Investigating Function in Human Auditory Cortex with Magnetoencephalography

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Department of Electrical & Computer Engineering
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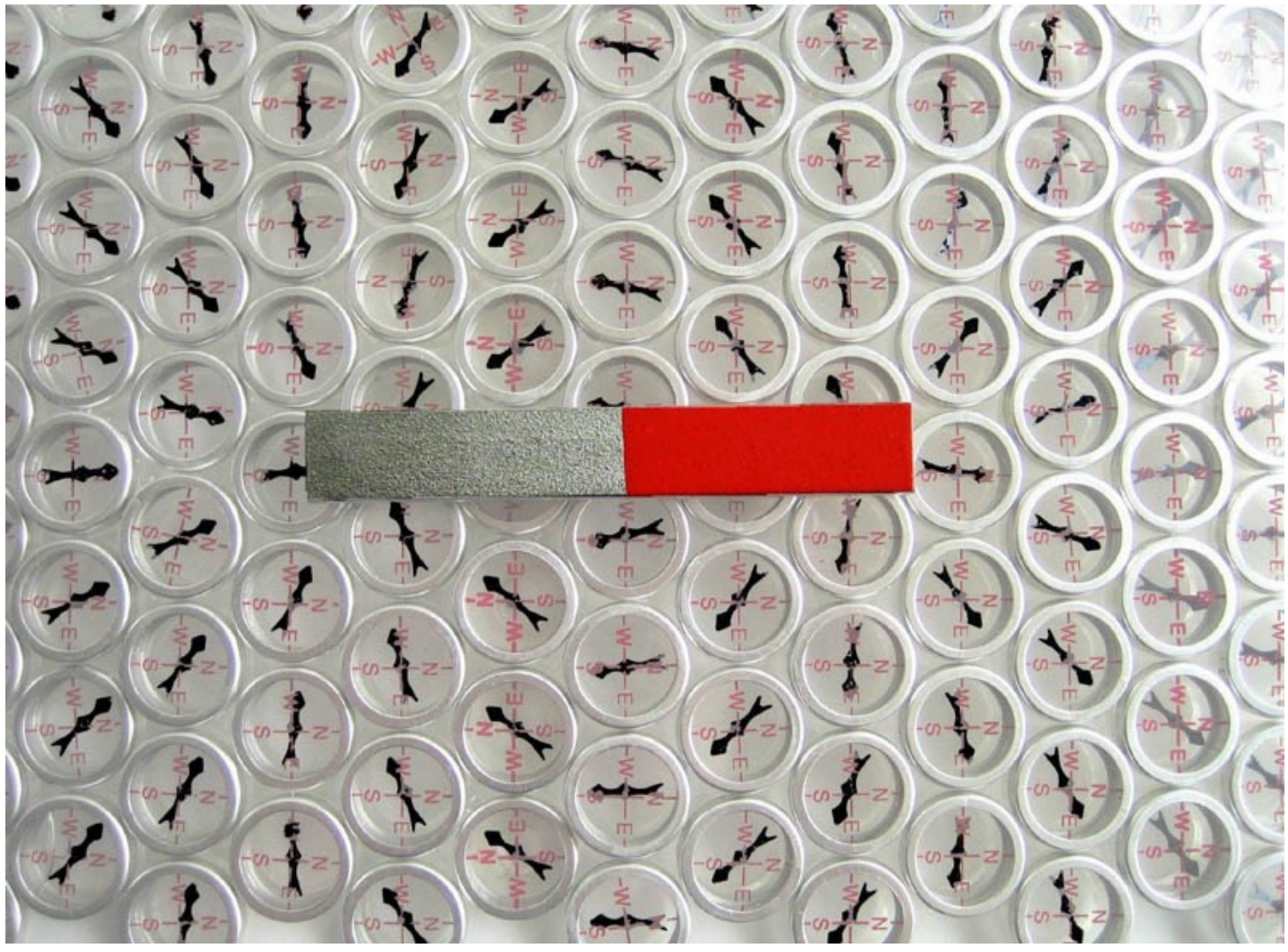
University of Maryland

