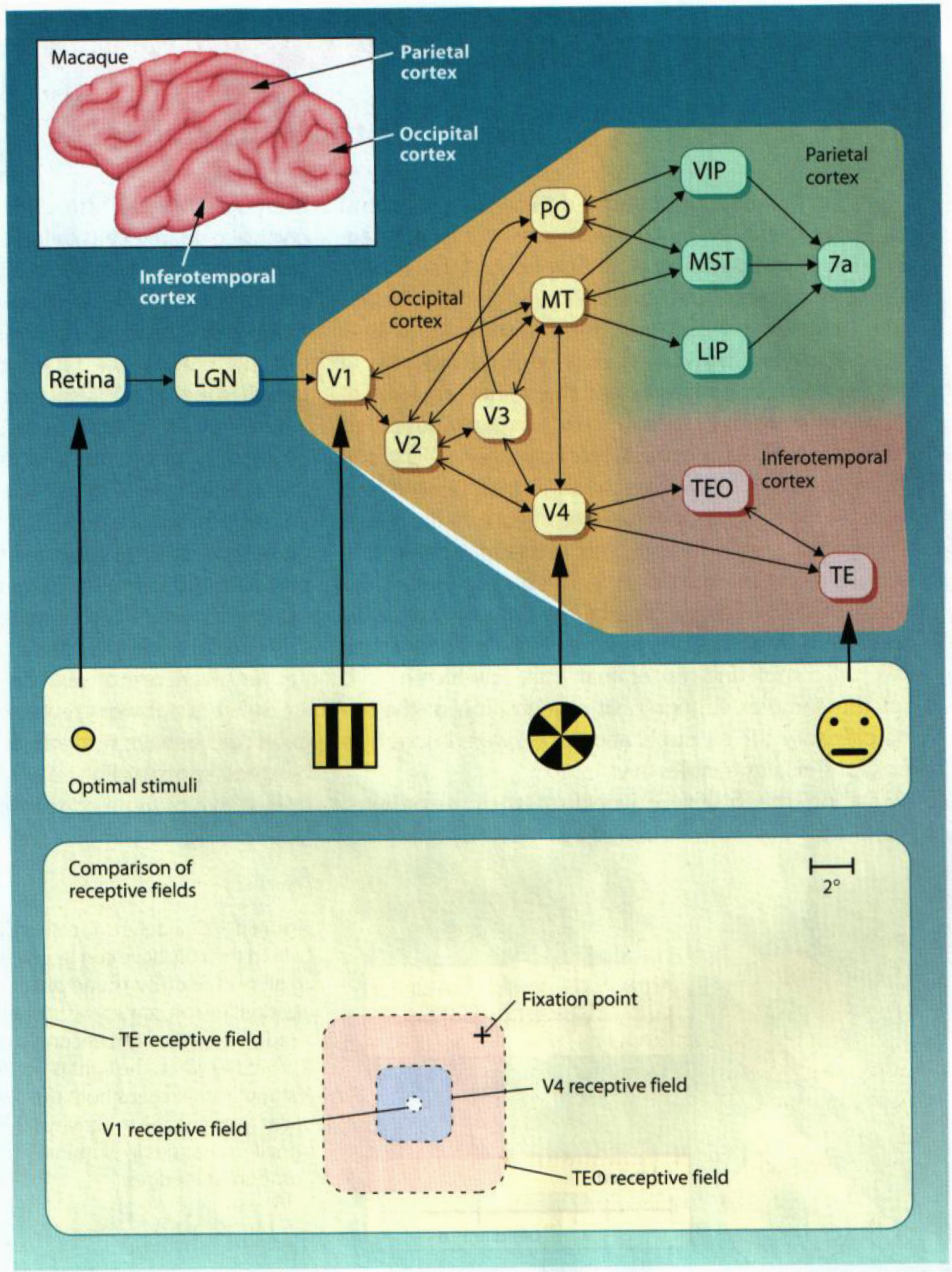


Figure 3.17 Primary sensory and motor cortex and surrounding association cortex. The blue regions show the primary cortical receiving areas of the ascending sensory pathways and the primary output region to the spinal cord. The secondary sensory and motor areas are colored red. The remainder is considered association cortex.





Macaque
Parietal cortex
Occipital cortex
Inferotemporal cortex
Occipital cortex
Parietal cortex
Inferotemporal cortex
Retina
LGN
V1
V2
V3
V4
PO
MT
VIP
MST
LIP
7a
TEO
TE
Optimal stimuli
Comparison of receptive fields
2°
Fixation point
TE receptive field
V4 receptive field
V1 receptive field
TEO receptive field

?

Sensory processing
(sensory evidences)

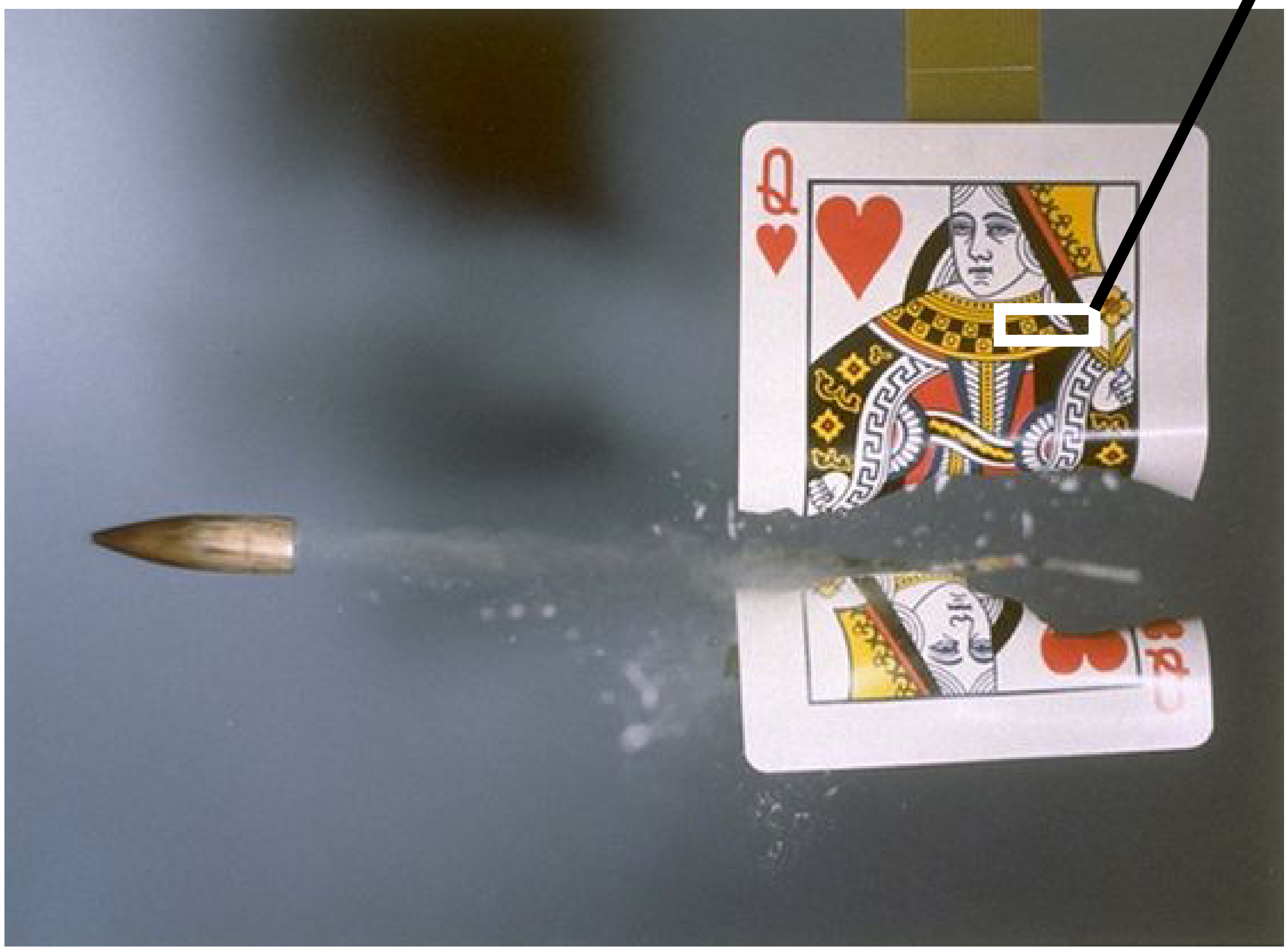
Decision making

Methods

1. Lesions
2. Electrical stimulation of the brain
3. Transcranial Magnetic Stimulation – TMS
4. Electrophysiology (cell recordings)
5. EEG, MEG
6. Functional Magnetic Resonance Imaging – fMRI

Spatial resolution

Temporal resolution



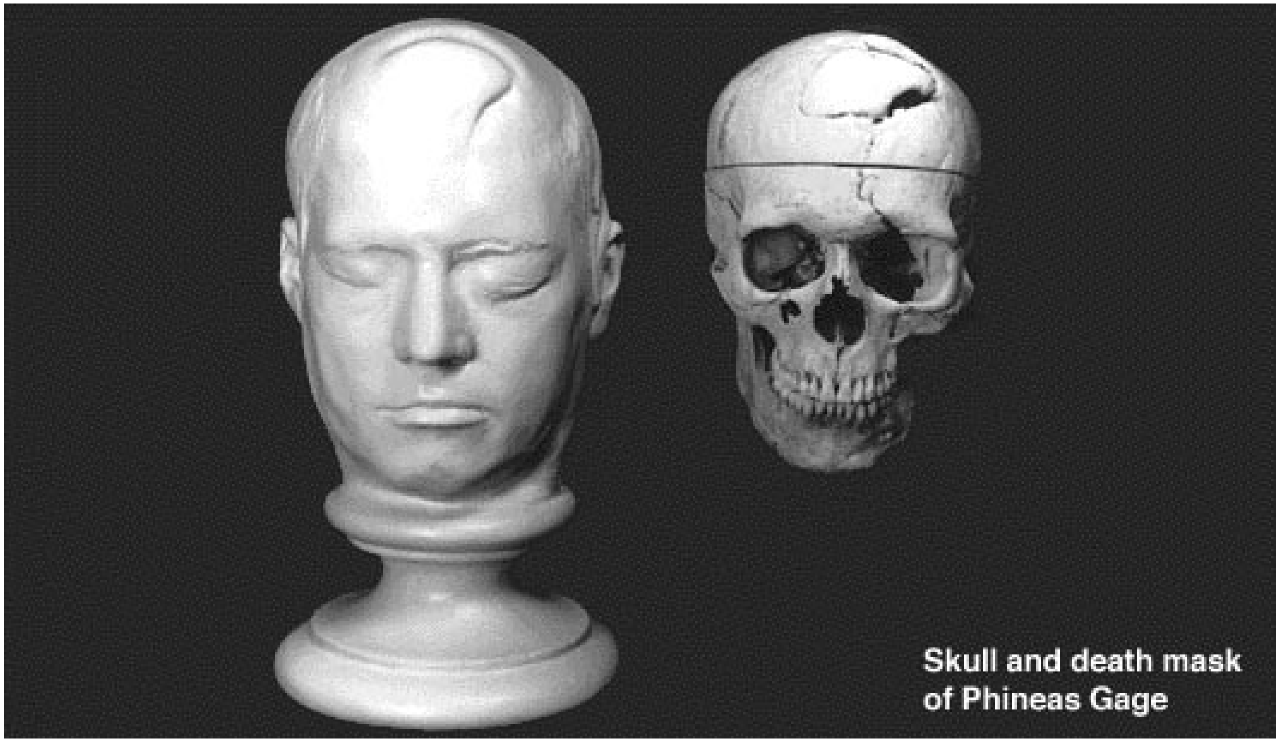
Harold Edgerton

I. Lesions

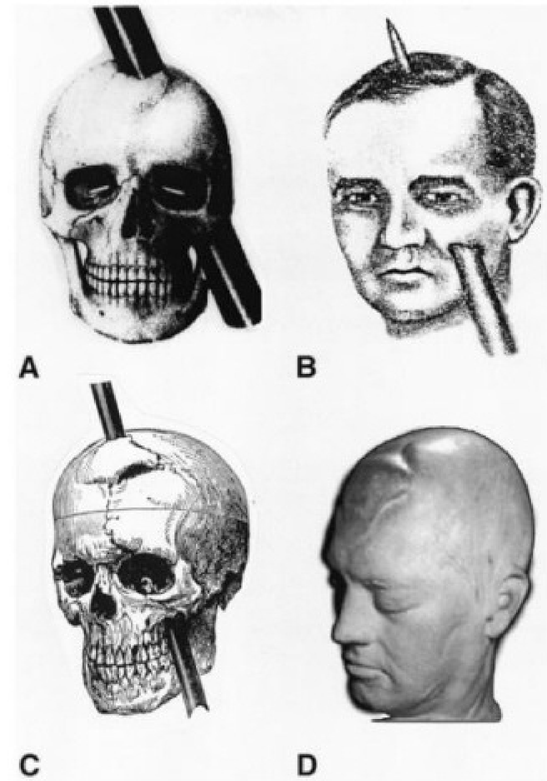
A **lesion** – any abnormal tissue damaged by disease or trauma (from the Latin word *laesio* – injury).

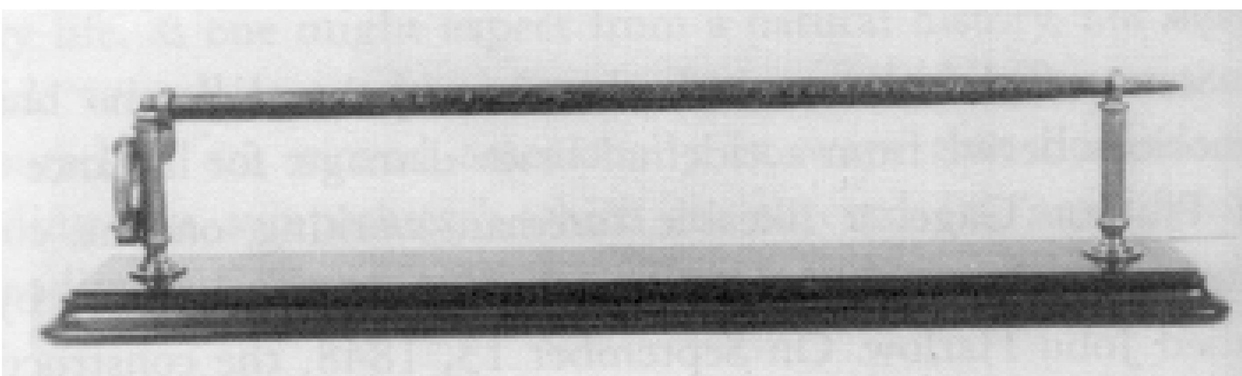
Neuropsychology – discipline that studies lesion in humans and animals, i.e. the structure and function of the brain related to specific psychological processes and overt behaviors.

Phineas P. Gage
(July 9?, 1823 – May 21, 1860)



Skull and death mask of Phineas Gage





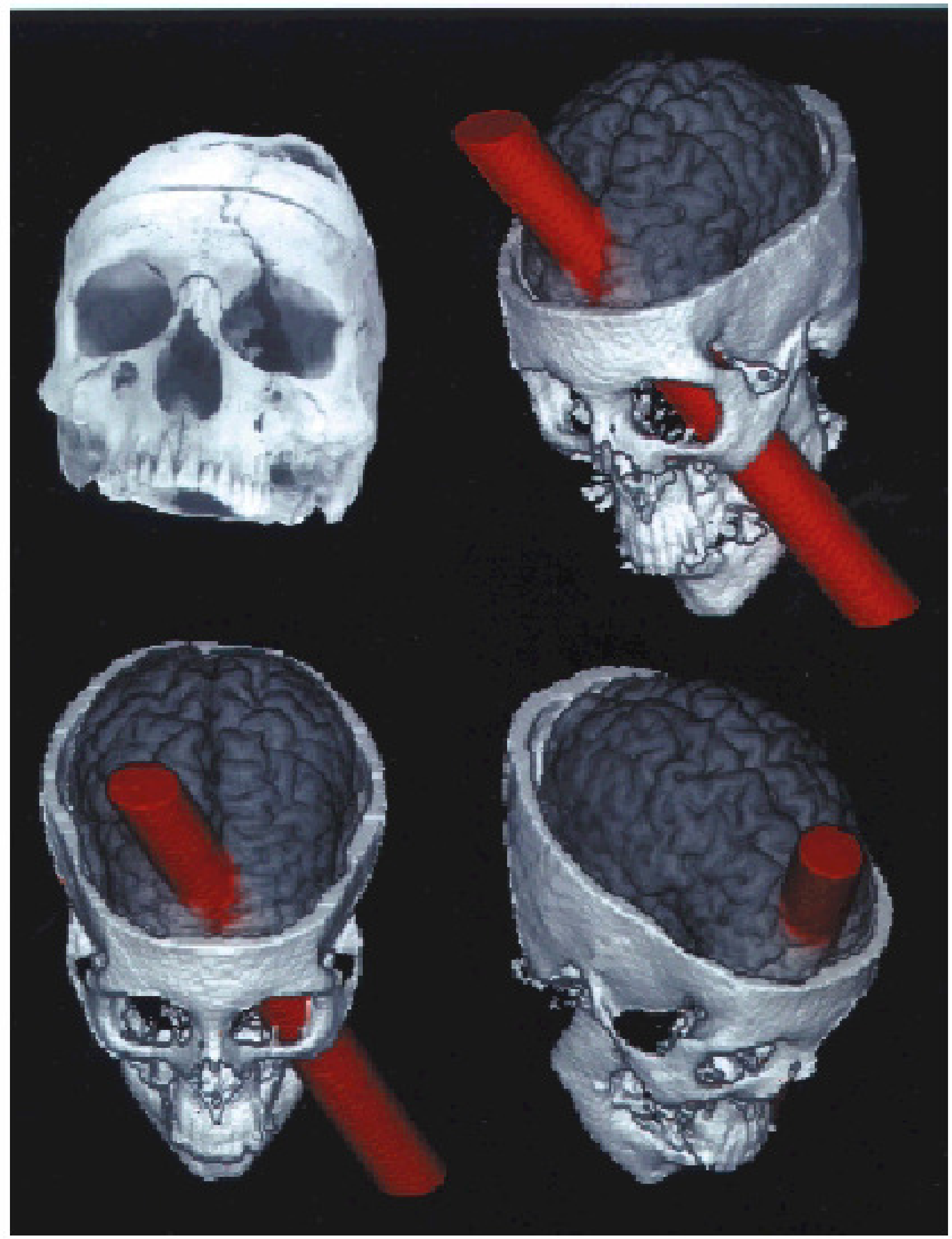
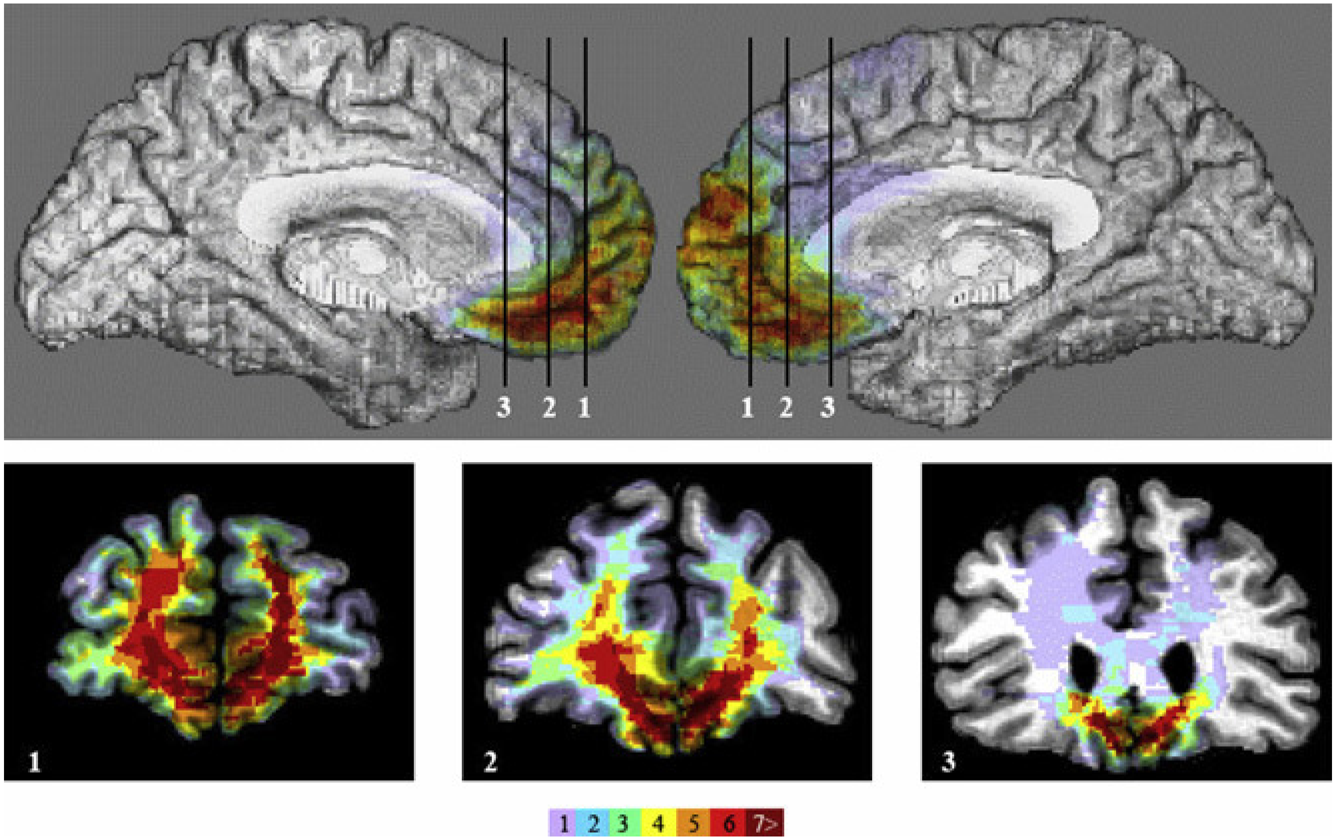


Fig. 1. Reconstruction of the lesion incurred by Phineas Gage, in which an iron bar was driven through his prefrontal cortex as a result of a blasting accident. Courtesy of Hannah Damasio.

Raymond J. Dolan, 1999



Antonio Damasio’s patients:

Orbitofrontal / ventromedial prefrontal cortex

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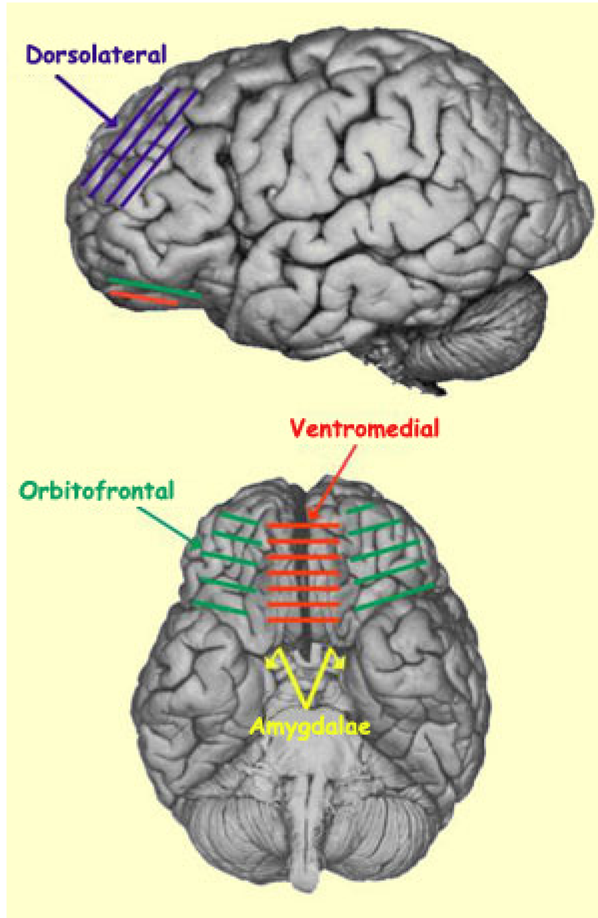
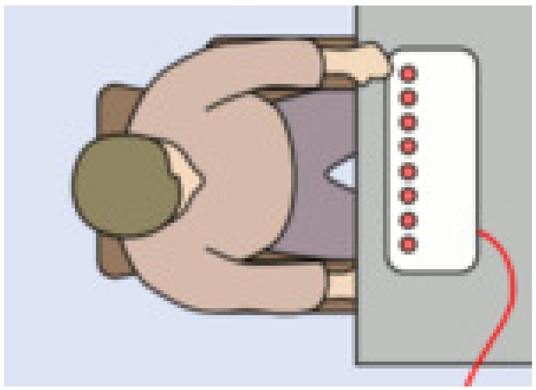
Neuron. 2010 Mar 25;65(6):845-51.

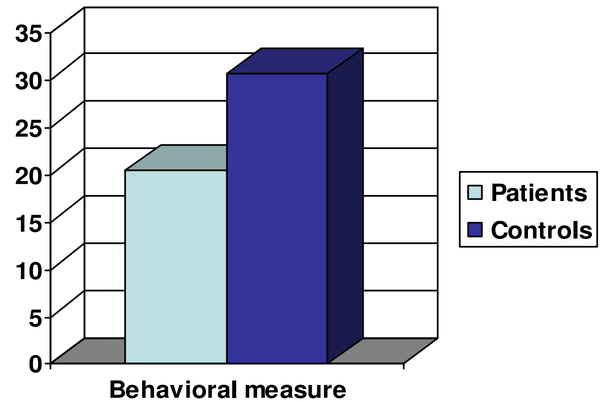


Ventro-medial prefrontal cortex is involved in emotional learning, anticipation of the future positive and negative consequences of the action.