Magnetism

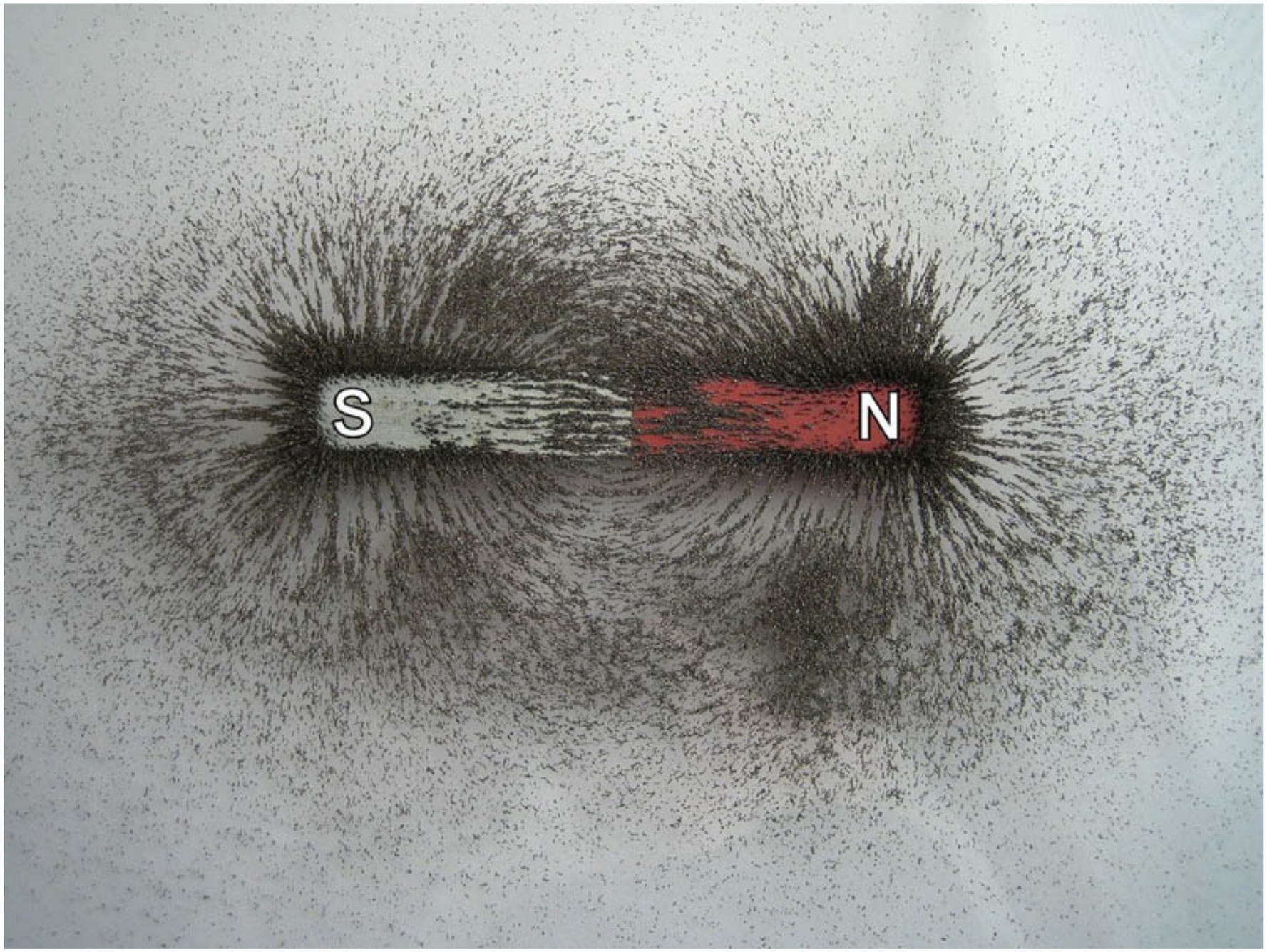
http://www.naturalmagnetism.com/magnetic-poles.html

Measuring Magnetic Fields



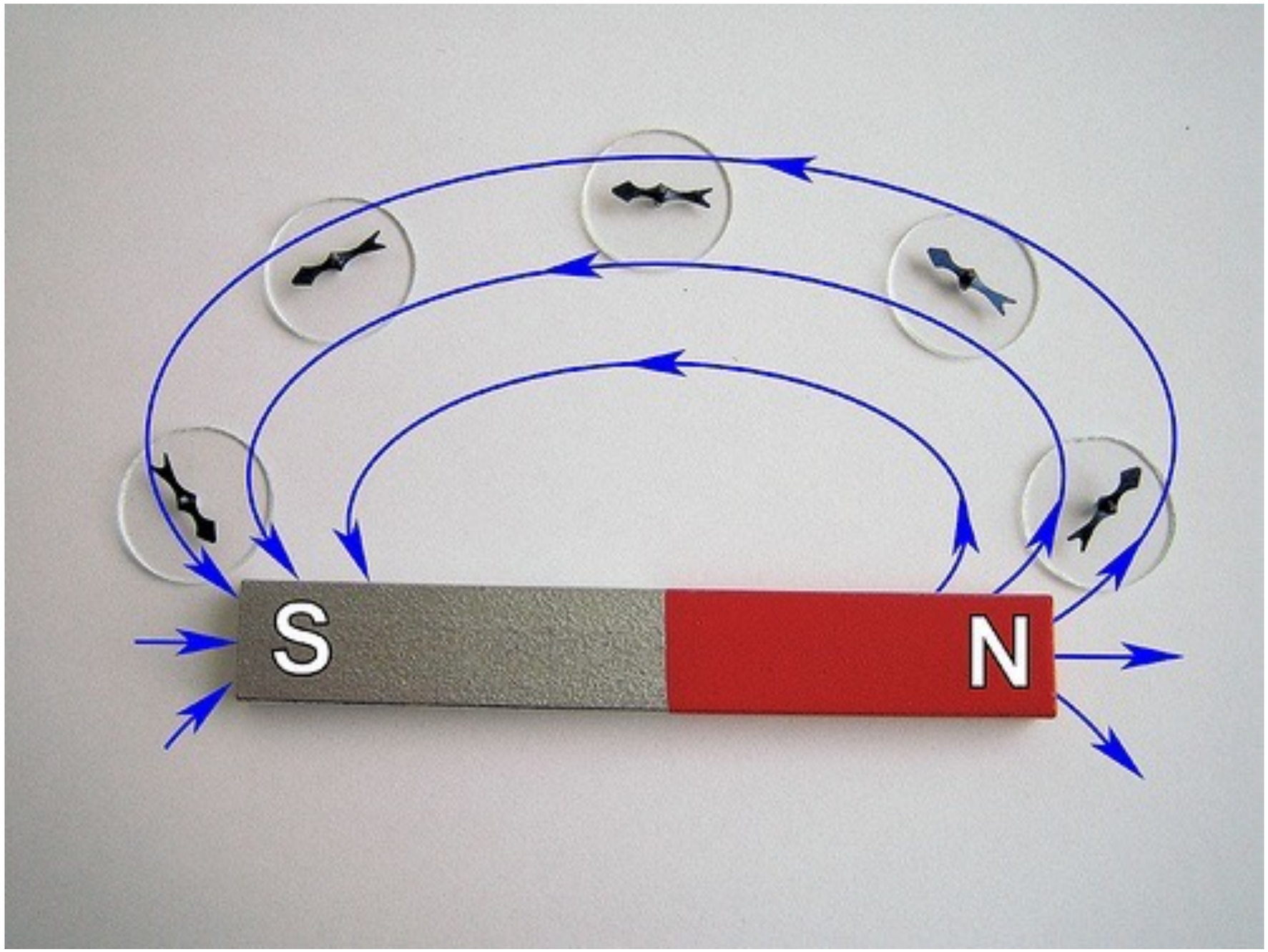
http://memolition.com/2014/01/19/photos-to-help-you-visualize-magnetic-fields-6-pictures/

Measuring Magnetic Fields



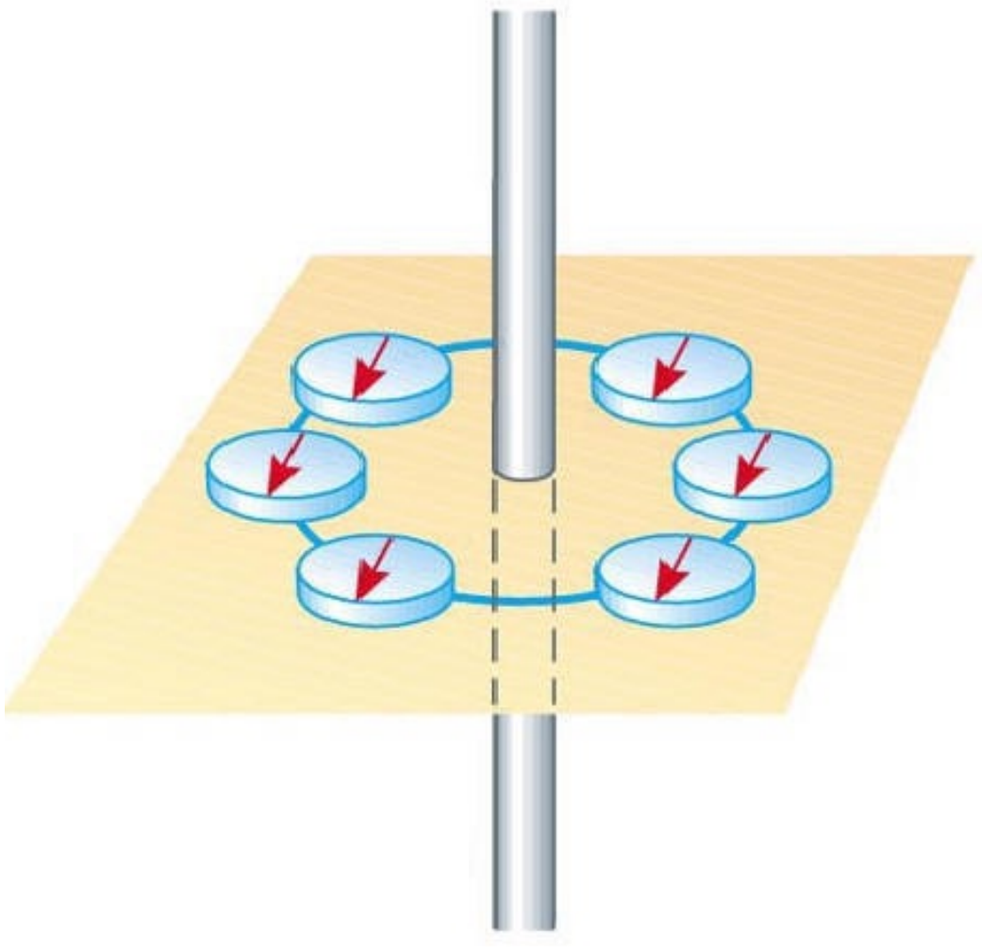
http://memolition.com/2014/01/19/photos-to-help-you-visualize-magnetic-fields-6-pictures/