Read “Lesion” results

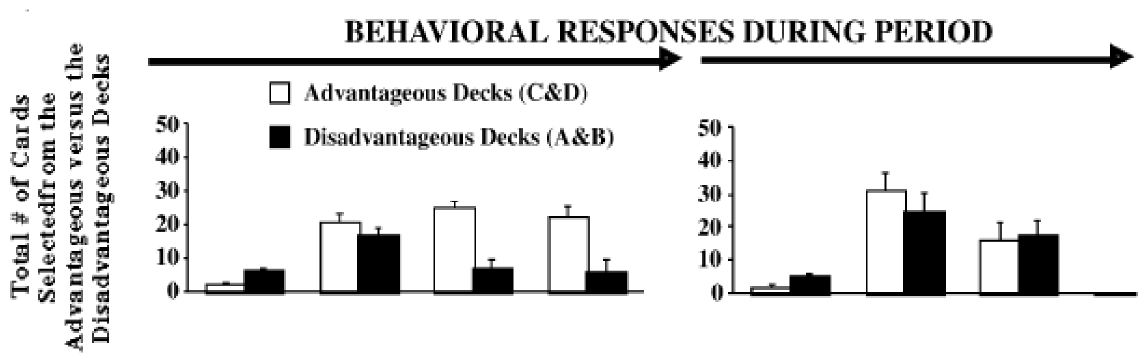
Behavioral responses





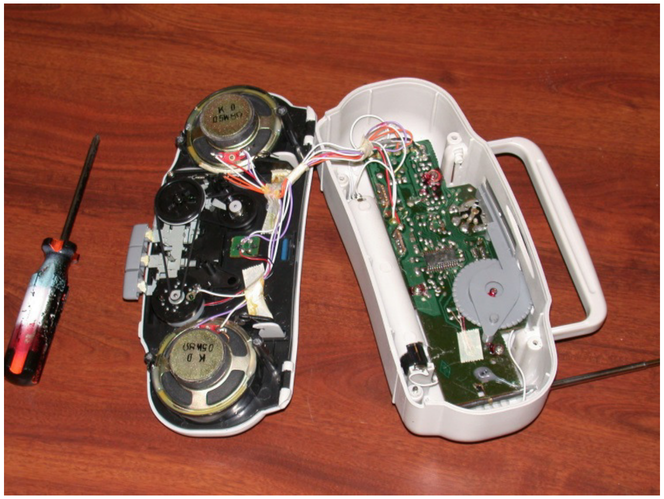
Normal

Ventromedial Prefrontal

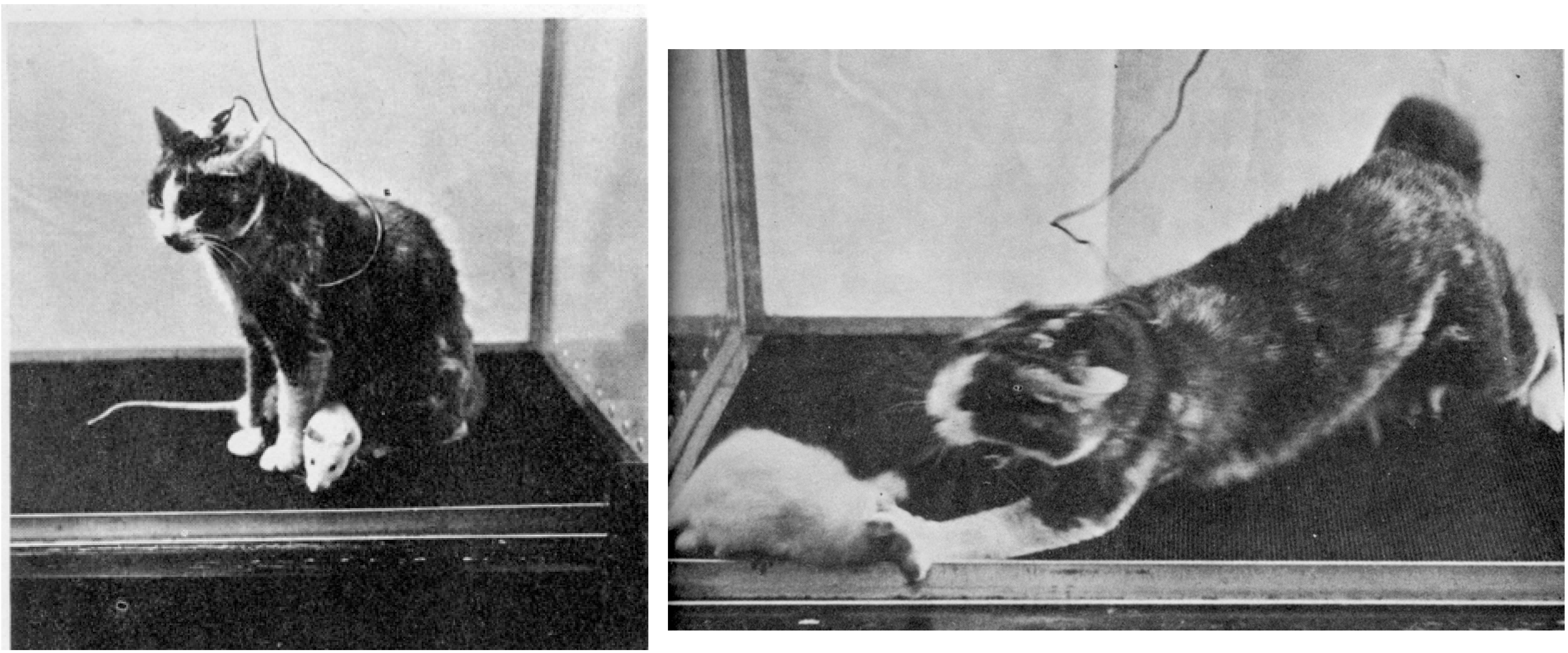


Lesions: Advantages vs. disadvantages

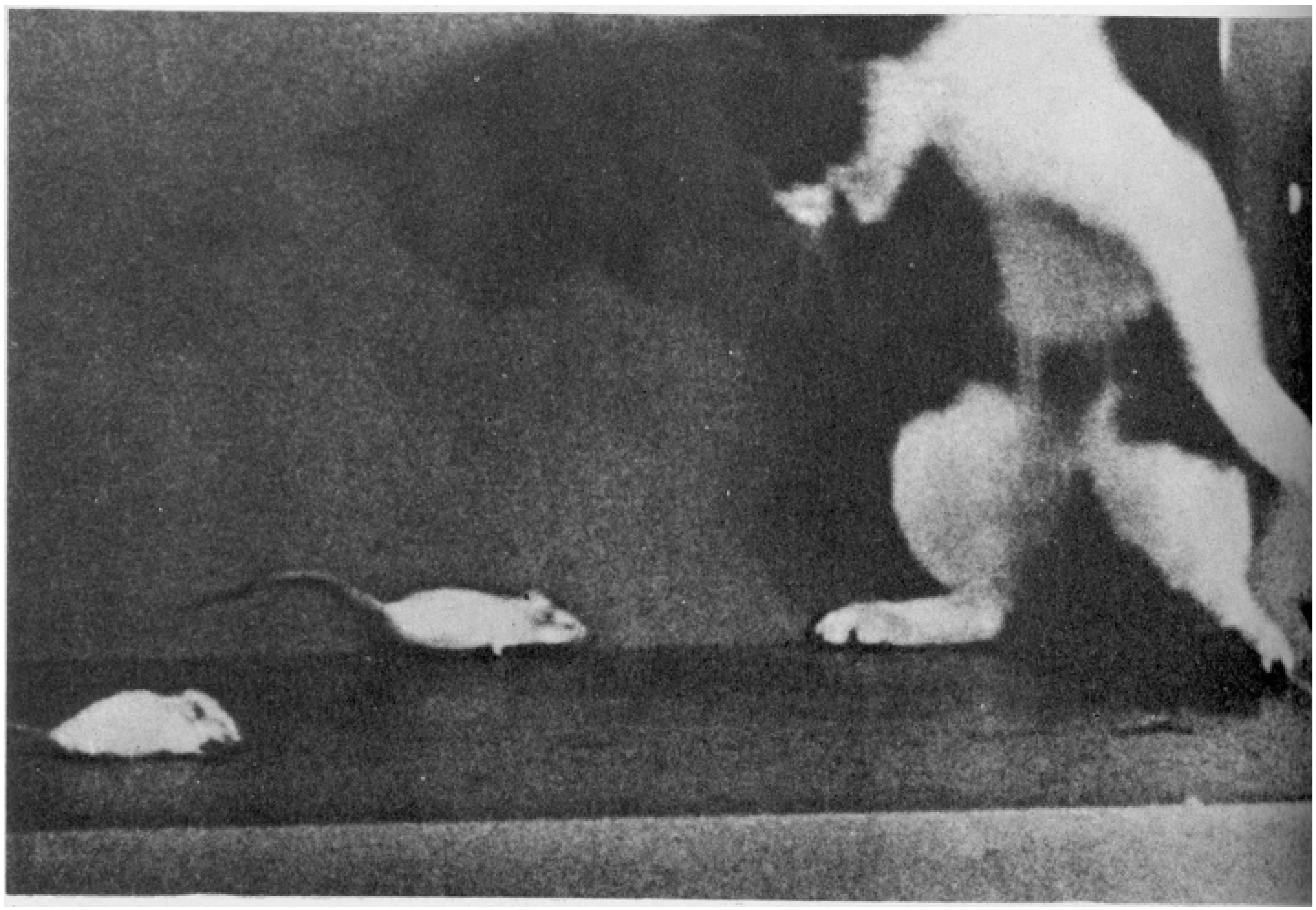
- often rare
- usually not focal
- consequences are long-term
- can be compensated by brain plasticity
- a possibility of fuzzy interpretations
- show the **casual** role of the brain region
- bring unique insights



II. Stimulation of the brain

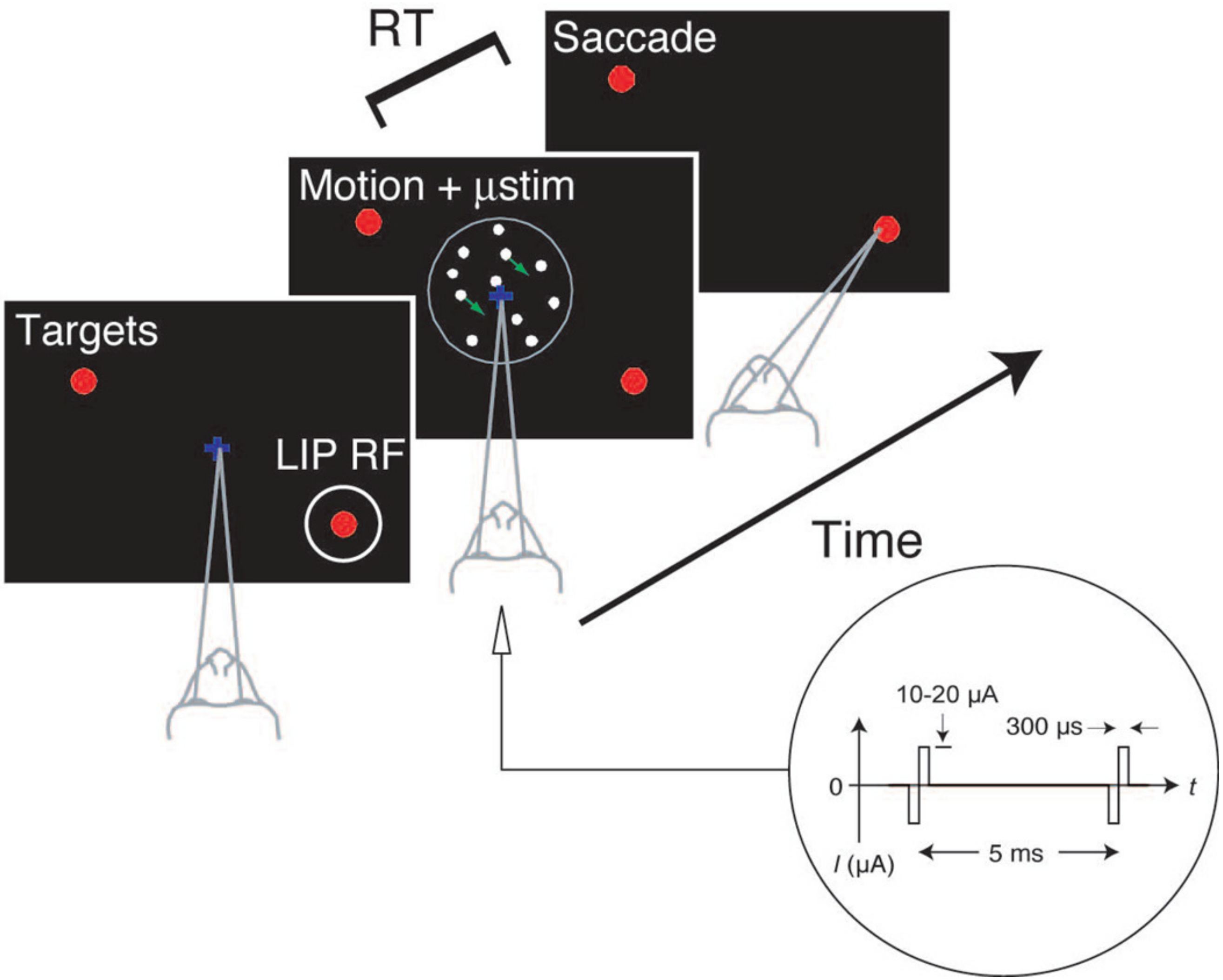


In the 1960s Flynn found that electrical stimulation of lateral hypothalamus elicits predatory aggression in cats, whereas stimulation of the medial hypothalamus elicited vicious attack behaviour.

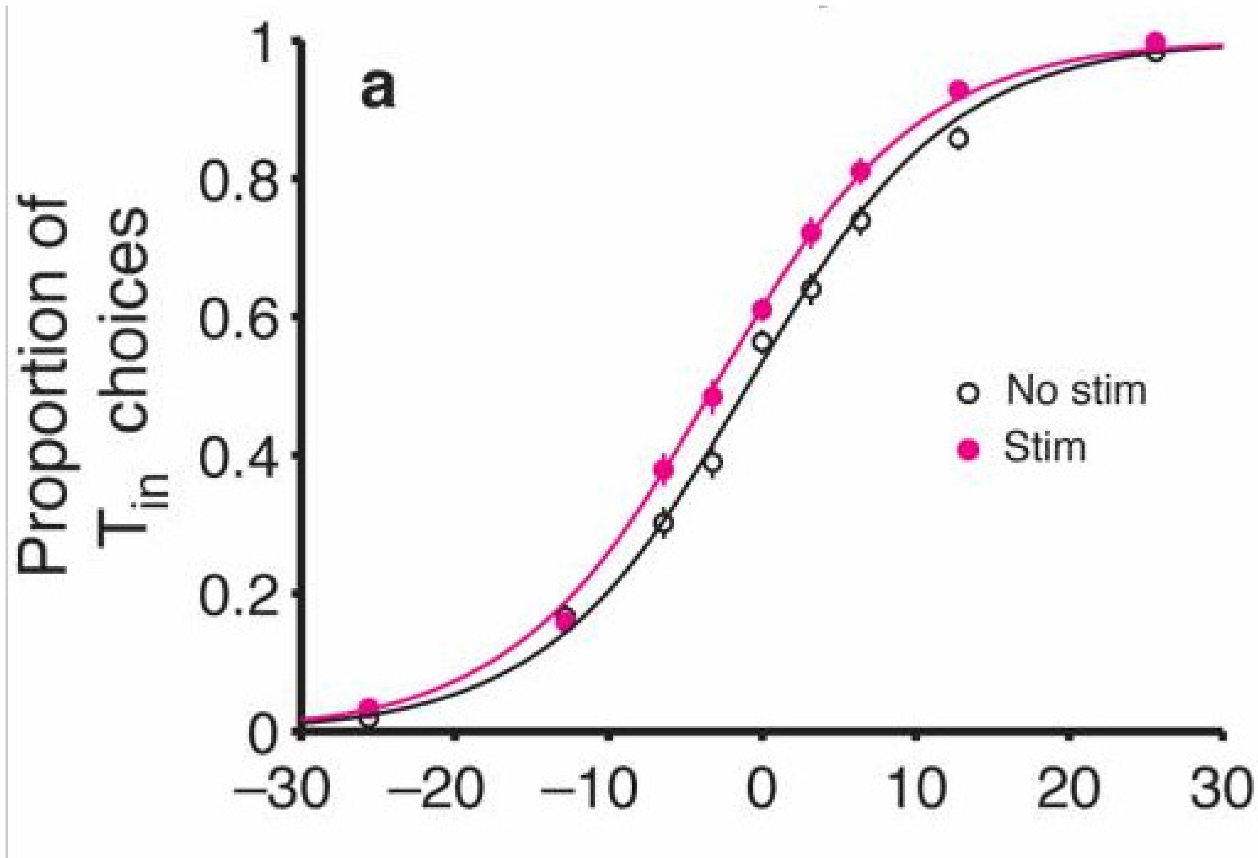


Jose Delgado's "Physical Control of the Mind"

Perceptual decisions



Nat Neurosci. May 2006; 9(5): 682–689.



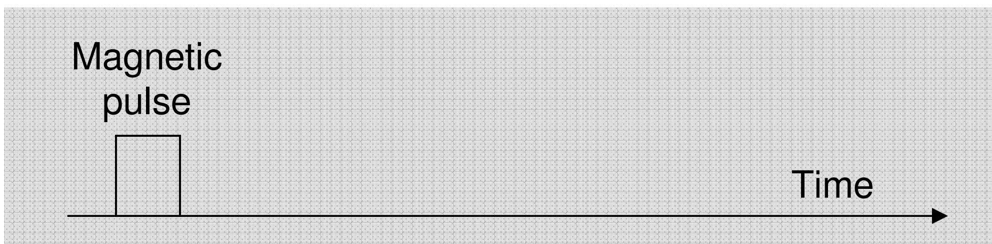
Nat Neurosci. May 2006; 9(5): 682–689.

Stimulation: Advantages vs. Disadvantages

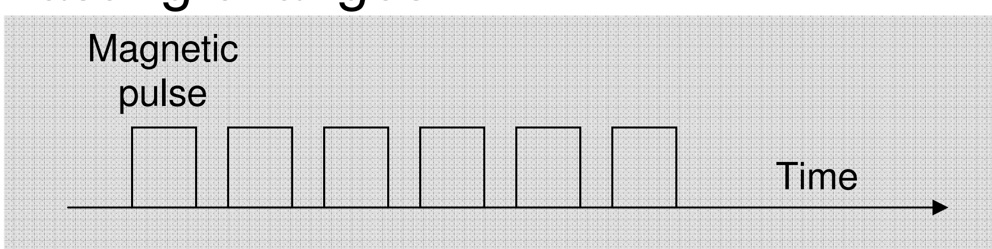
- Short-term effects
- Invasive (damages tissues)
- Normally can not be applied to humans
- Relatively not-focal, i.e. you could unintentionally stimulate many regions at the same time
- Possible fuzzy interpretations (similar to lesions study)

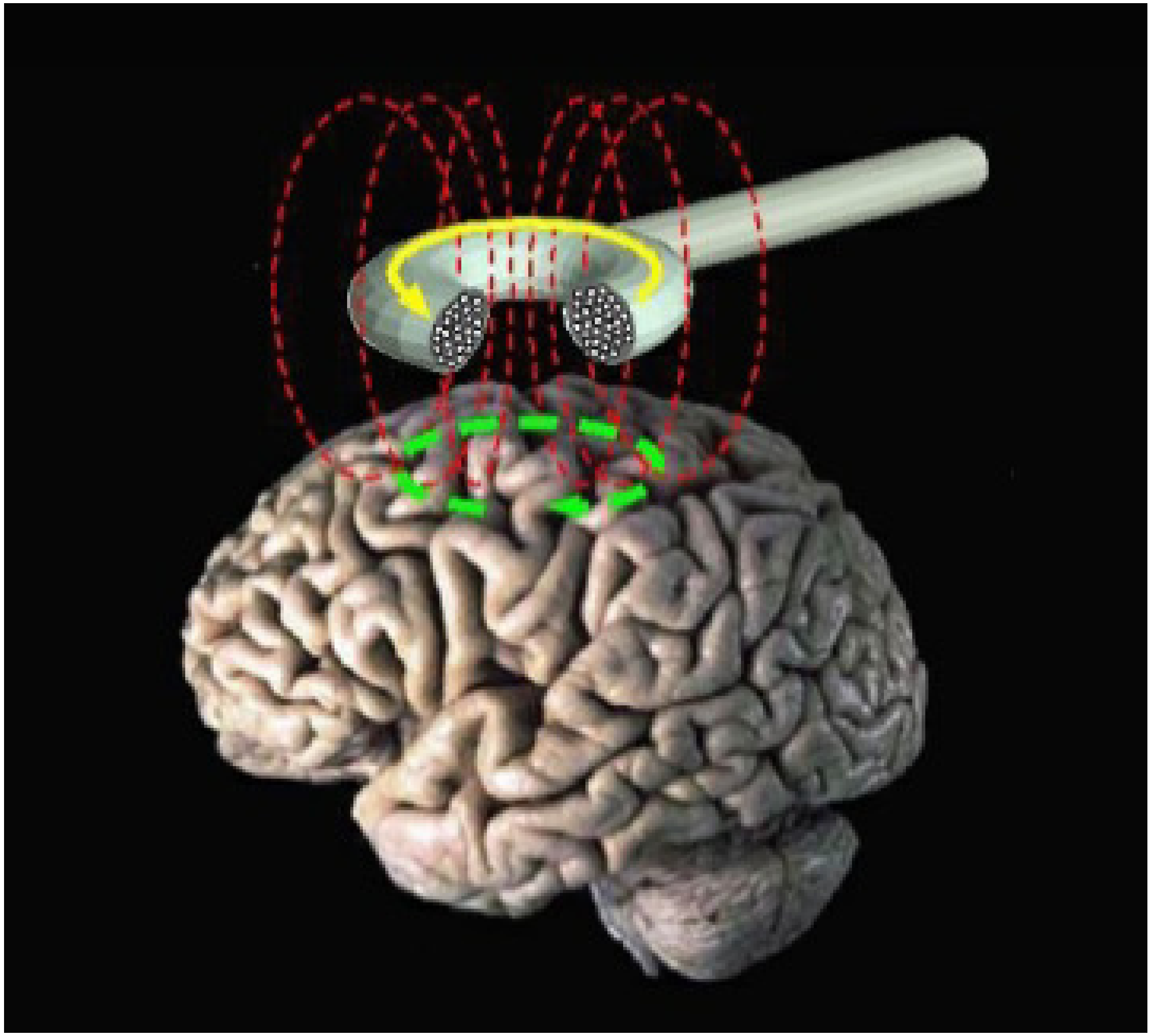
III. TMS – Transcranial Magnetic Stimulation

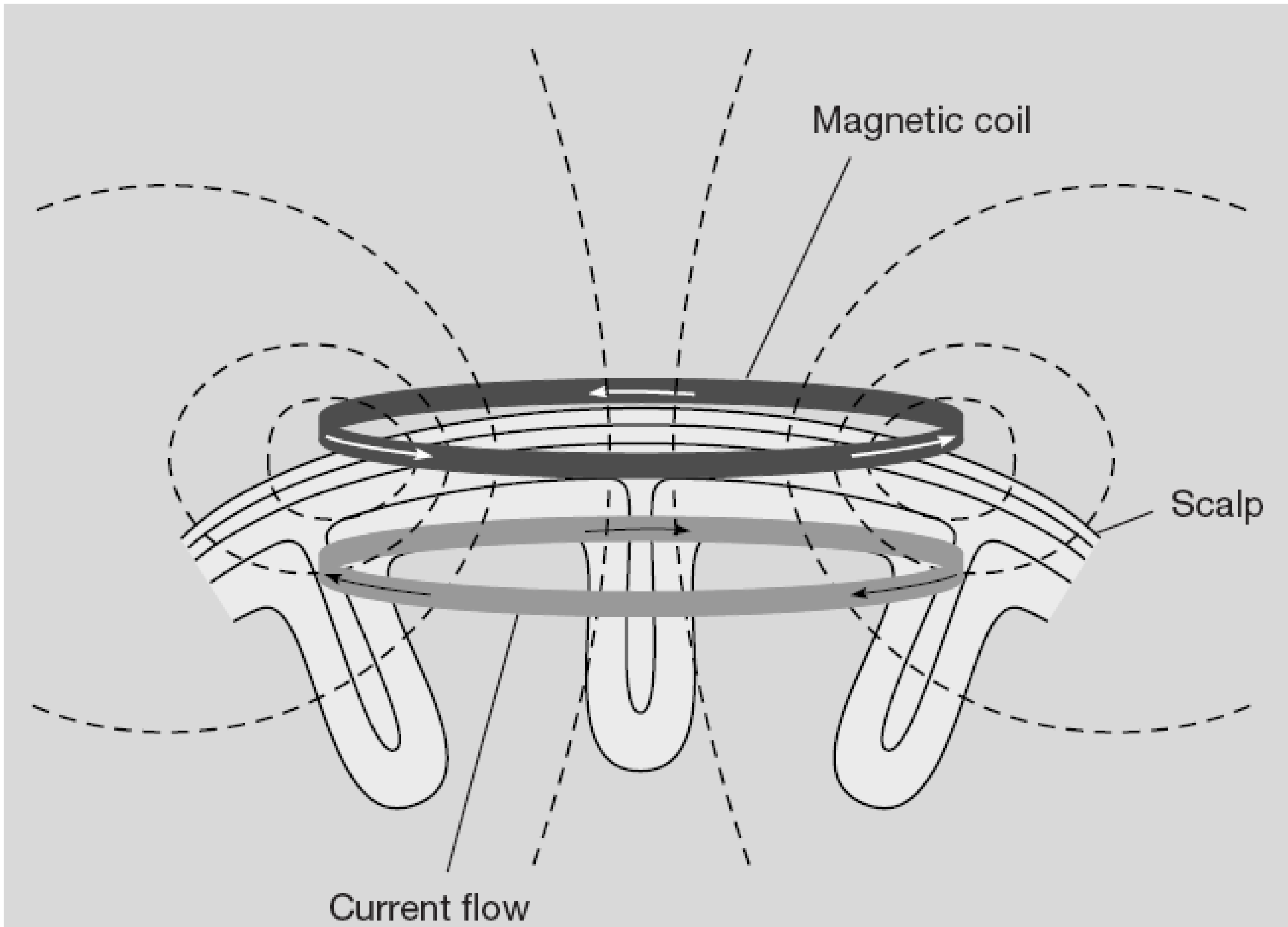
TMS - rapidly changing magnetic fields (electromagnetic induction) induce weak electric currents in the brain, i.e. affect neurons.



Repetitive **TMS** (rTMS) – repetitive TMS pulses. rTMS produce longer lasting changes.






Magnetic coil
Scalp
Current flow

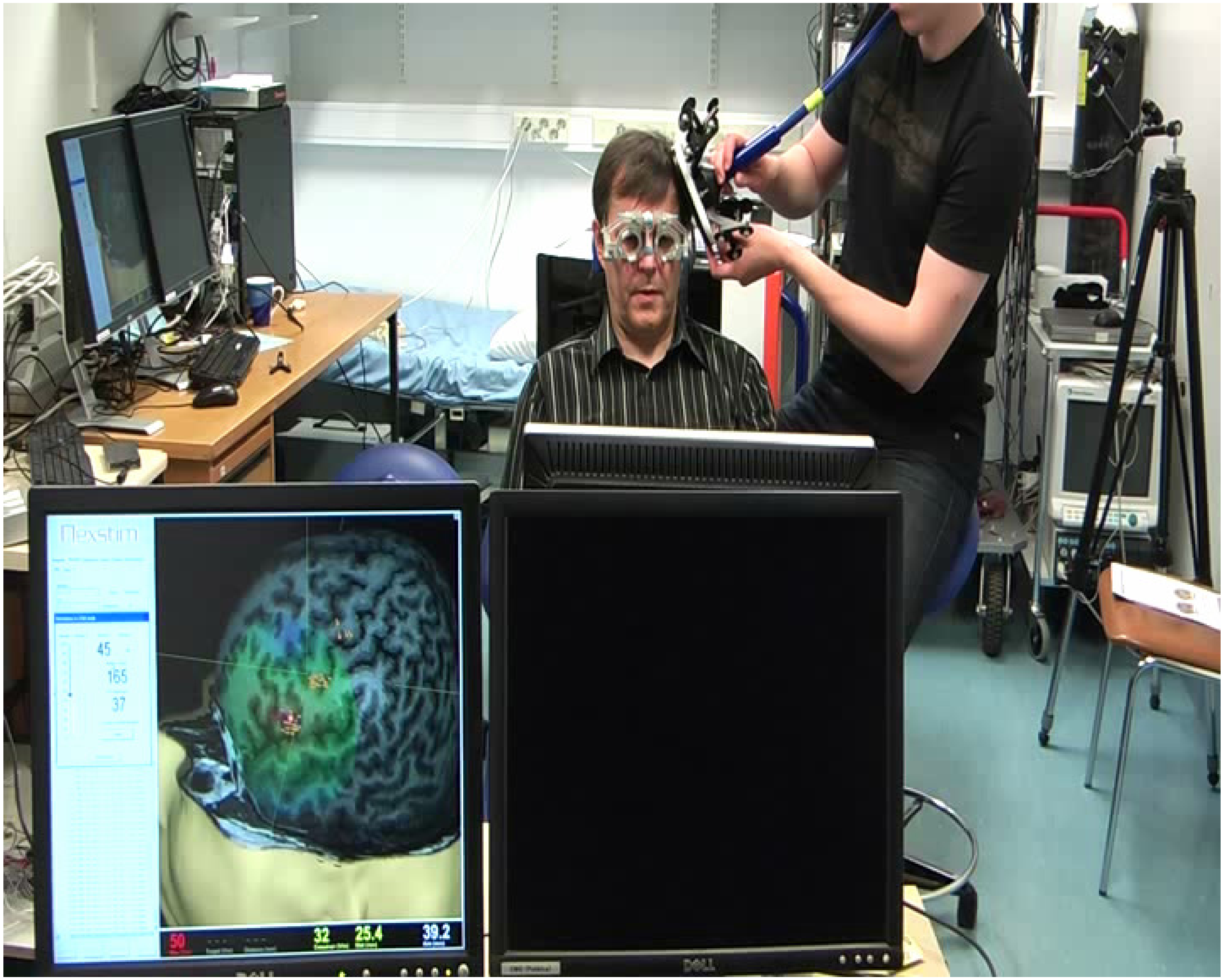
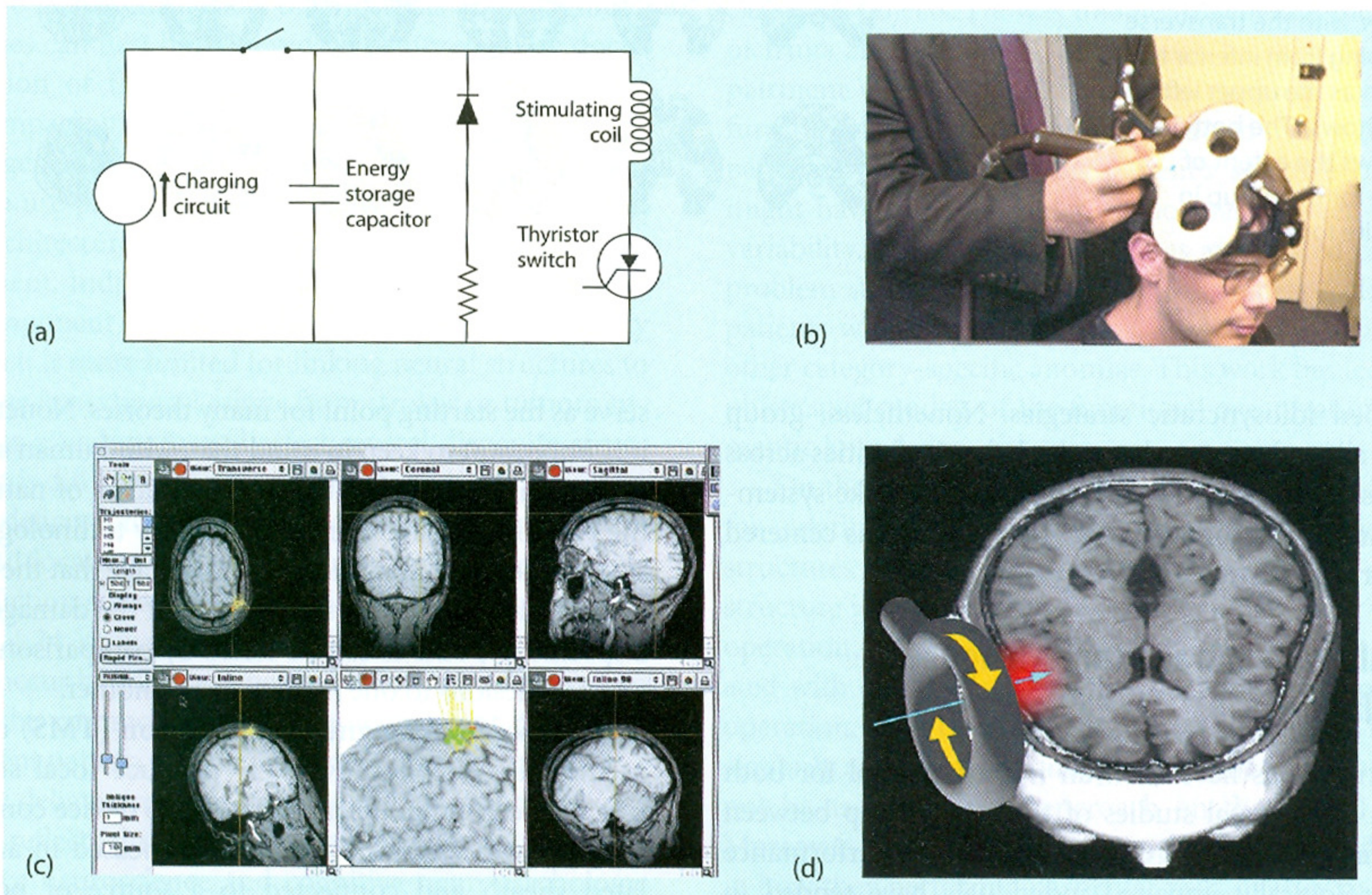
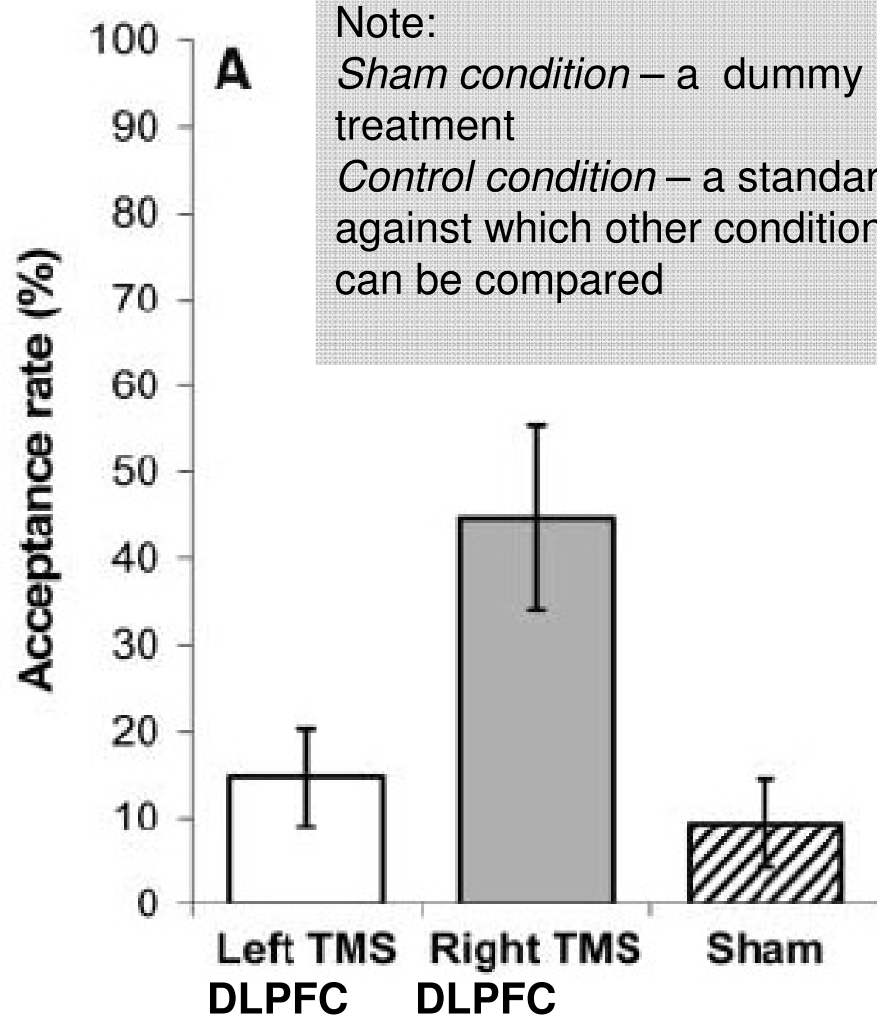

nexstim
45
165
37
50
32
25.4
39.2
DELL

Figure 4.25 Transcranial magnetic stimulation. **(a)** This schematic shows the electrical circuit used to induce the TMS pulse. **(b)** Here the TMS coil is being applied by an experimenter. Both the coil and the subject have affixed to them a tracking device to monitor the head/coil position in real time. **(c)** The subject's MRI can be used along with the tracking system to display the cortical area being targeted. **(d)** The TMS pulse directly alters neural activity in a spherical area of approximately 1 cm^3.



Read TMS results

Figure Acceptance rates of unfair financial offers across treatment groups. Subjects whose right DLPFC is disrupted exhibit a much higher acceptance rate than those in the other two treatment groups.

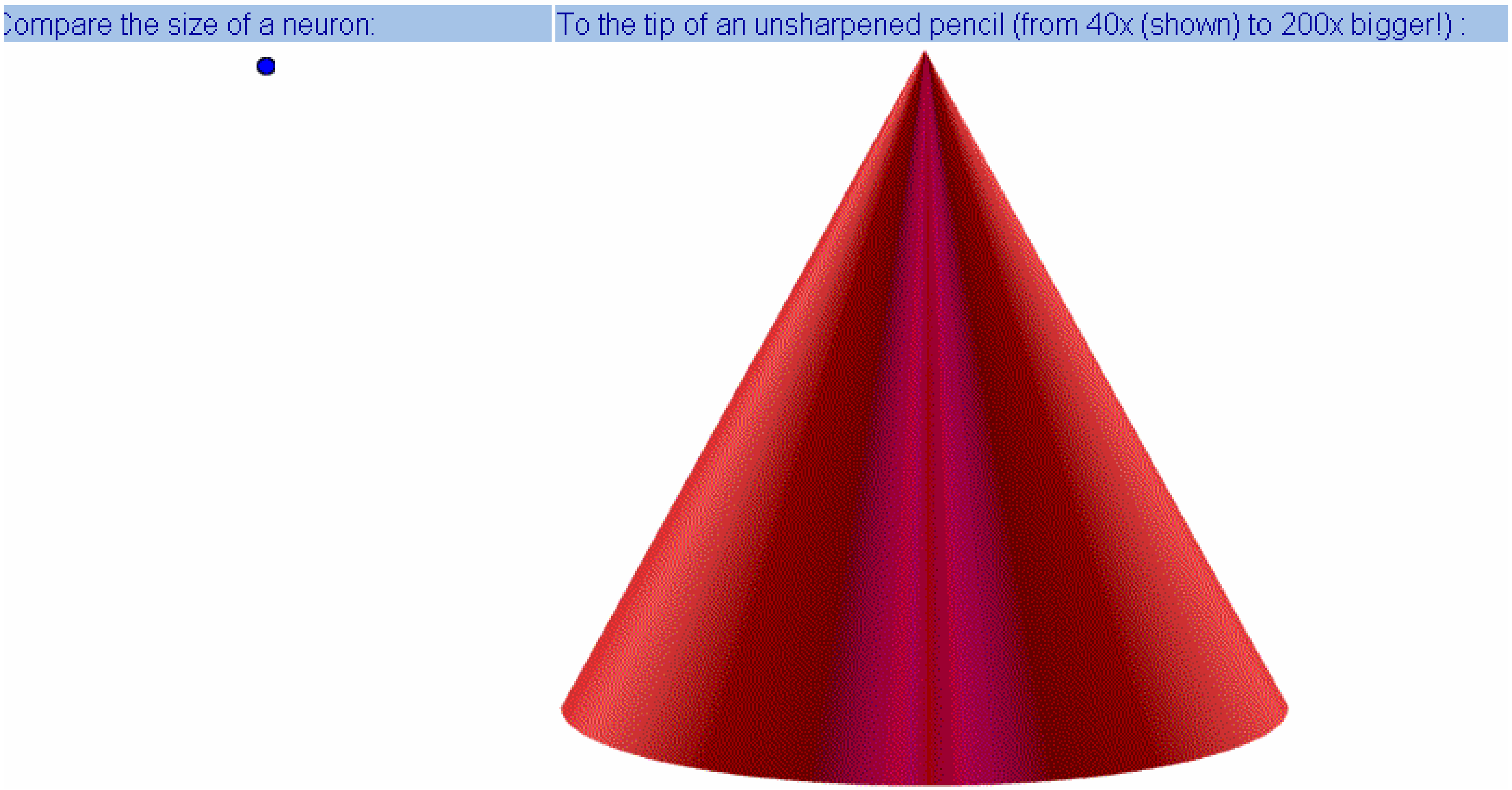


Note:
Sham condition – a dummy treatment
Control condition – a standard against which other conditions can be compared

SCIENCE VOL 314 3 NOVEMBER 2006

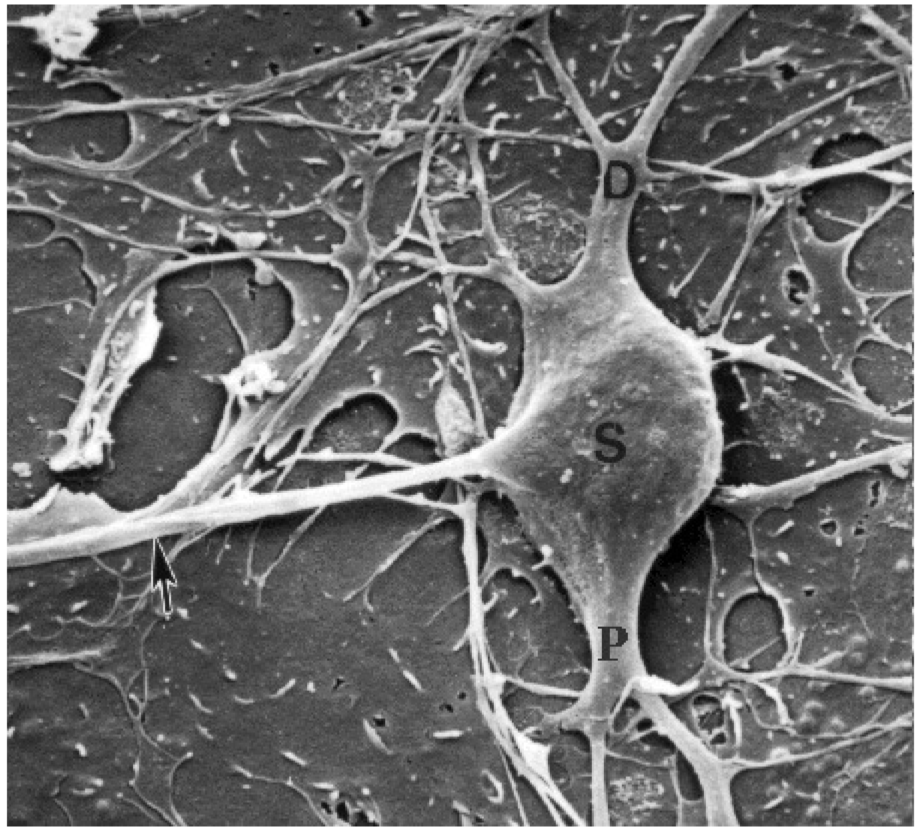
TMS:
Advantages vs. disadvantages

- Transient or long-term effects
- Shows causal neural mechanisms
- Difficult to stimulate deep brain areas
- There are medical limits for MF exposure
- Produces loud sounds and muscles constructions
- A mild risk of epileptic seizures

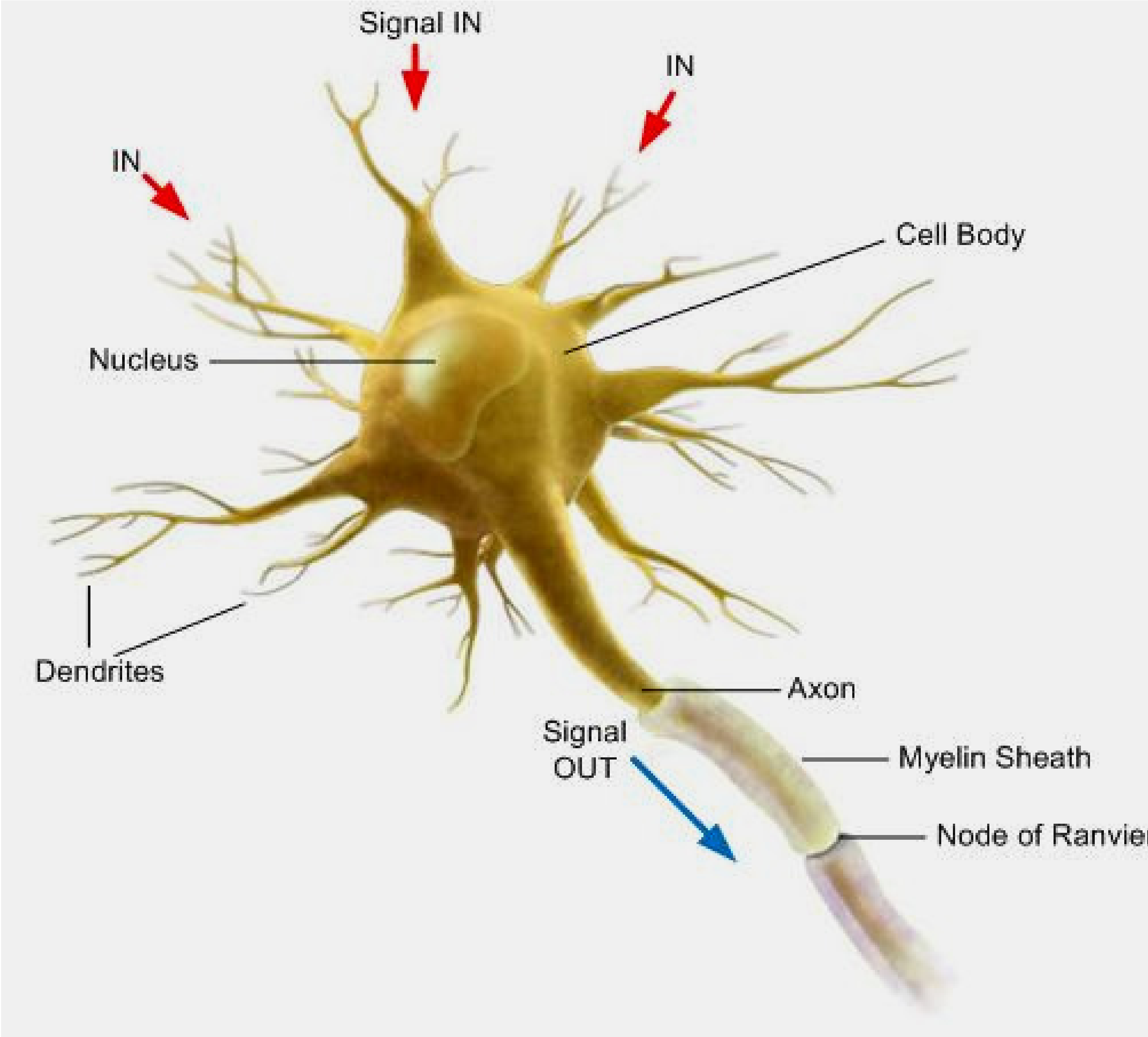


The typical size of neurons is between 10 - 50 micrometers (1 µm, 0.000001 meters)

http://www.ualberta.ca/~neuro/OnlineIntro/NeuronExample.htm

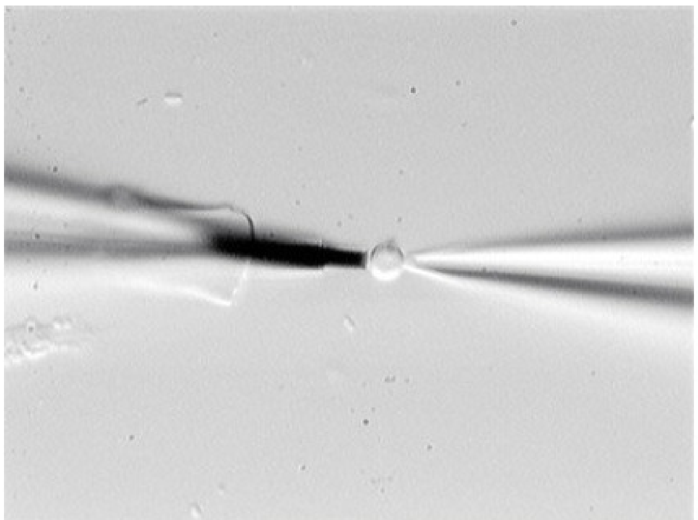


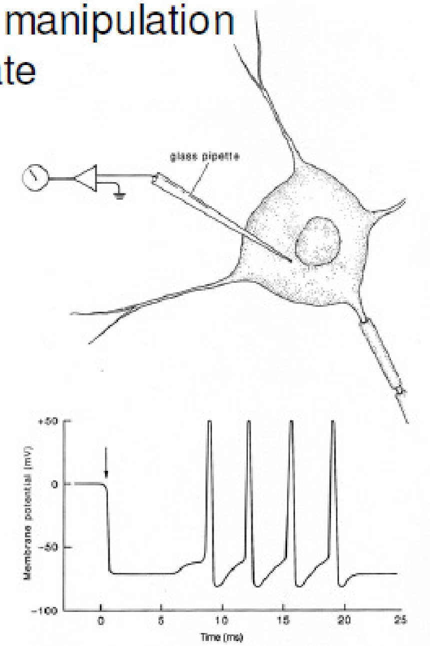
http://faculty.fortlewis.edu/KENDALL_D/Physiology%20Web


Signal IN
IN
IN
Cell Body
Nucleus
Dendrites
Axon
Signal
OUT
Myelin Sheath
Node of Ranvier

Single cell recording

Single cell recording – Determine experimental manipulation that produce a consistent change in of the firing rate



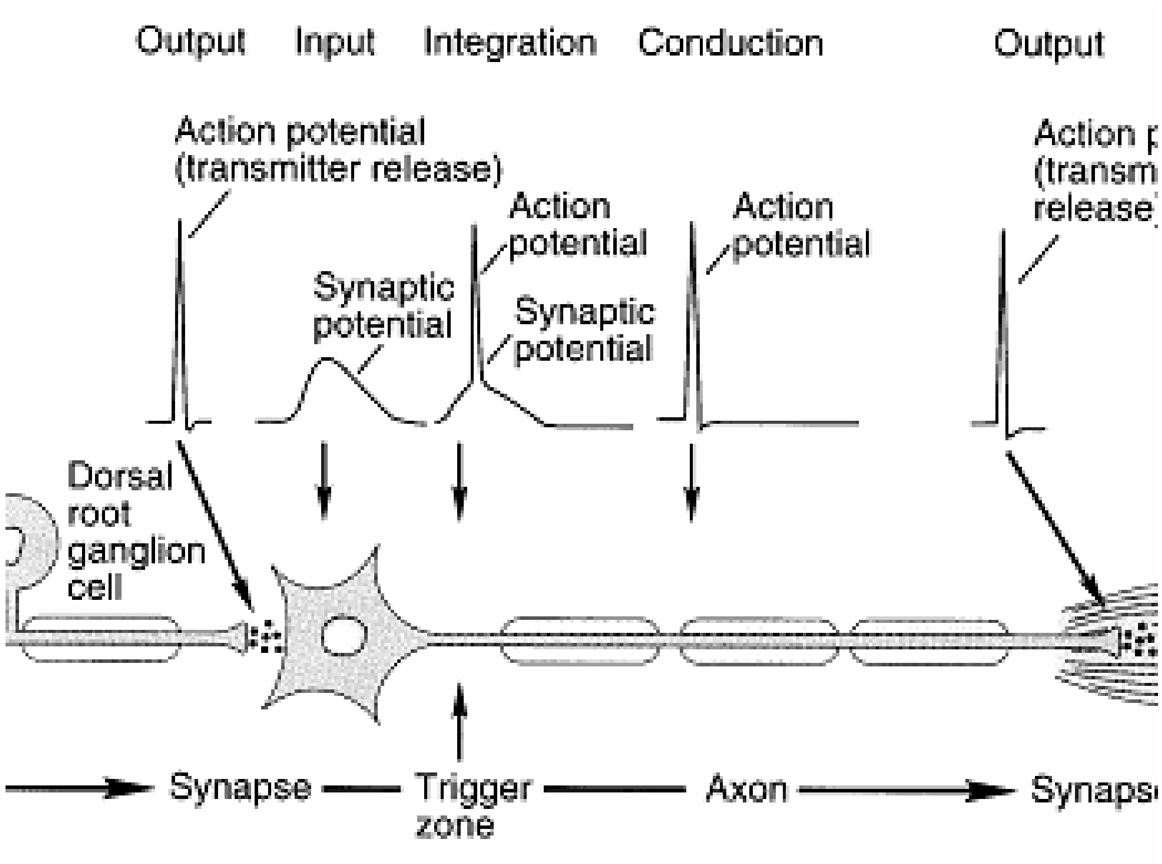


The fiber diameter is 6 µm

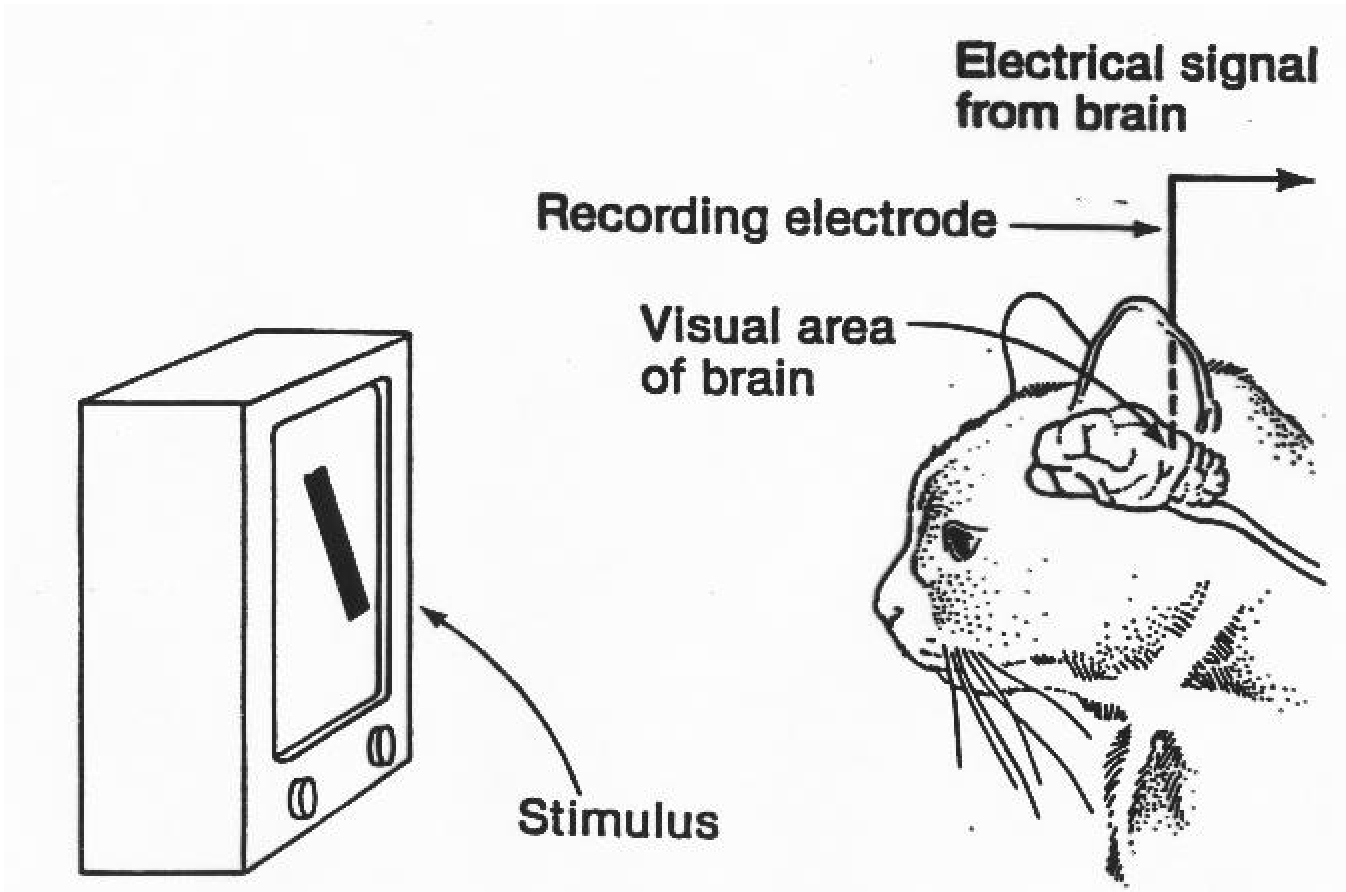
Firing rate – average number of action potentials

http://www.vandenhul.com/artpap/lsc-neuro.htm

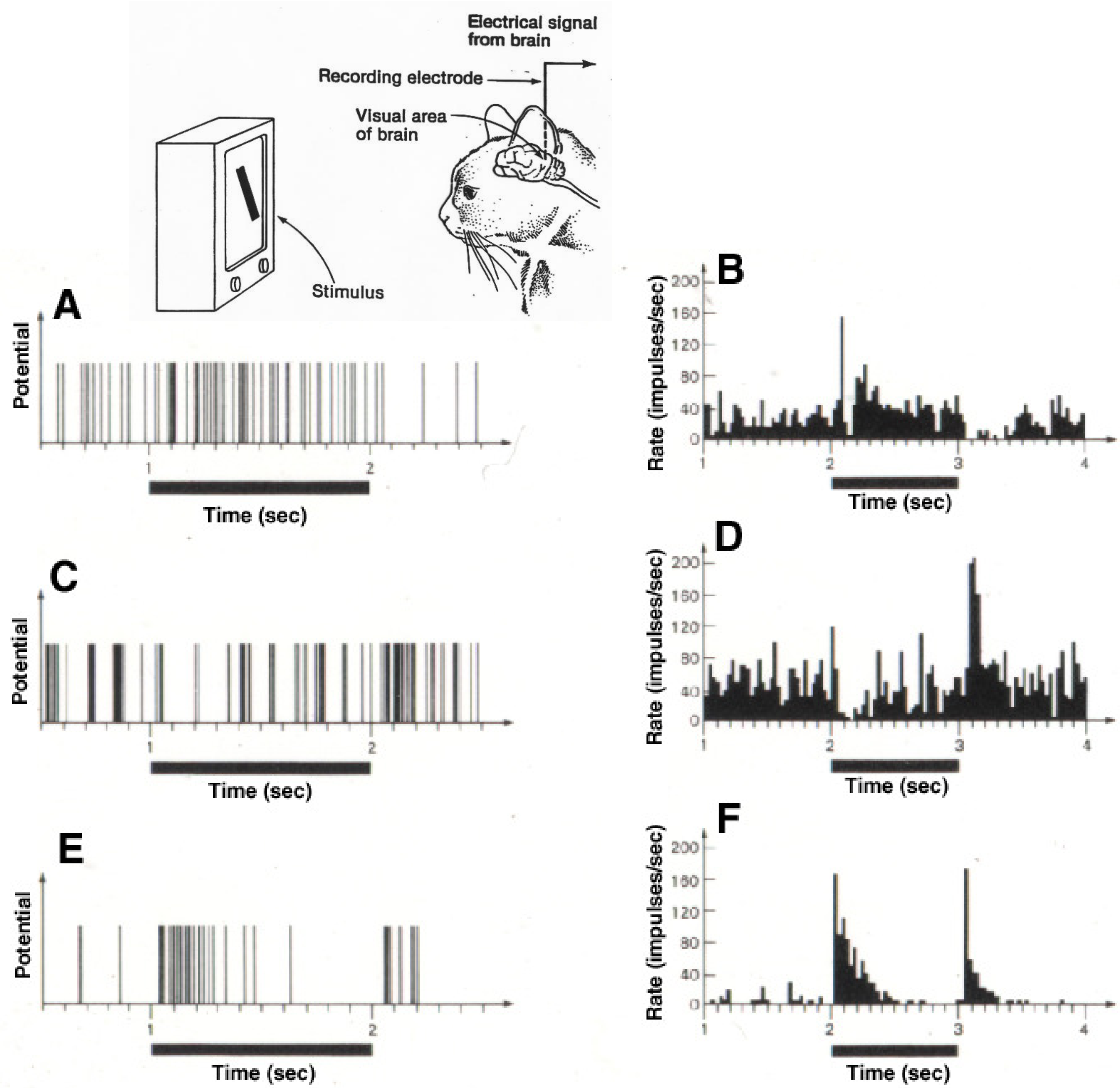
Firing rate – average number of action potentials



The neuron can be modelled as a computational element which sums its inputs within its time-constant and, whenever this sum, minus inhibitory effects, exceeds a threshold, produces an action potential which propagates to all of its outputs.

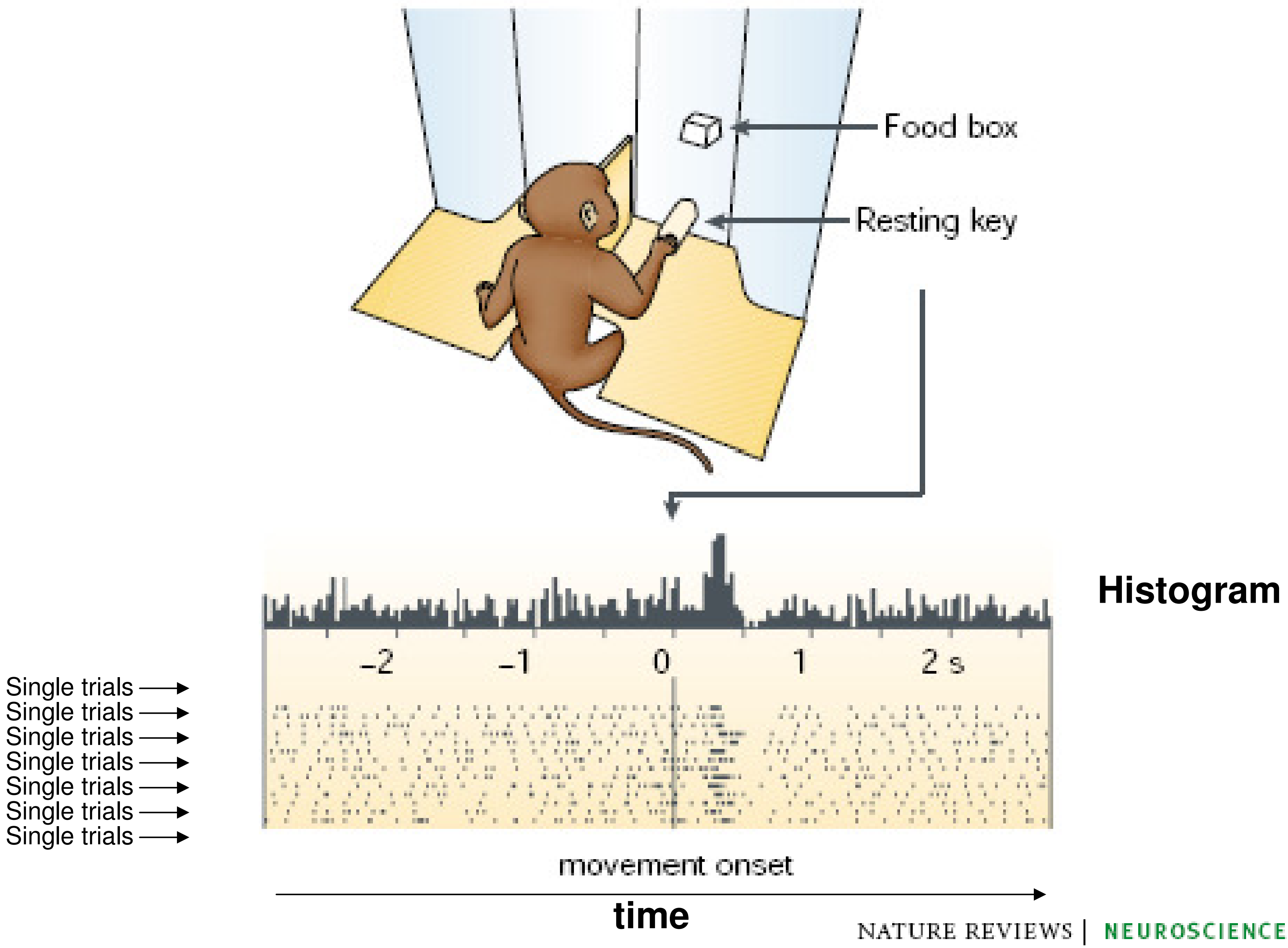


www.caip.rutgers.edu/~feher/SandP/prep1_5.html



Single spikes **Histograms**

Read results

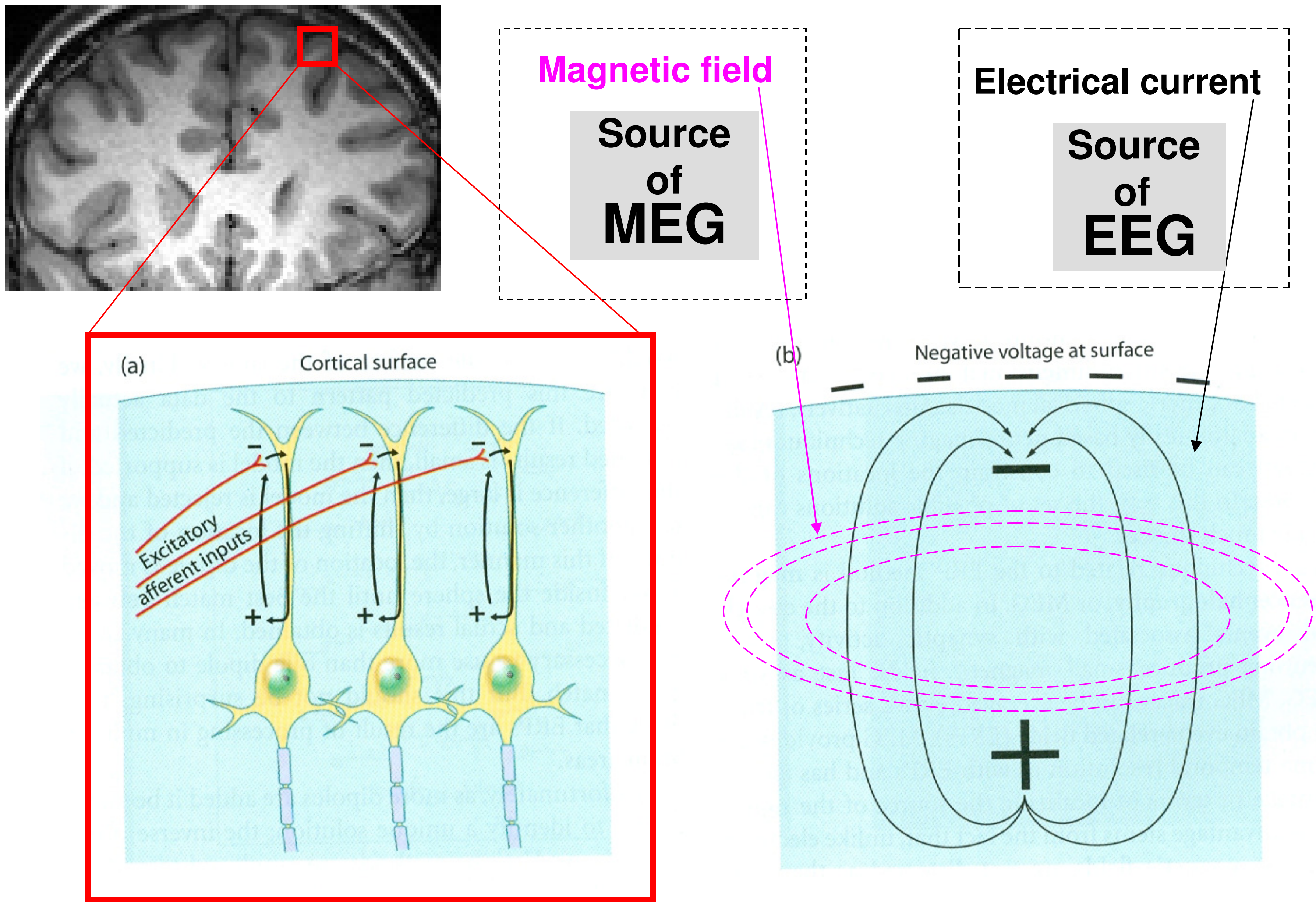


Single-/multi-unite recording: Advantages vs. disadvantages

- The only direct measure of neuronal activity
- Invasive (needs an operation)
- Limited to few neurons
- Unclear information code

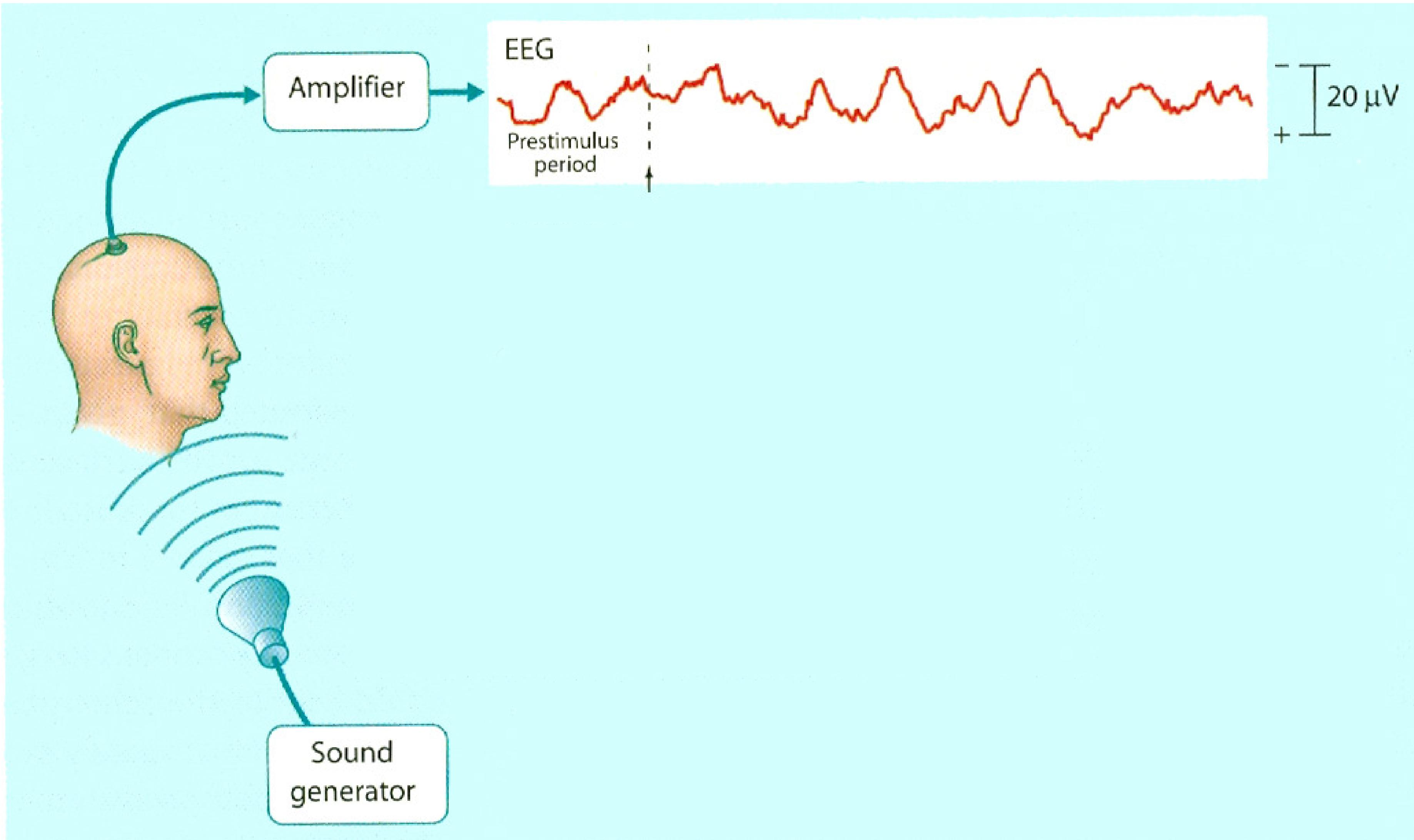
V. EEG & MEG

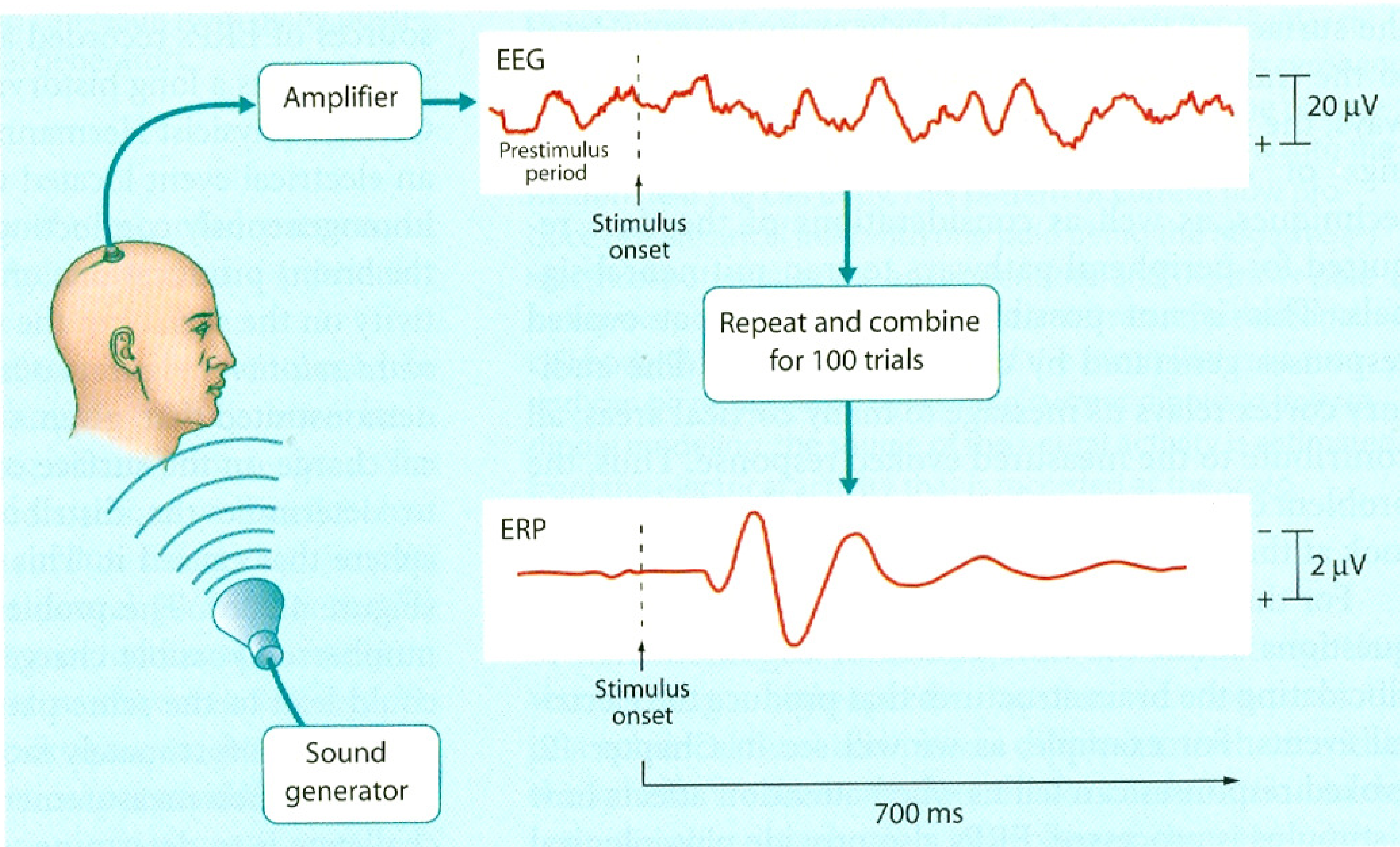
- Electroencephalography (EEG) is the recording of electrical activity along the scalp produced by the firing of neurons within the brain.
- Magnetoencephalography (MEG) measures the magnetic fields produced by electrical activity in the brain.



Magnetic field
Source of MEG
Electrical current
Source of EEG
(a)
Cortical surface
Excitatory afferent inputs
(b)
Negative voltage at surface


FP1-F3
FP2-F4
F3-C3
F4-C4
C3-P3
C4-P4
P3-O1
P4-O2
FP1-F7
FP2-F8
F7-T3
F8-T4
T3-T5
T4-T6
T5-O1
T6-O2

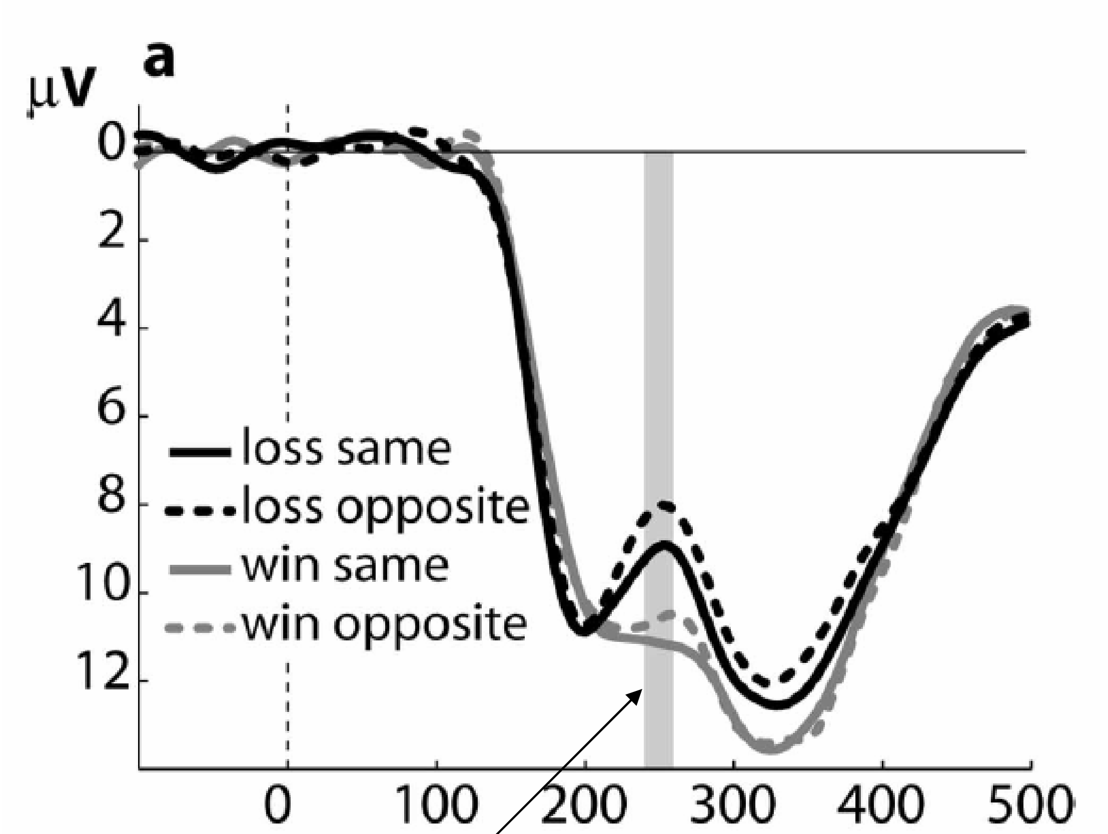

Amplifier
EEG
Prestimulus
period
−
20 μV
+
Sound
generator

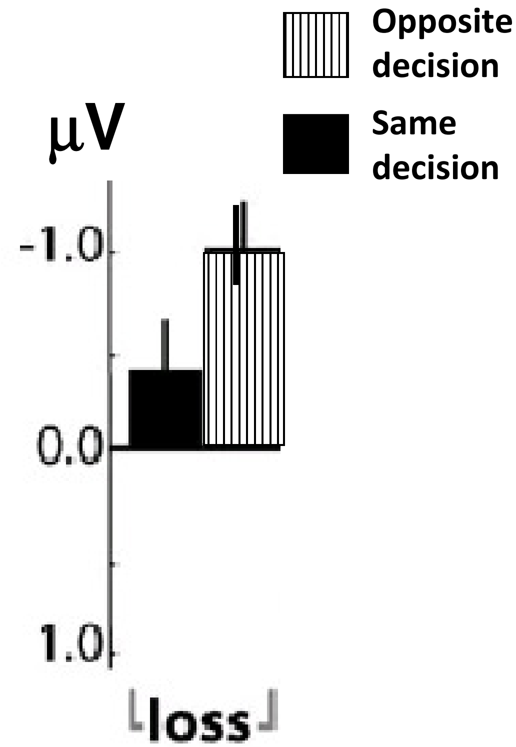

Amplifier
EEG
Prestimulus
period
Stimulus
onset
20 μV
Repeat and combine
for 100 trials
ERP
Stimulus
onset
2 μV
Sound
generator
700 ms

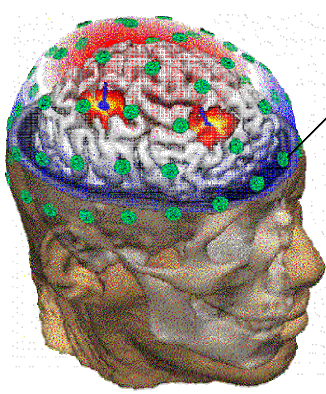
Matching pennies

The game is played between two players, Player A and Player B.
Each player has a penny and must secretly turn the penny to heads or tails.
If the pennies match (both heads or both tails) Player A keeps both pennies.

If the pennies do not match (one heads and one tails) Player B keeps both pennies,

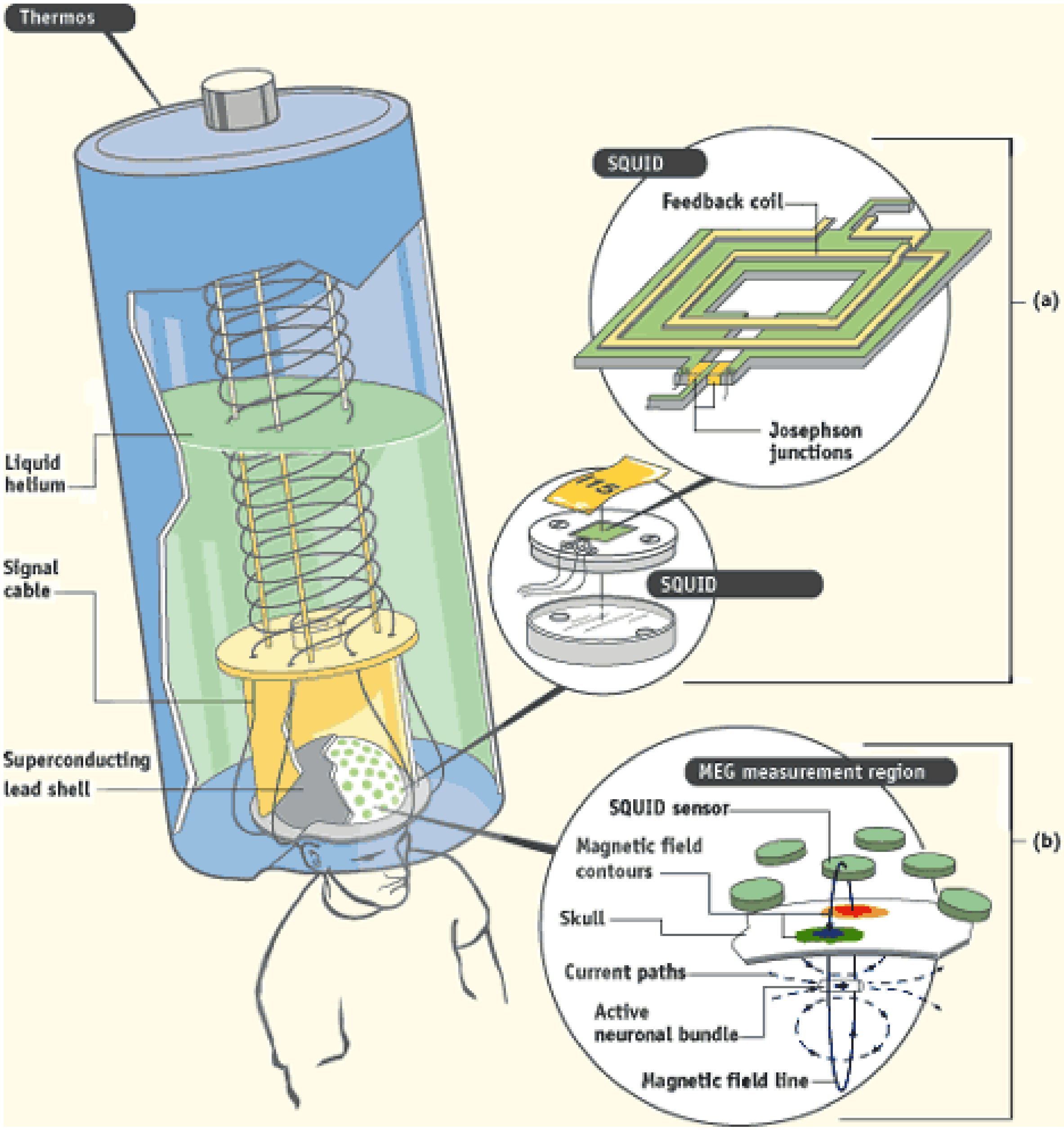






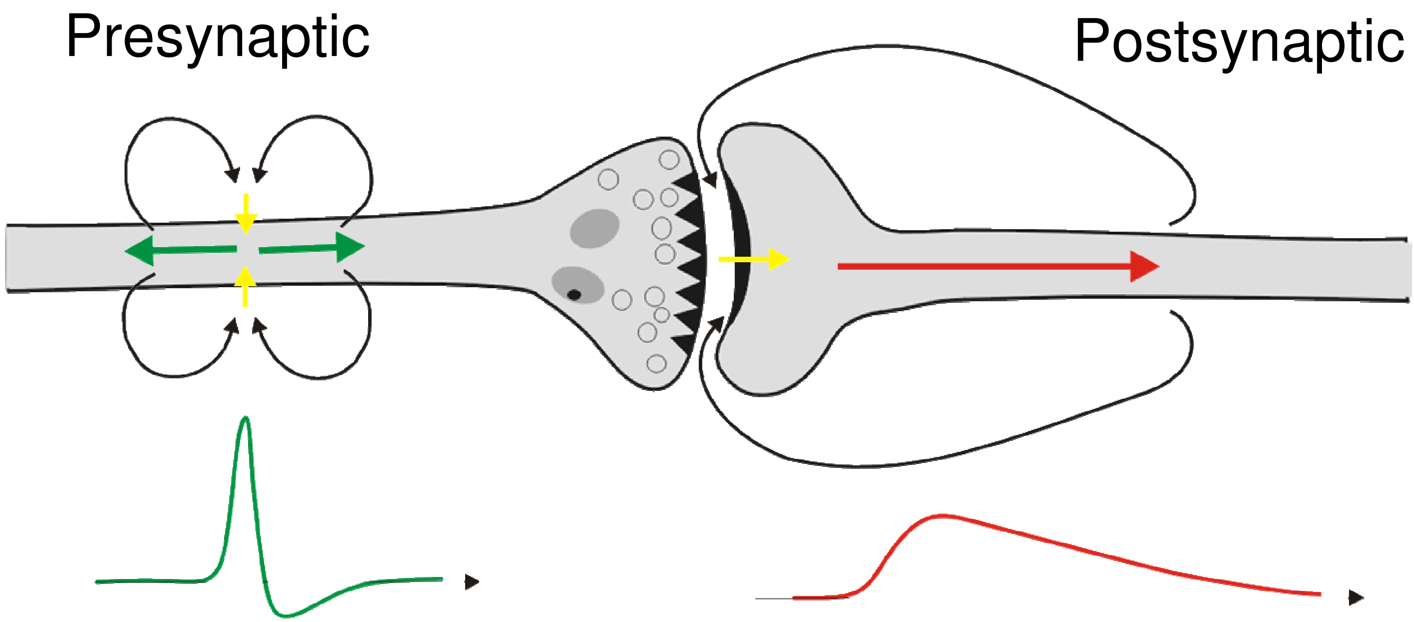
Feedback-locked ERPs sorted according to current outcome and future decision. ERPs after losses (black) and wins (gray) separated according to whether subjects chose the opposite (dashed lines) or the same (solid lines) target on the following trial as on the current trial. Light gray bar indicates time window used for analyses.

Cohen, M. X et al. J. Neurosci. 2007;27:371-378



MEG measures the magnetic fields produced by electrical activity in the brain via extremely sensitive devices such as superconducting quantum interference devices (SQUIDs).

Currents in axons and dendrites



Action potentials:

- Fast: no/little temporal summation
- Cancellation: fields diminish rapidly

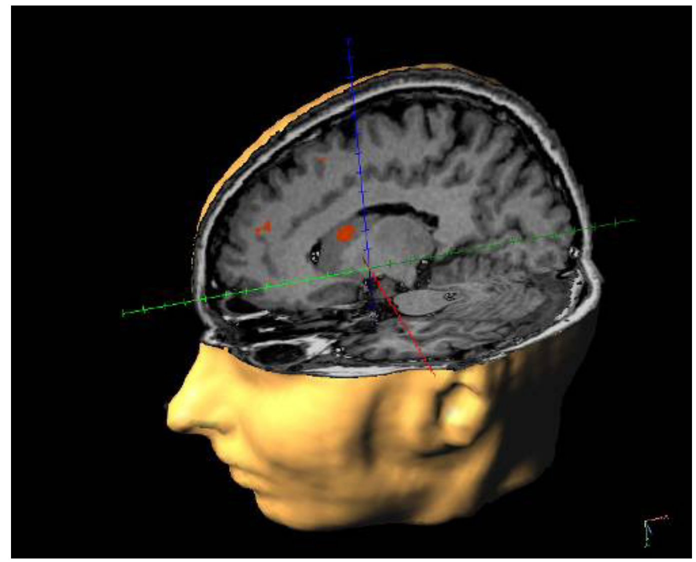
Postsynaptic potentials:

- Longer lived
- Main source of MEG and EEG

Advantages vs. disadvantages of MEG and EEG

- EEG is cheap
- MEG is quite expensive
- Perfect time resolution
- Relatively bad spatial resolution

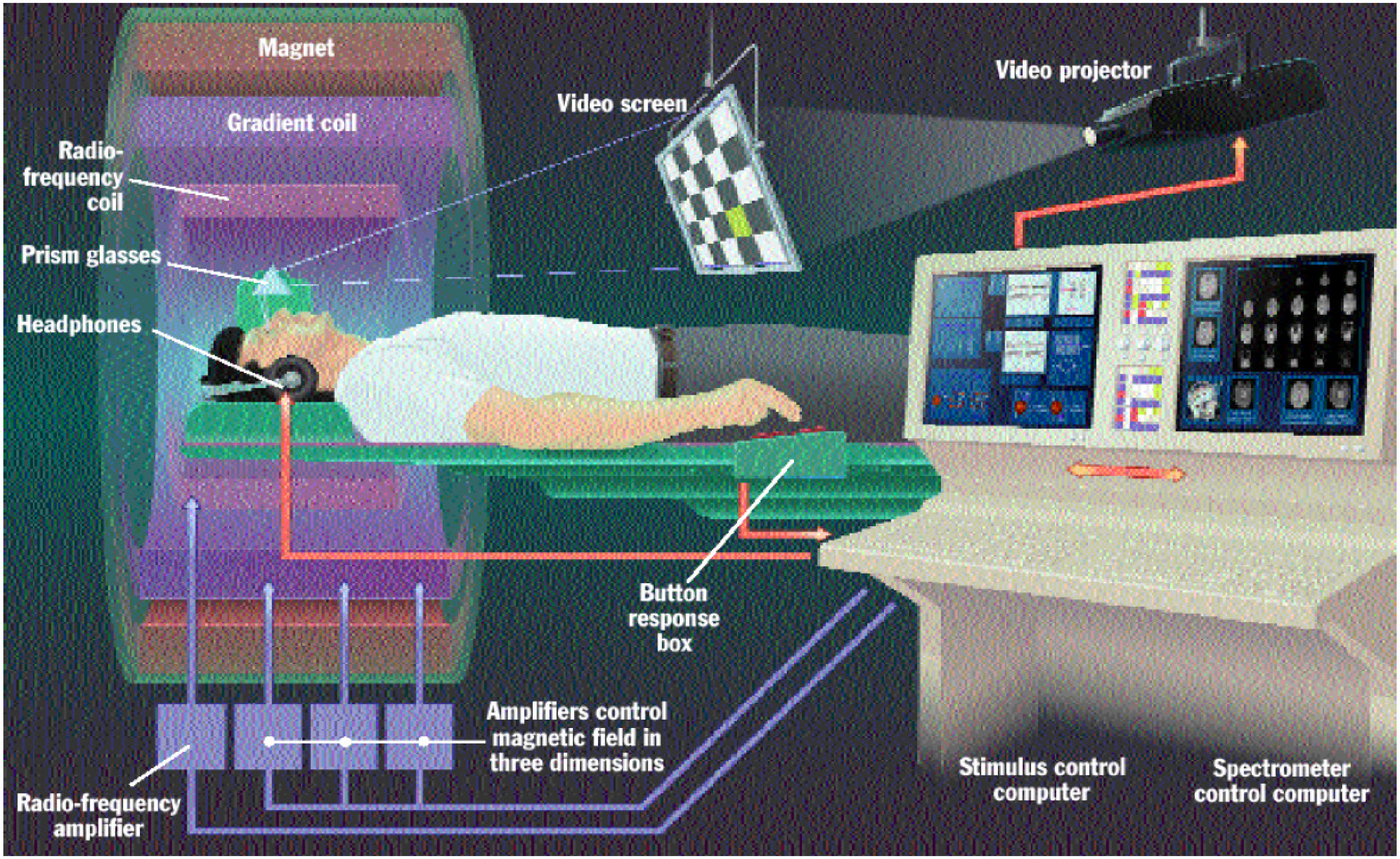
VI. functional Magnetic Resonance Imaging - **fMRI**



FUNCTIONAL Magnetic Resonance Imaging

Scott A. Huettel • Allen W. Song • Gregory McCarthy

fMRI physics and equipment



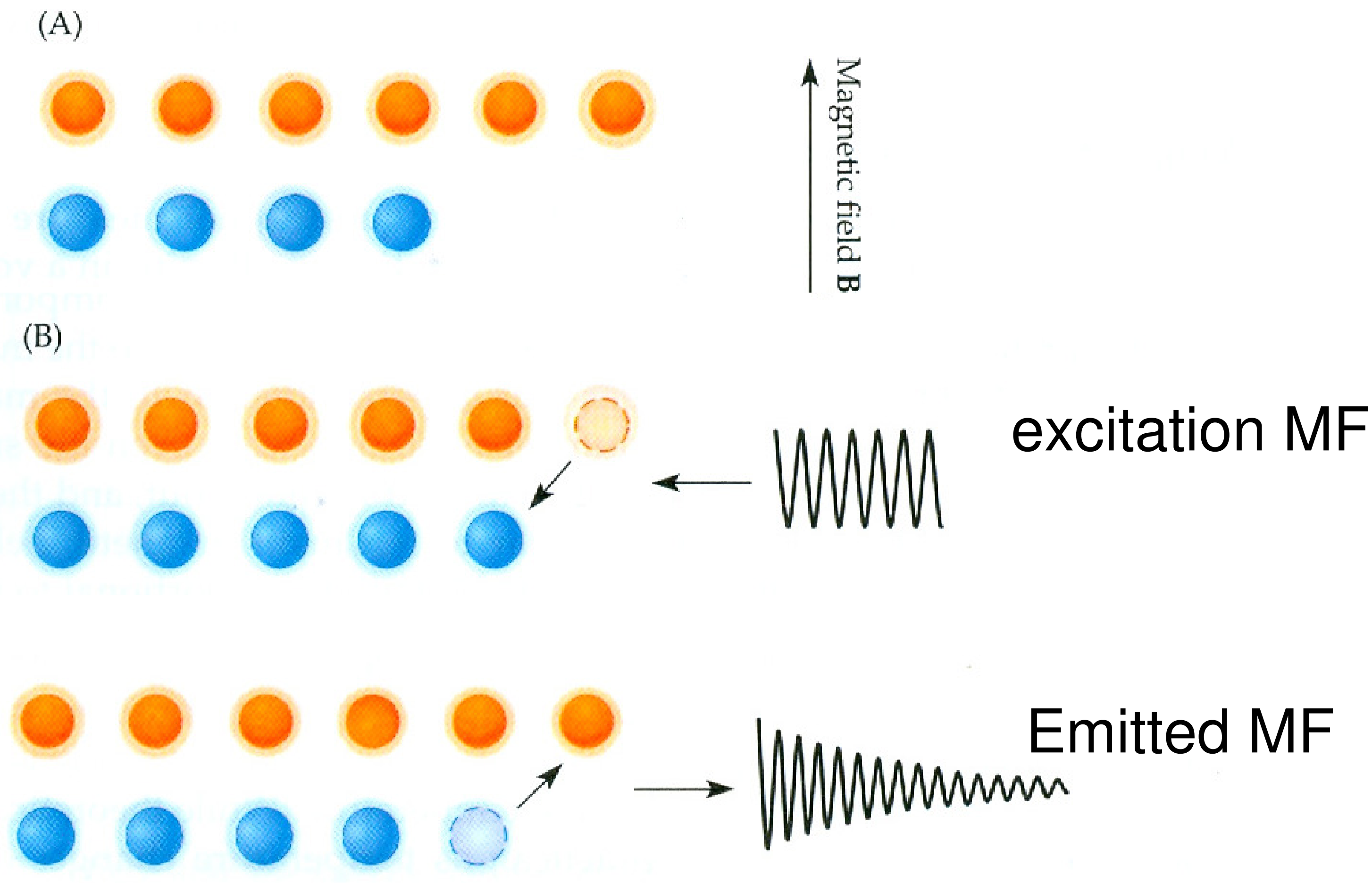
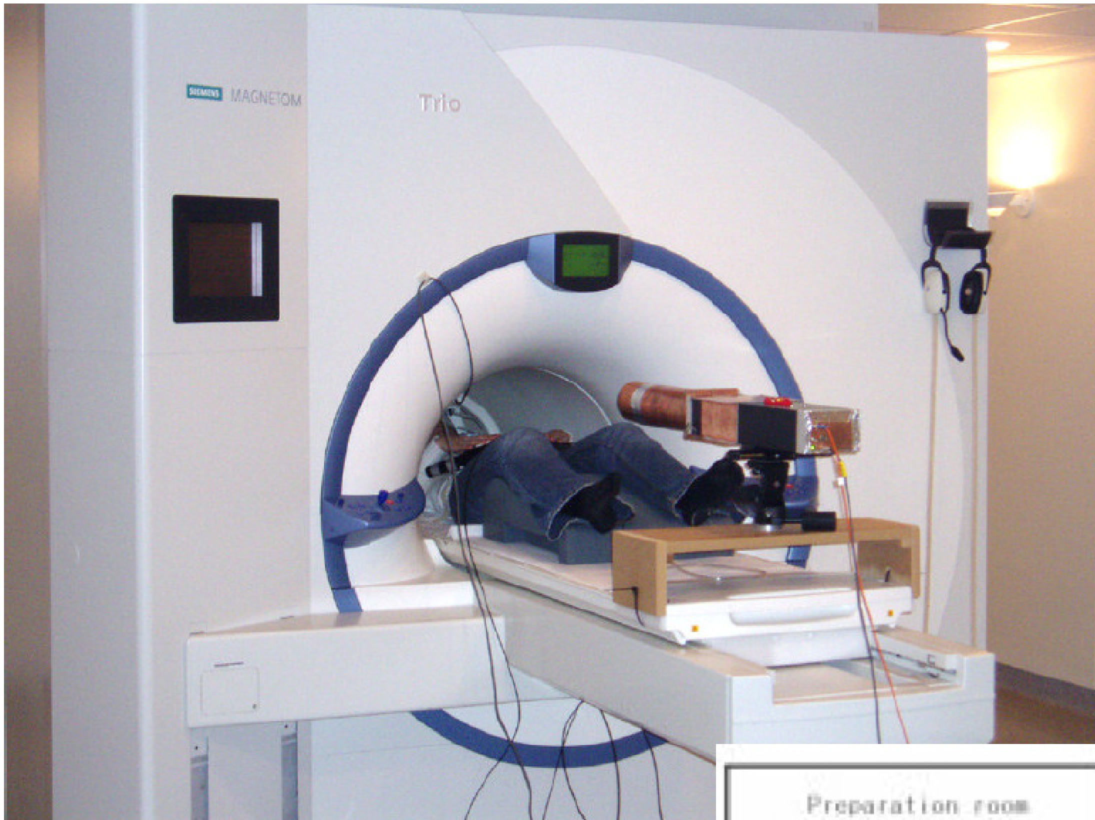
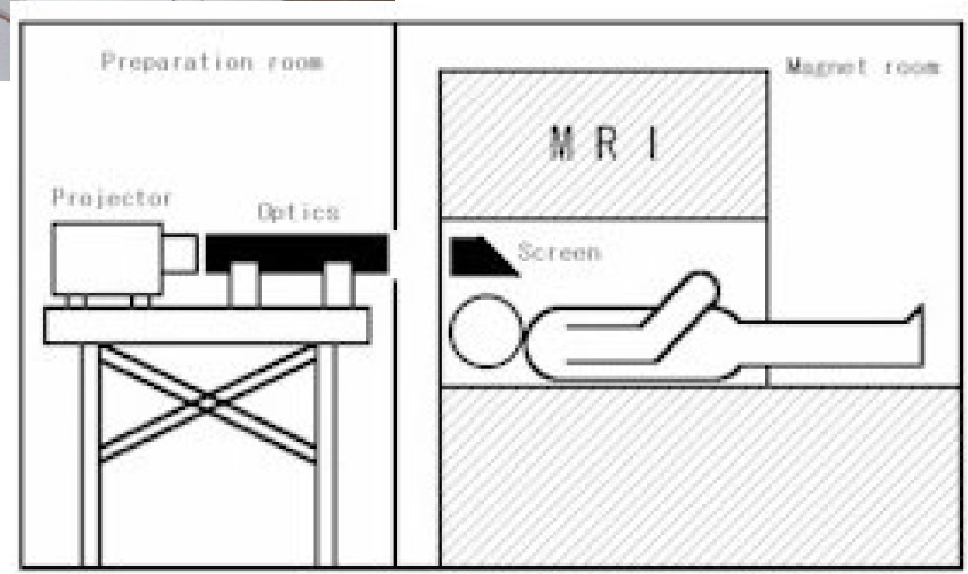
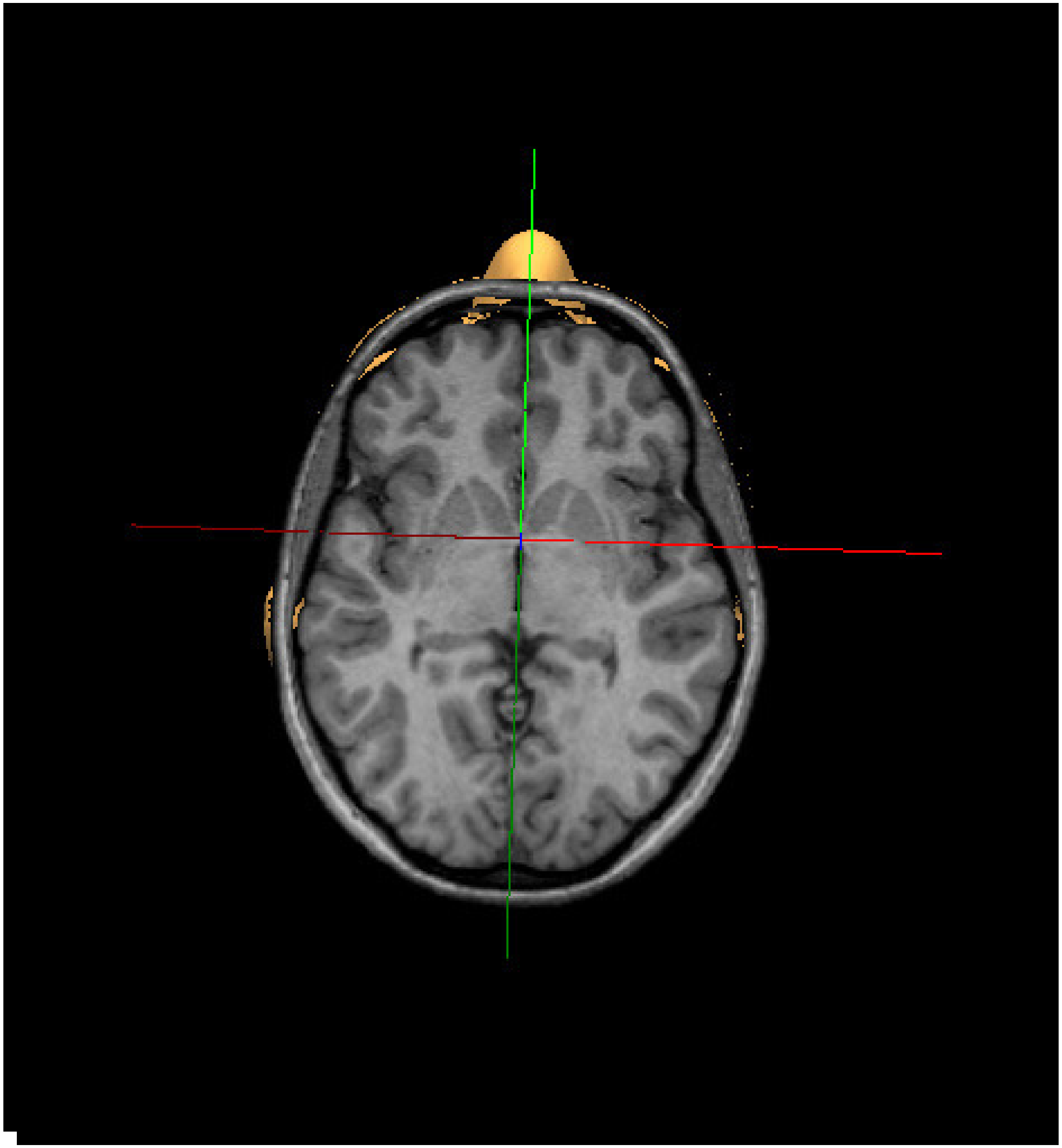


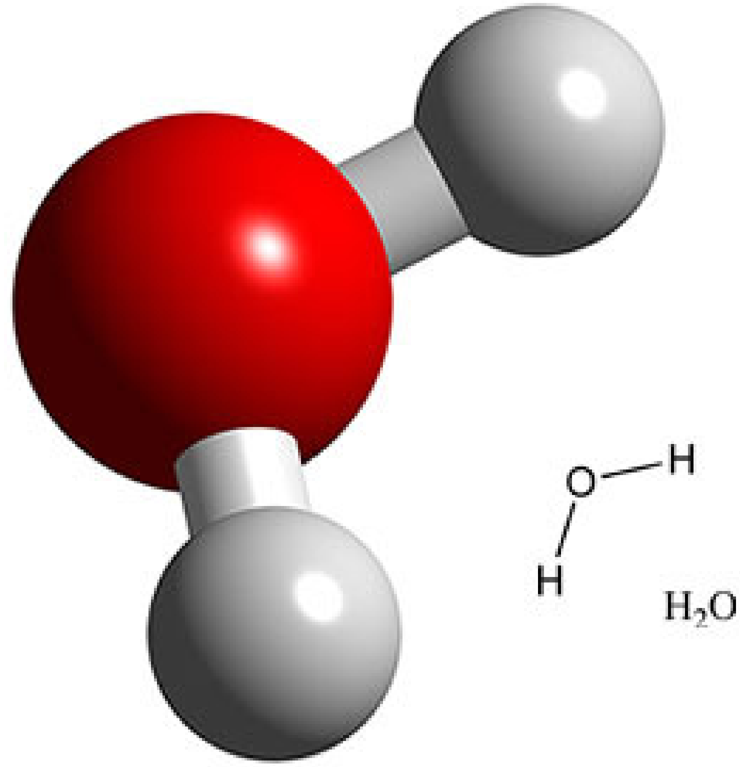
Figure 3.9 Change between states due to absorption or transmission of energy. When spins are placed in an external magnetic field (A), more will be at the low-energy state (orange) than at the high-energy state (blue). If an excitation pulse with the right amount of energy is applied, some spins will absorb that energy and jump to the high-energy state (B). But after the excitation pulse is turned off, some of the spins in the high-energy state will return to the low-energy state, releasing the absorbed energy (C).

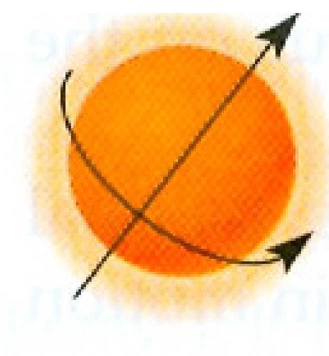

MAGNETOM
Trio


Preparation room
Magnet room
M R I
Projector
Optics
Screen



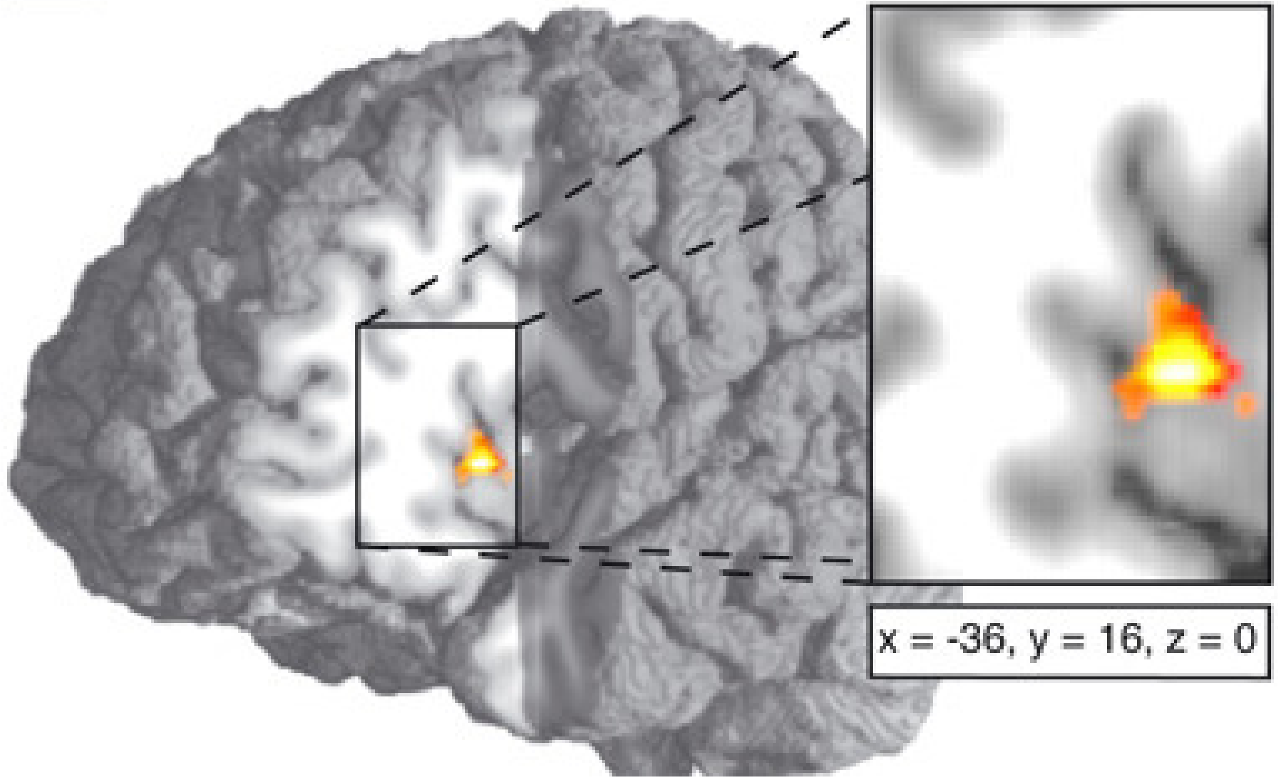
MRI –
structural
information





Protons of hydrogen (in the molecule of water) show different magnetic characteristics depending on the chemical environment.

BBC ONE


x = -36, y = 16, z = 0

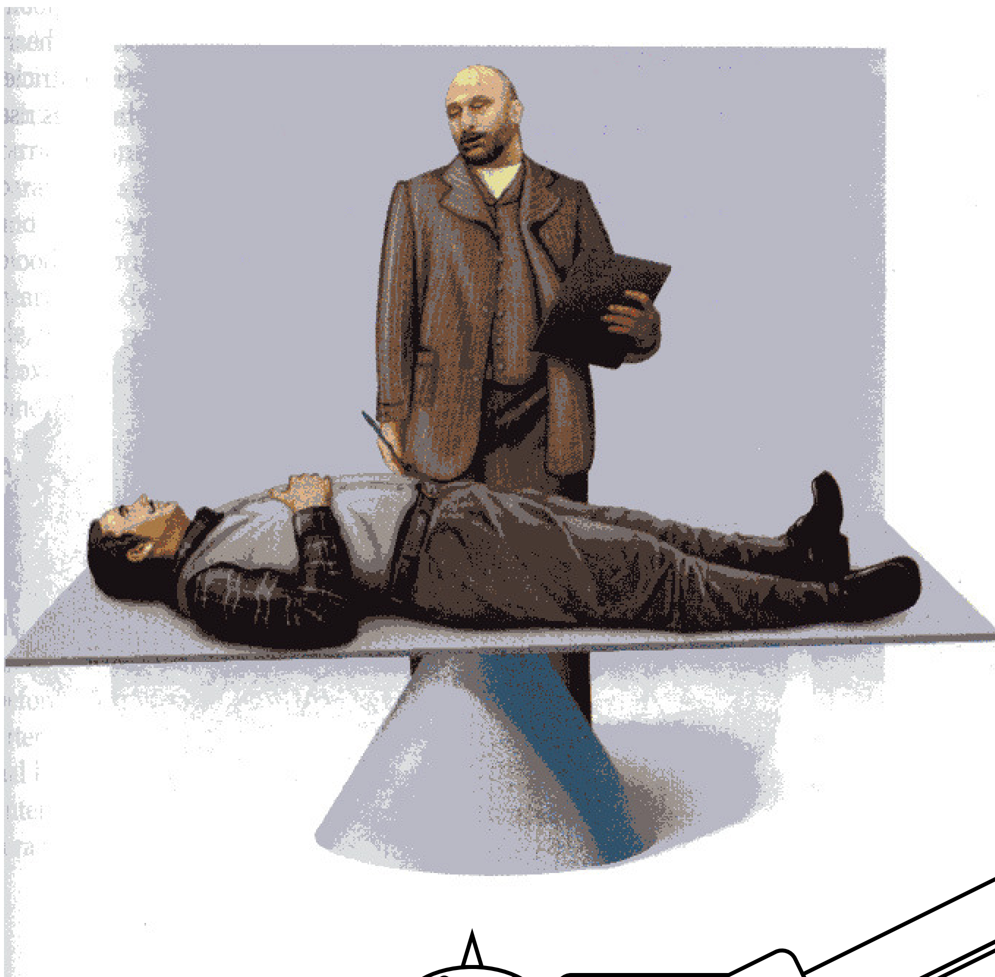
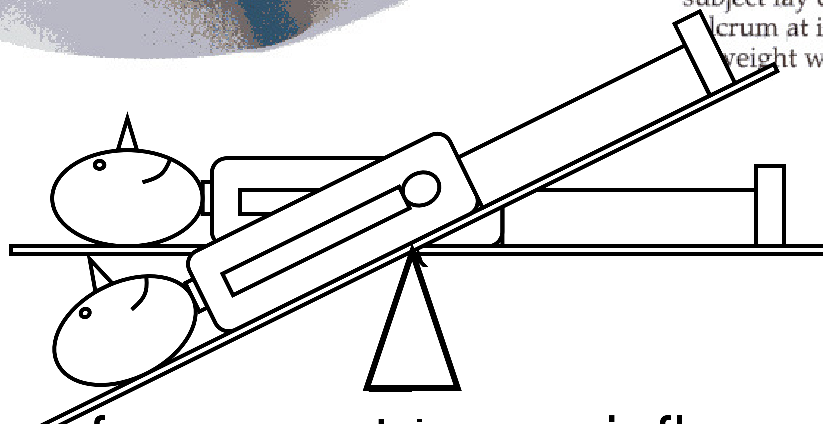


Figure 6.7 The crude imaging apparatus used by Angelo Mosso in the late nineteenth century. Mosso theorized that thinking drew blood to the brain, and constructed a balance device to measure changes in weight associated with this increased blood flow. The subject lay down on a large table with a lcrum at its center, so that any change eight would cause the table to tip.



Activity of neurons triggers inflow of blood.

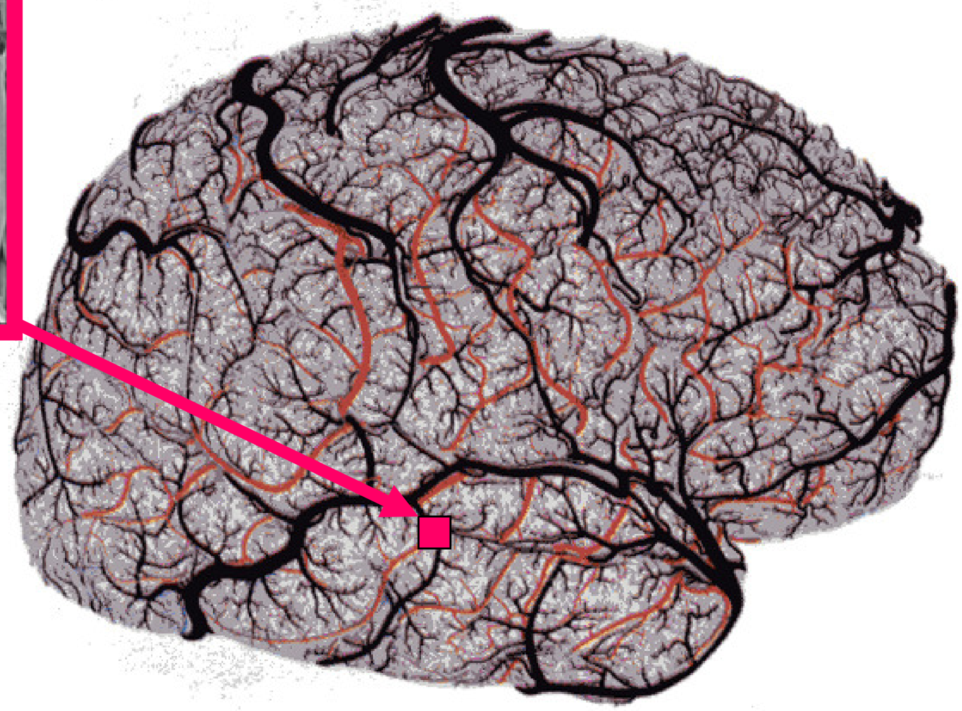
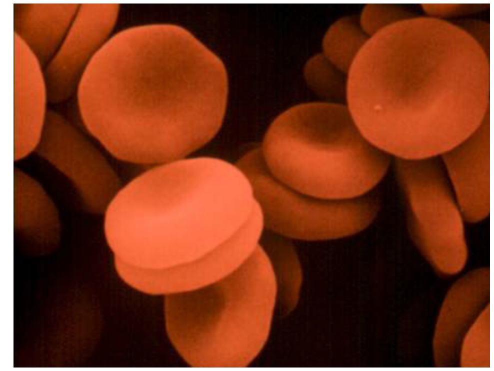
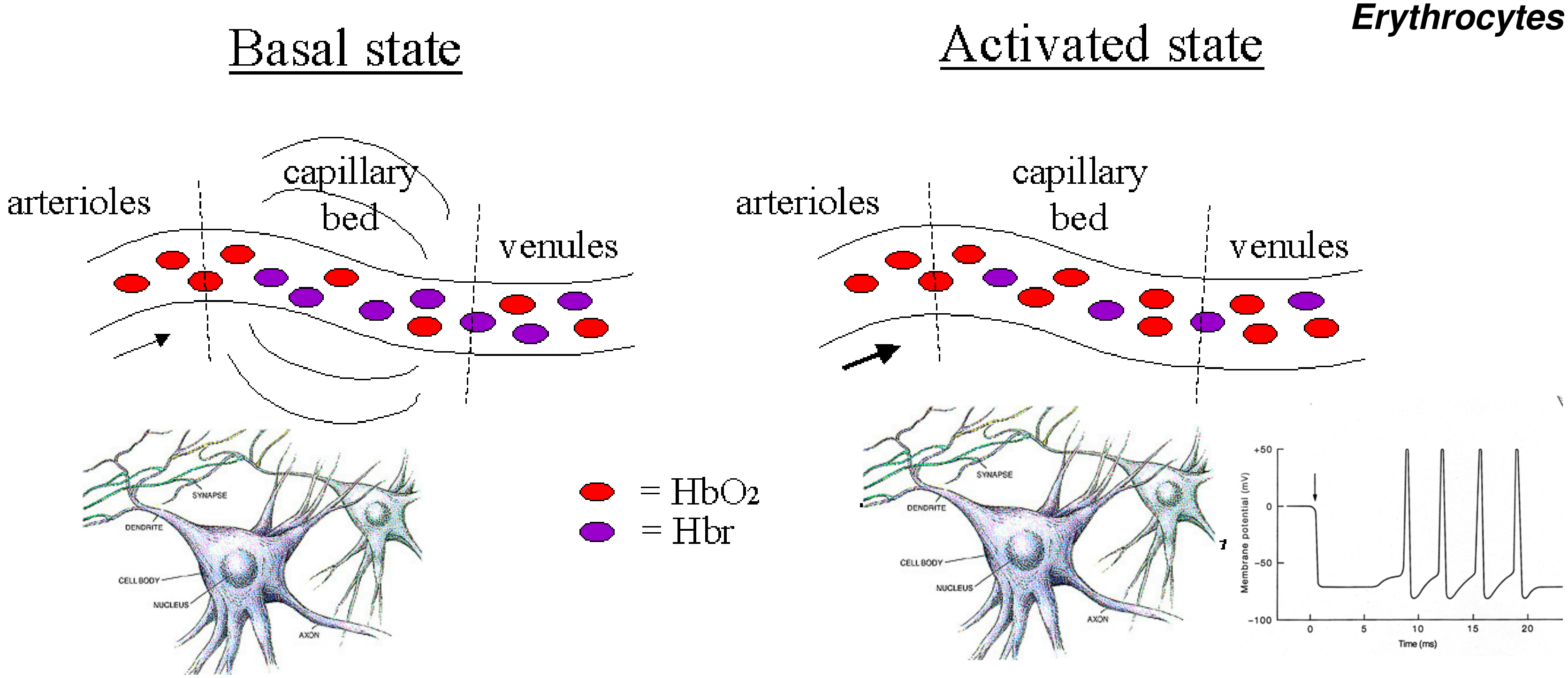


Figure 6.8 Blood supply to the human cerebrum. As illustrated here, the surface pattern of blood supply to the human cerebrum is highly complex. The red vessels are tributaries of the middle cerebral artery, the green vessels are tributaries of the anterior cerebral artery, and the blue vessels are tributaries of the posterior cerebral artery. The veins are shown in black. (From Duvernoy, Delon, and Vannson, 1981.)

Blood Oxygen Level-Dependent (BOLD) signal



Erythrocytes



When neurons are more active they consume oxygen that triggers originated blood inflow.

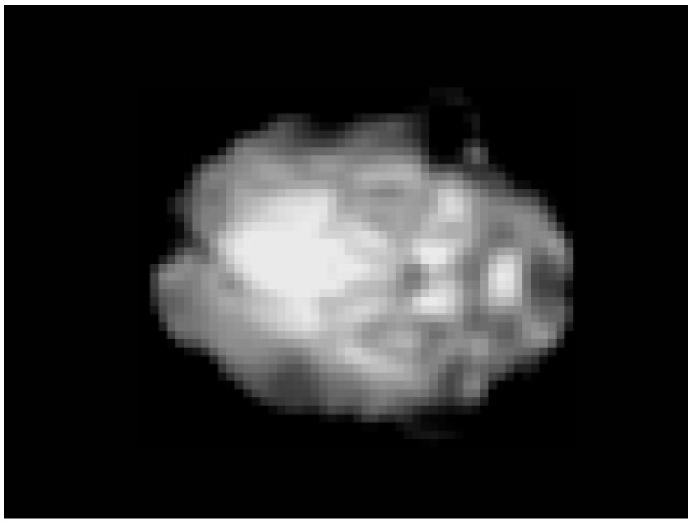
↑neural activity ➔ ↑ blood flow ➔ ↑ oxyhemoglobin ➔ ↑ T2* ➔ ↑ MR signal

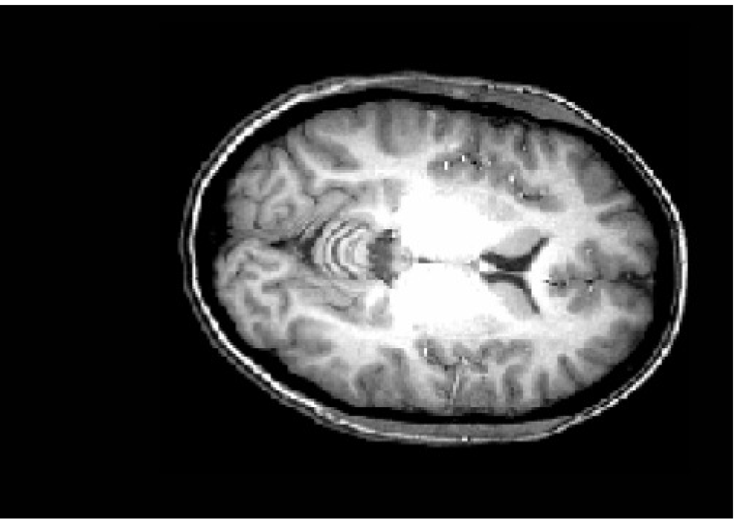
Source: fMRIB Brief Introduction to fMRI

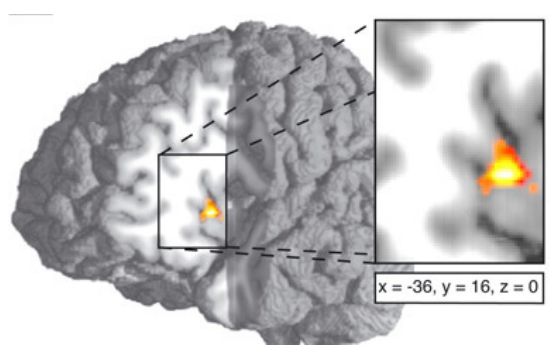
Method 1

Method 2

functional MRI vs. structural MRI



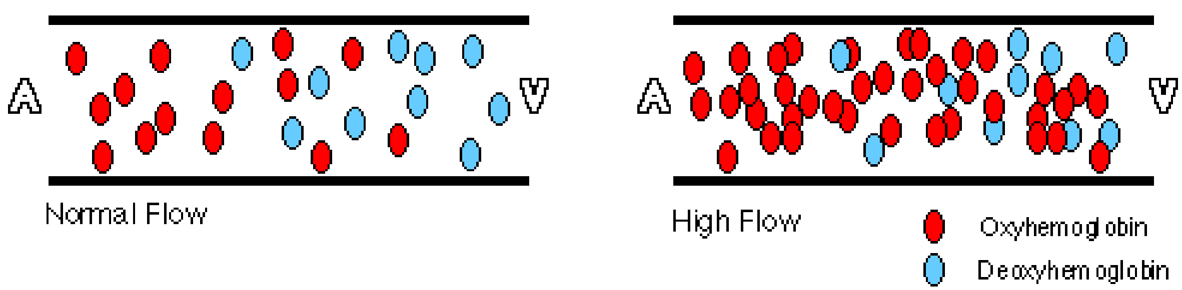




BOLD (Blood Oxygen Level Dependent) contrast imaging

- Takes advantage of the different magnetic properties of oxyhemoglobin (HbO_2) and deoxyhemoglobin (Hb)

Hb is paramagnetic and introduces an inhomogeneity into the nearby magnetic field, whereas HbO_2 is weakly diamagnetic and has little effect.



neuronal activity

↓

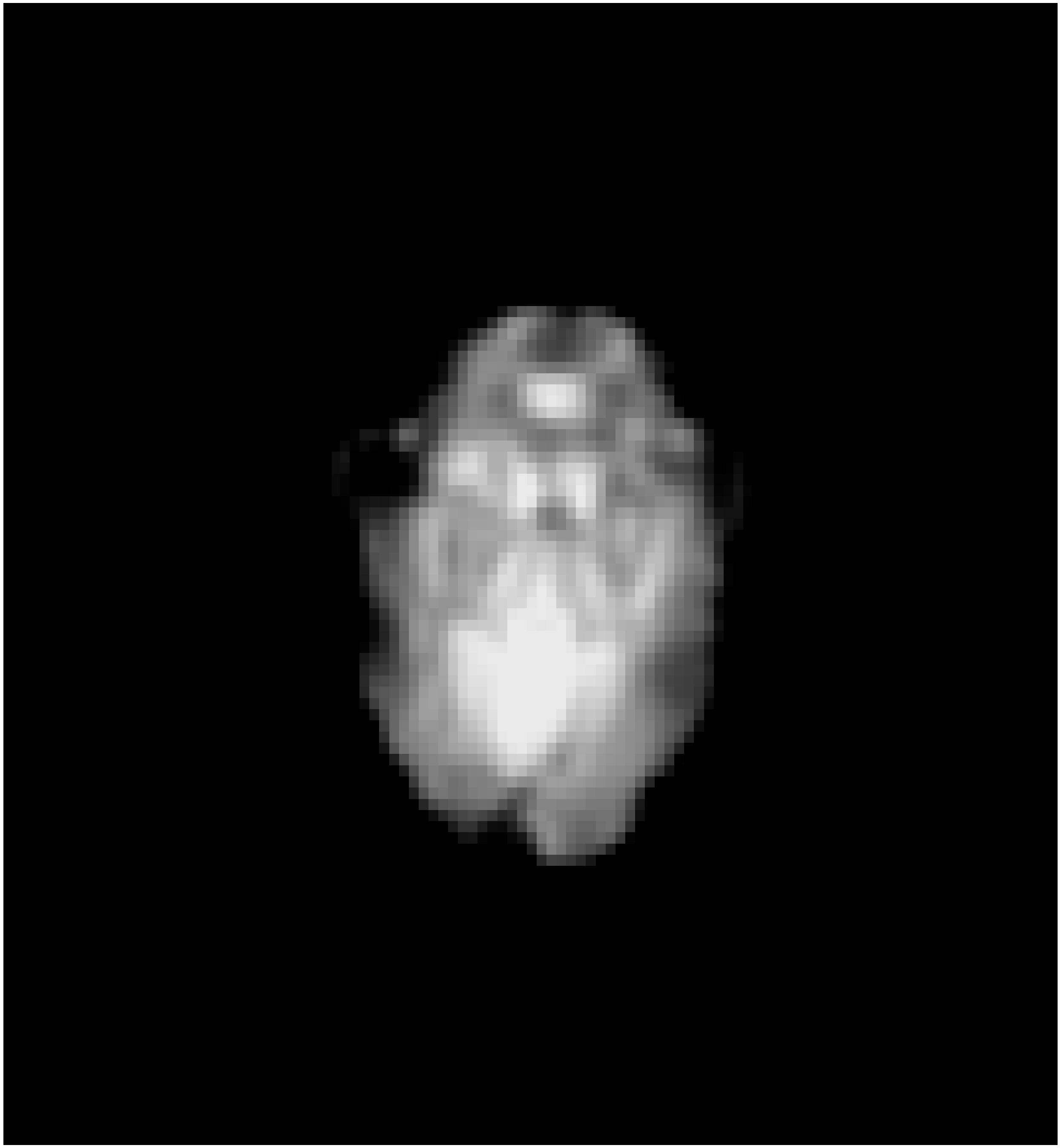
local blood flow increases overcompensating for oxygen consumption

↓

oxygen level in venous blood is elevated

↓

larger MR signal.



functional
MRI

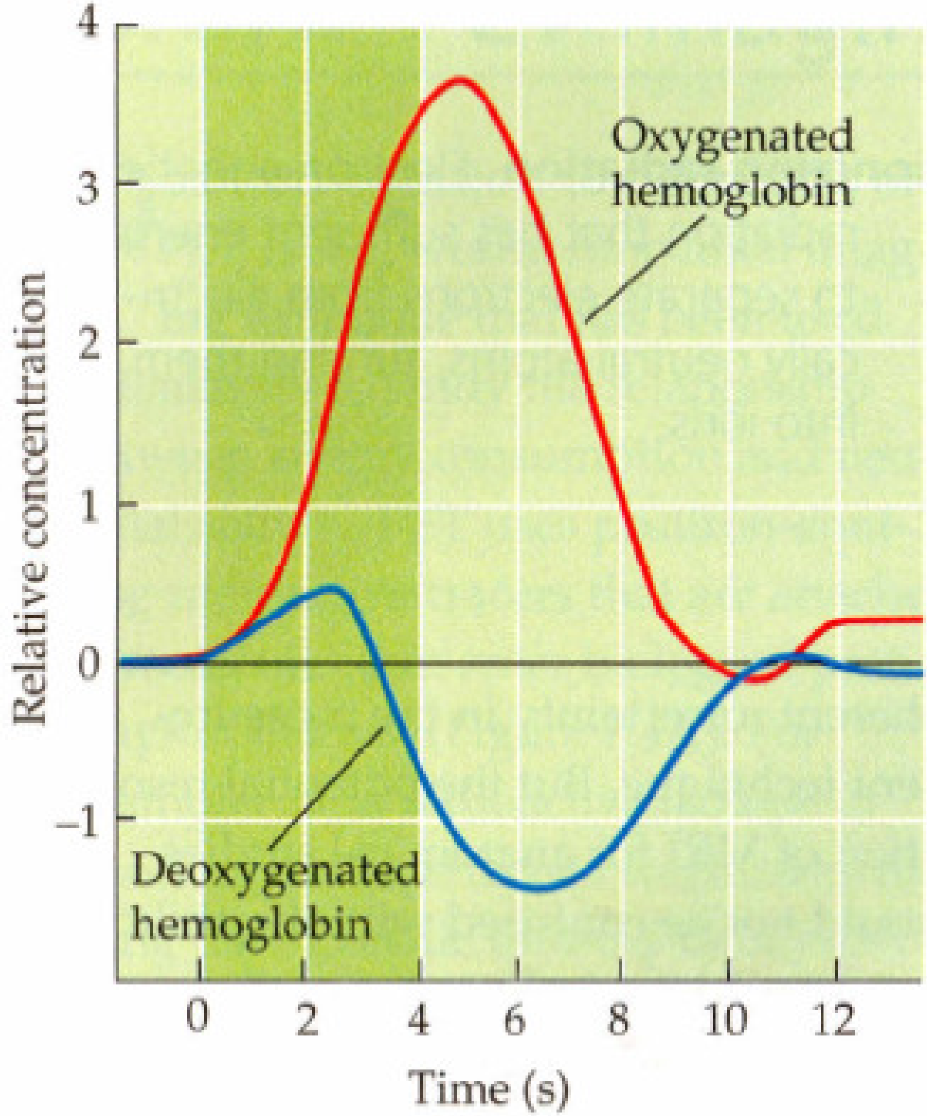
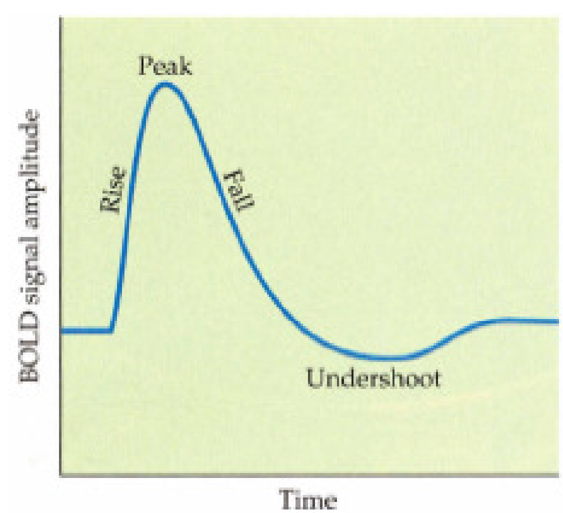
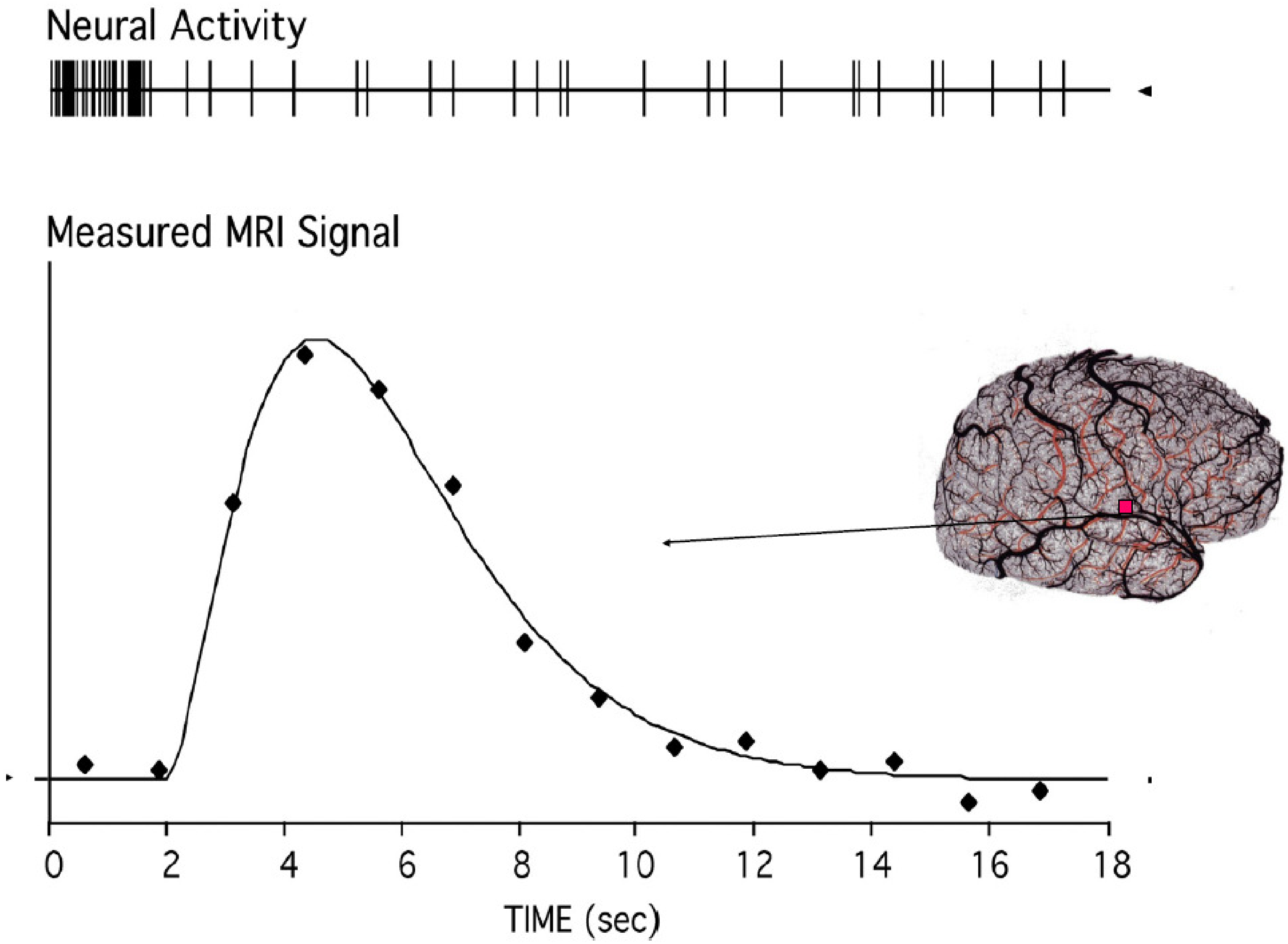


Figure 7.5 Changes in oxygenated and deoxygenated hemoglobin following neuronal stimulation. This figure shows that the concentration of deoxygenated hemoglobin increases rapidly at stimulus onset, peaking at about 2 s, and then declines to a minimum value about 6 s after onset. The oxygenated hemoglobin signal shows no decline, but begins rising shortly after stimulus onset and reaches a peak at about 5 to 6 s, with a slow decline to about 10 s. (Data from Malonek and Grinvald, 1996.)

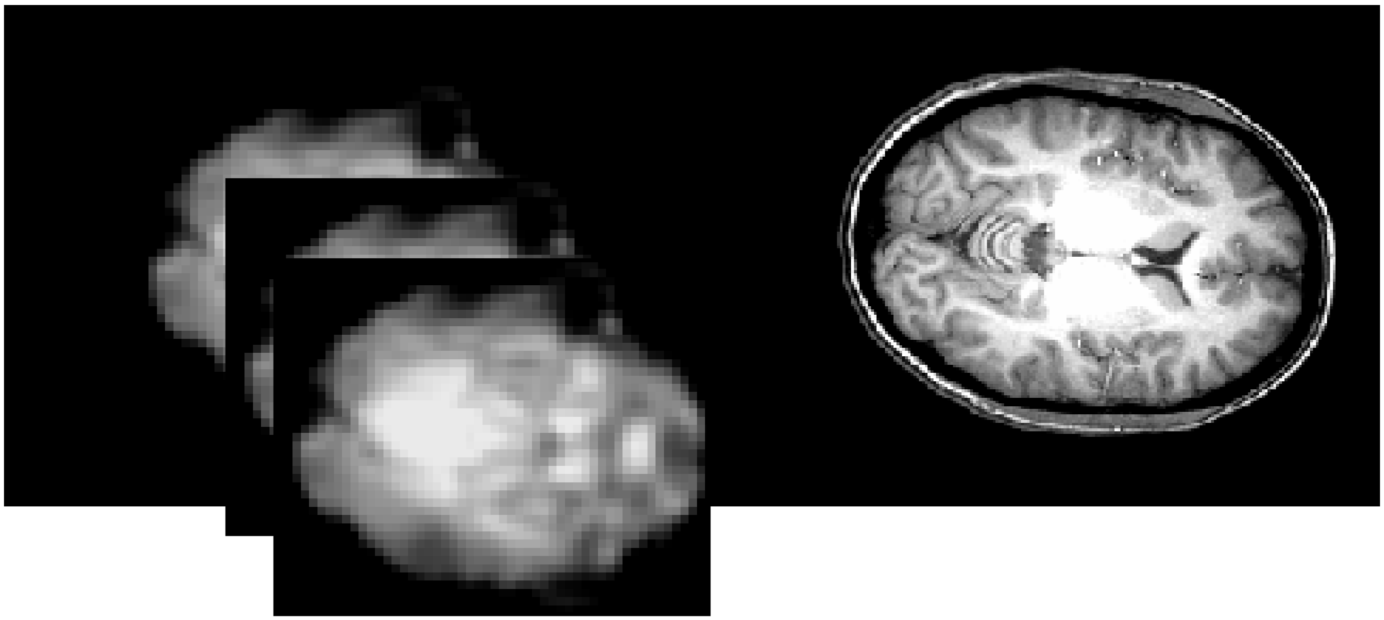




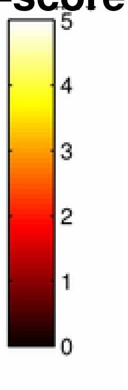
• **The central assumption:** the fMRI signal is approximately proportional to some measure of the local neural activity, averaged over several millimeters and several seconds.

Method 1 **Method 2**

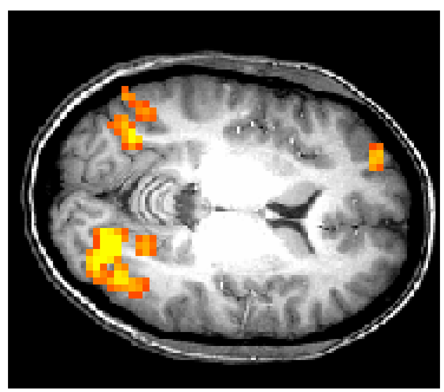
functional MRI **vs.** **structural MRI**



Z-score

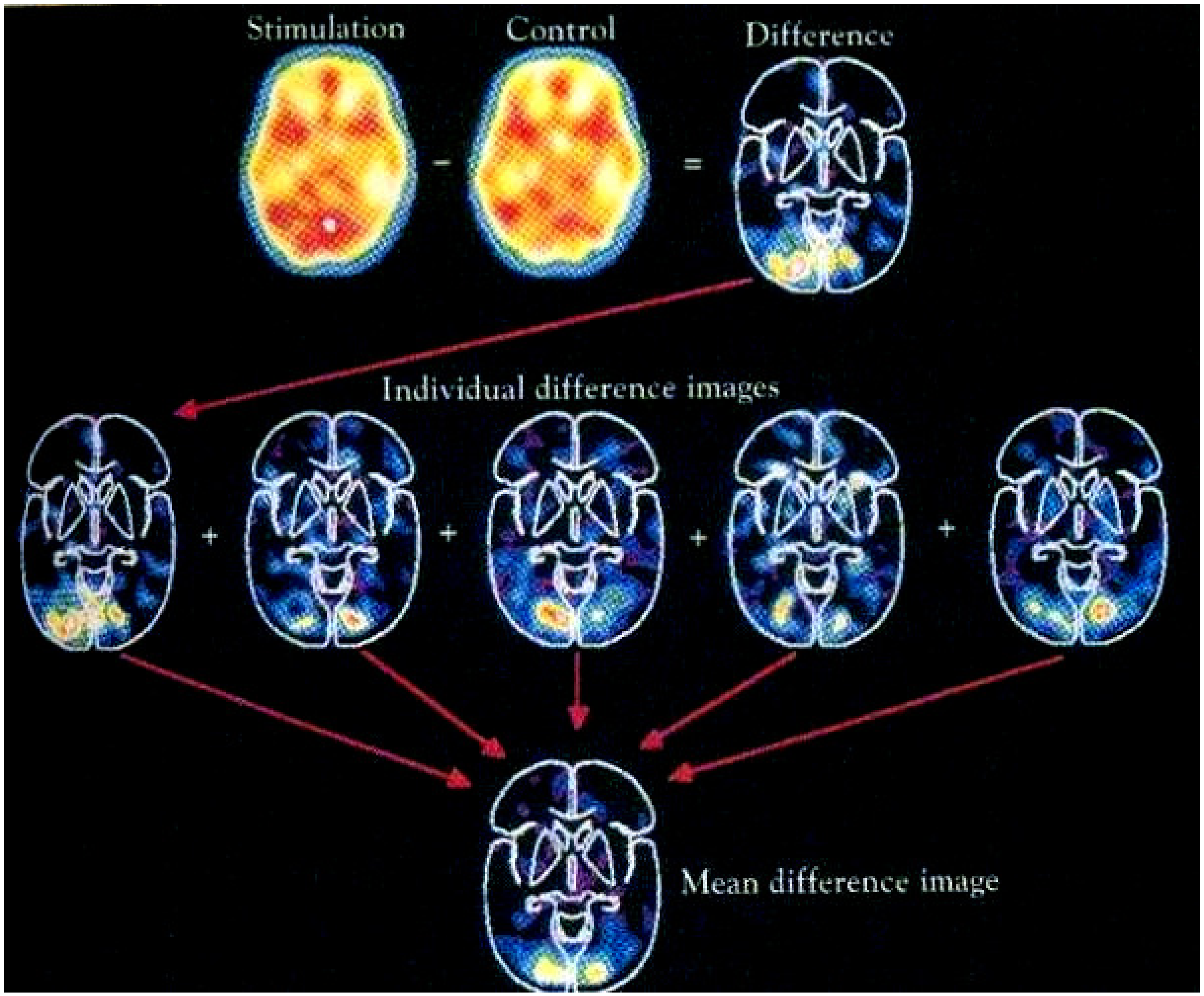


Statistical Map
superimposed on anatomical MRI image



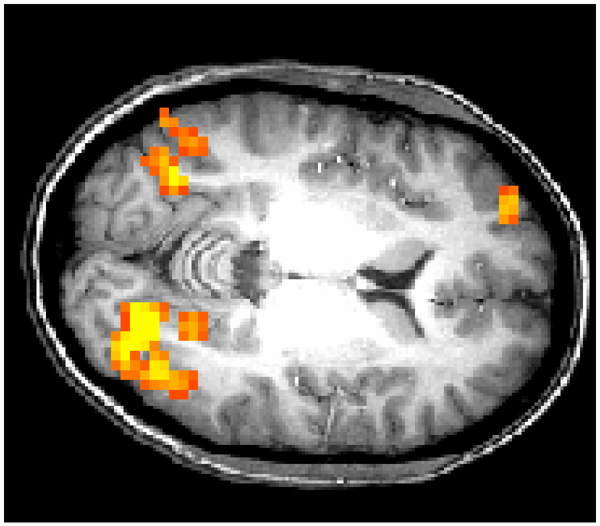
The result of a fMRI study is a combination of functional and structural MRIs

Brain Activations

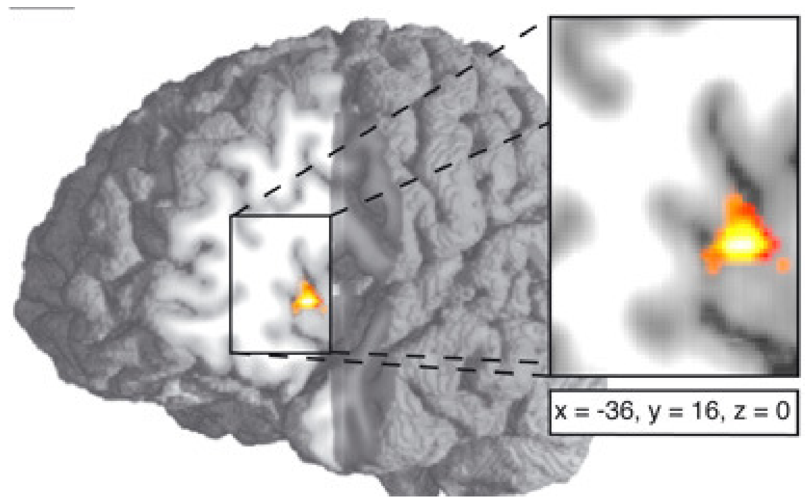


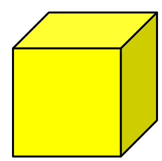
Source: Posner & Raichle, Images of Mind

2-D



3-D

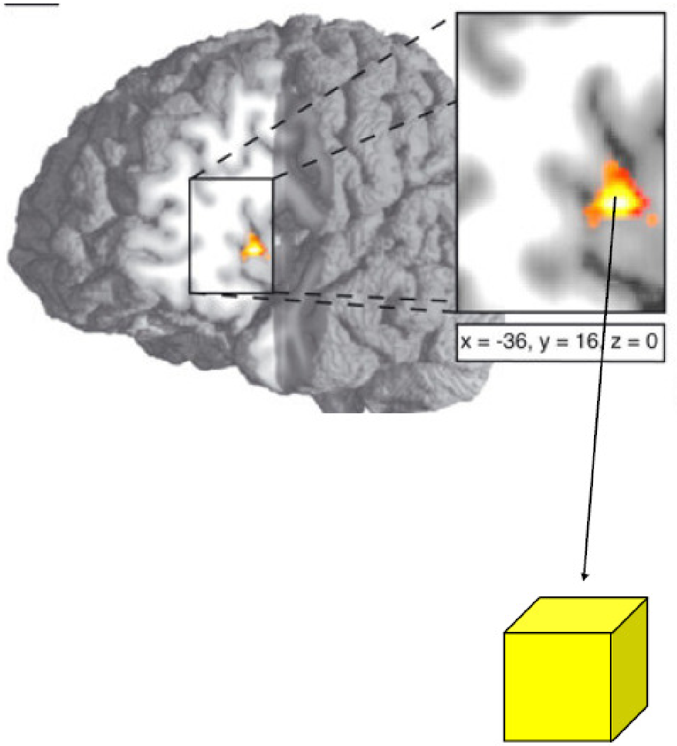




Voxel – the smallest 3-D unit

Activation – a cluster of significant Voxels

Statistical Map

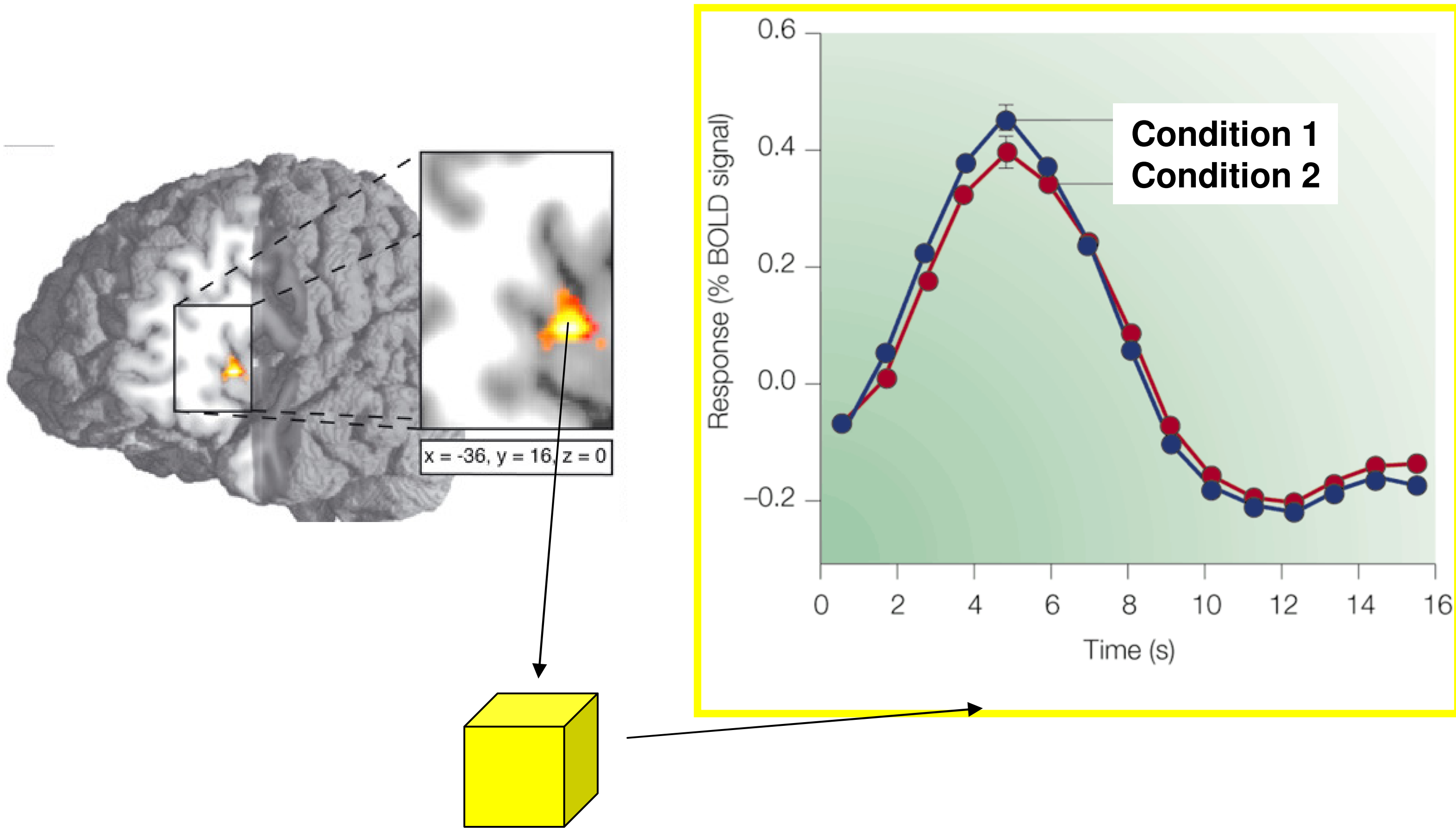


Significant voxel

Pixel

Statistical Map

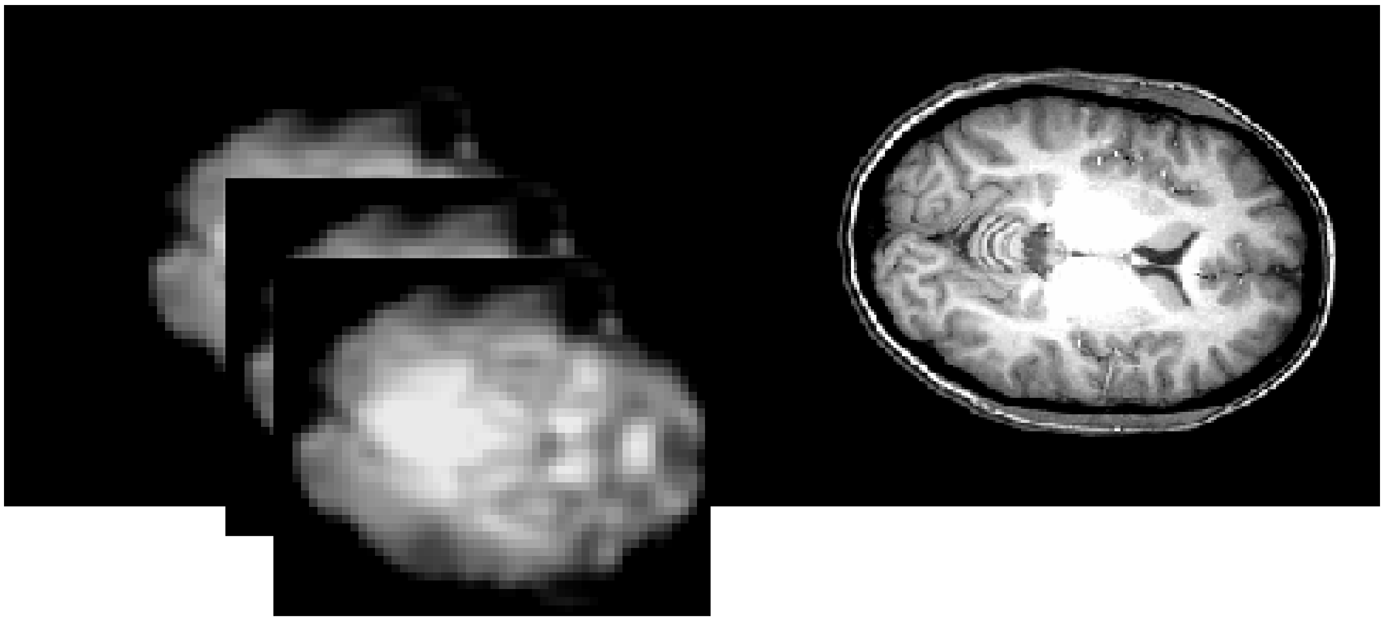
BOLD response



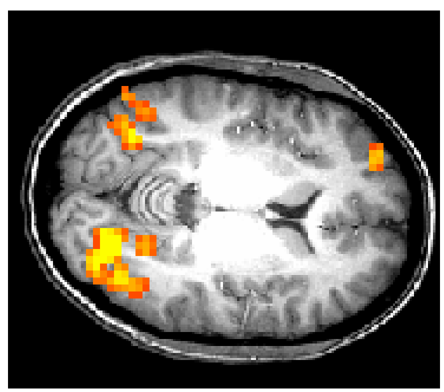
Significant voxel

Method 1 **Method 2**

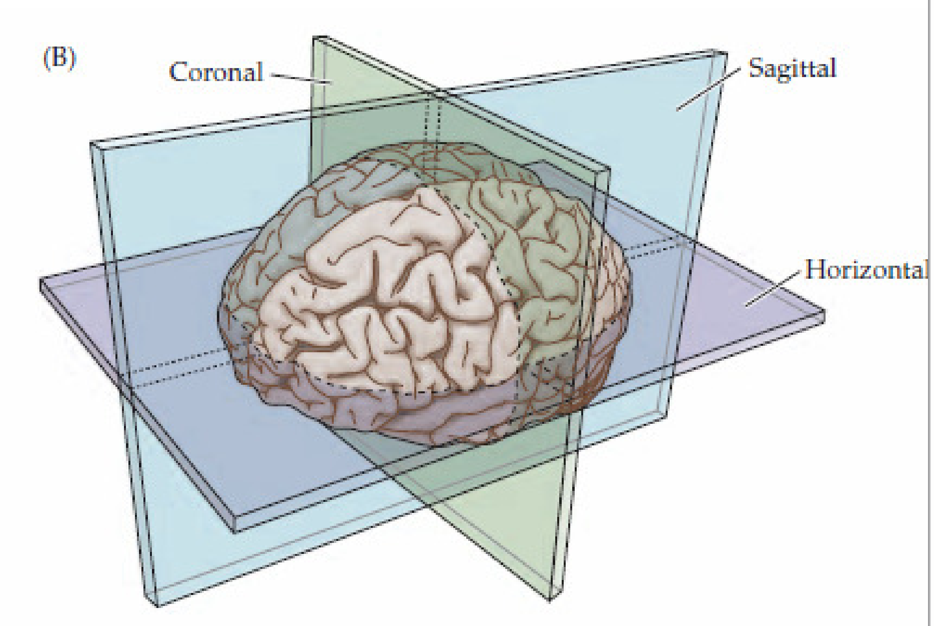
functional MRI **vs.** **structural MRI**

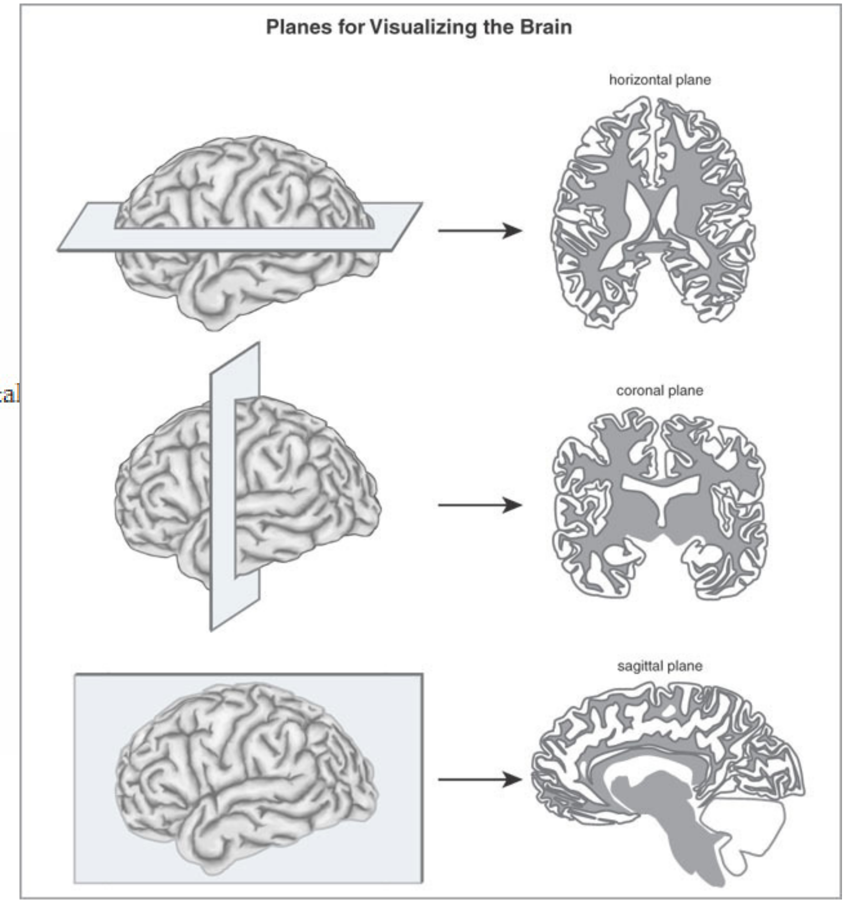


Statistical Map
superimposed on anatomical MRI image

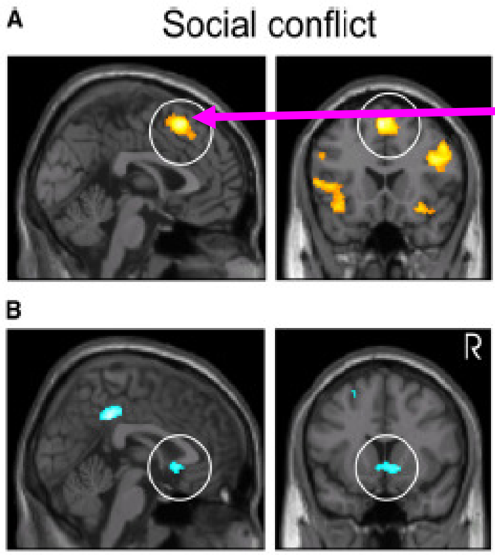


The result of a fMRI study is a combination of (1) functional and (2) structural MRIs


(B)
Coronal
Sagittal
Horizontal


Planes for Visualizing the Brain
horizontal plane
coronal plane
sagittal plane

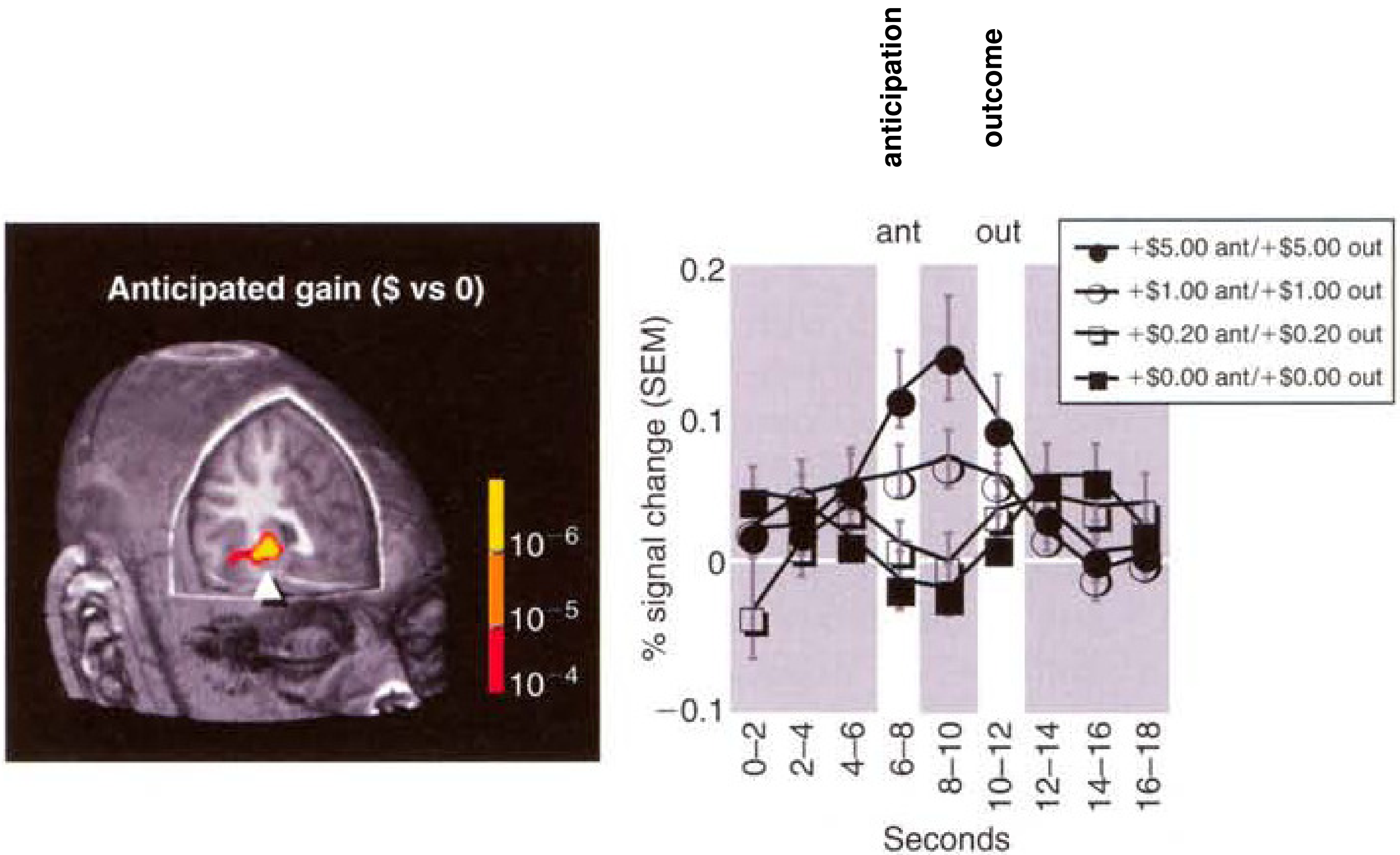
Read fMRI results



1. Activation
2. Coordinate in 3-D space
3. Size in Voxels
4. Significance

Table 1. Significant Activation Clusters for Social Conflict Contrast

Brain Region	HEM	x	y	z	No. of Voxels	Z
Activations						
Rostral cingulate zone (RCZ): medial/superior frontal gyrus, cingulate gyrus BA 6/8/24/32	L/R	−3	14	48	591	5.26
Precuneus, cuneus, BA 7/19	L	−20	−69	37	233	3.94
Precuneus, BA7/19	R	12	−75	45	989	4.97
Middle frontal gyrus, BA9	L	−36	−3	37	666	4.61
Middle frontal gyrus, BA9	R	36	14	23	844	4.87
Cerebellum	L	−34	−58	−28	357	4.30
Insula, BA13	L	−41	18	4	276	4.22
Insula, BA13	R	27	16	13	149	3.92
Middle frontal gyrus, precentral gyrus, BA 6	R	29	−3	51	149	4.19
Midbrain	R	10	−21	−14	52	3.66*
Midbrain	L	−3	−15	−3	27	3.55*
Midbrain	L/R	3	−27	−3	32	3.55*



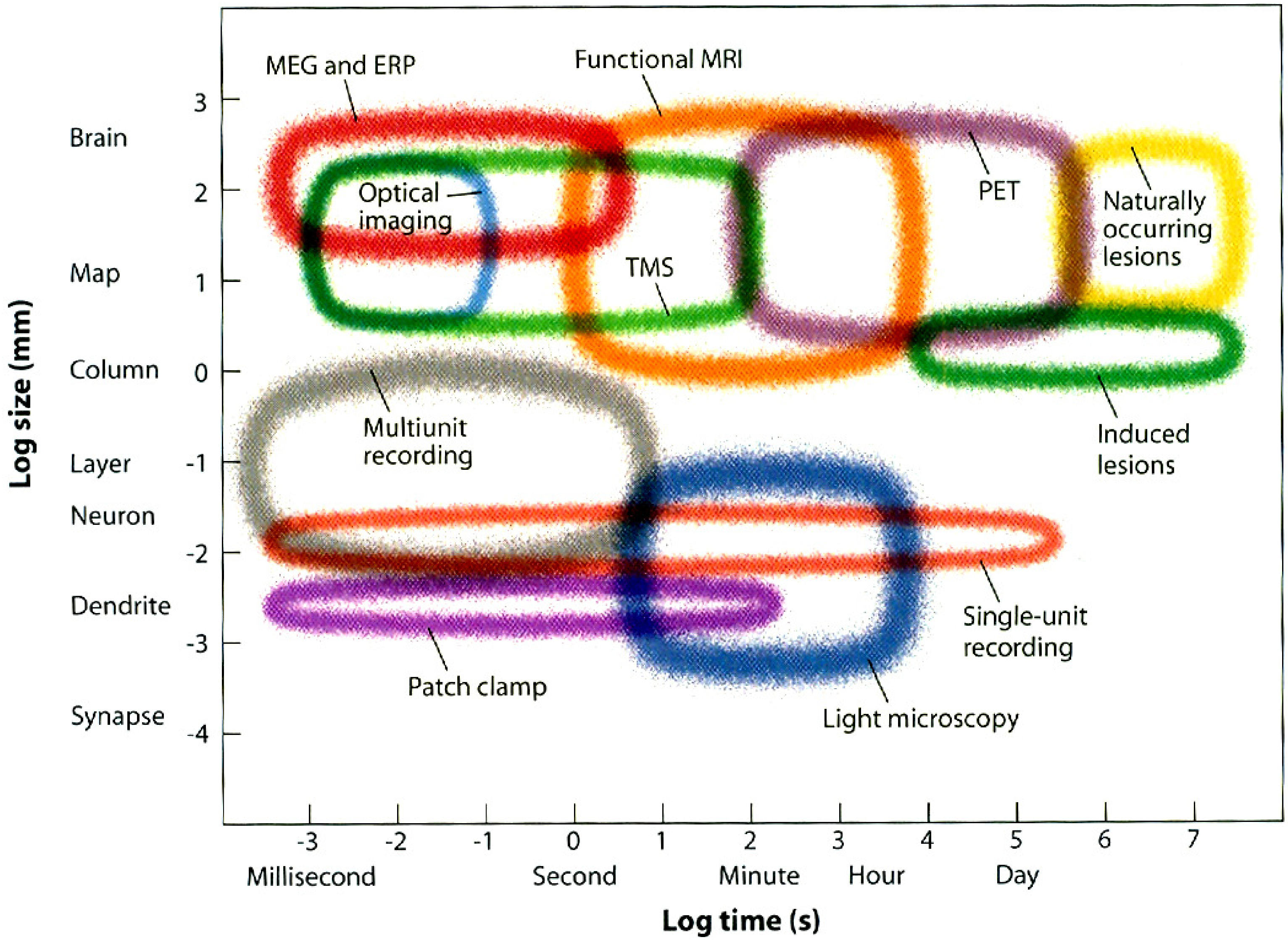
Anticipation of monetary gains of increasing magnitude elicits proportionally increasing NAcc activa

Activity of the ventral striatum related to the expected magnitude of the monitory outcome

Advantages vs. disadvantages

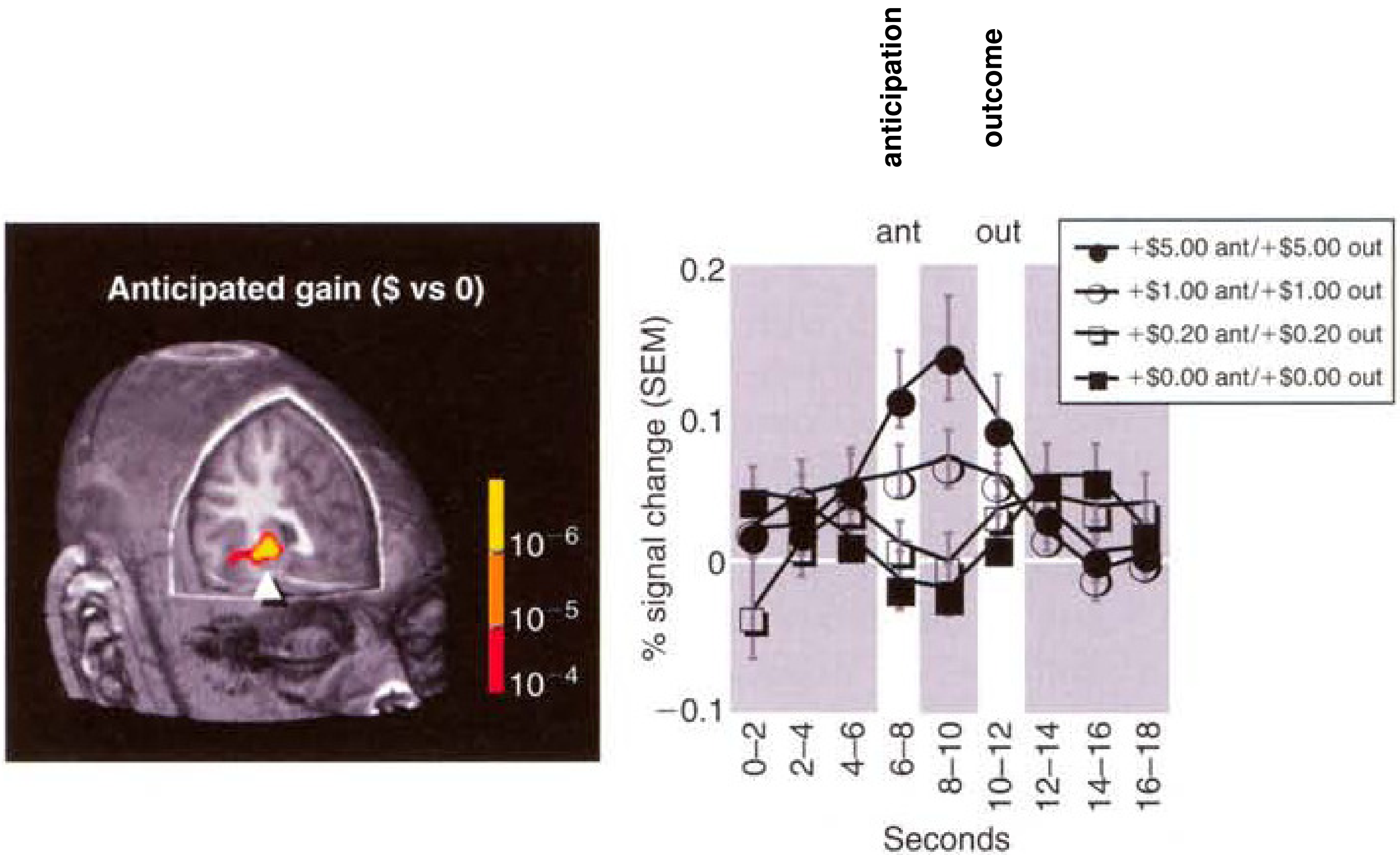
- Noninvasive
- Good 3D resolution
- Indirect (measures BOLD response)
- Bad timing (few seconds time resolution)
- Noisy
- Has restrictions for subjects

Neuroscience methods



General limitations of brain imaging studies

- Many trials for every experimental condition
- Need proper statistics
- Require group statistics
- Different time/spatial resolution
- Require laboratory environment



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