Magnetic Field "Lines"



http://spacegrant.montana.edu/MSIProject/magneticfields.html

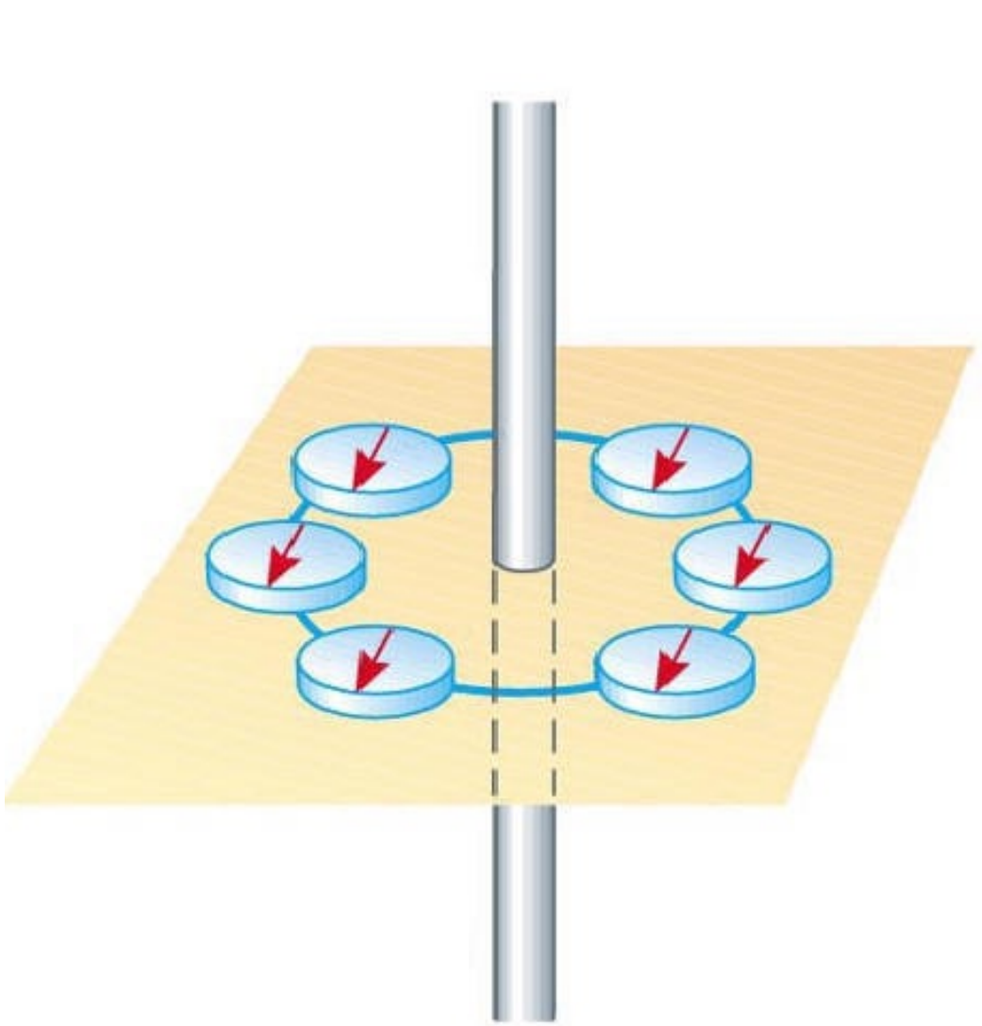
Other Magnetic Fields



Electric Current Off

http://titan.bloomfield.edu/facstaff/dnicolai/Physics/Physics106/Phy106-lessons/lesson5-106.htm les-of-magnetism

Other Magnetic Fields



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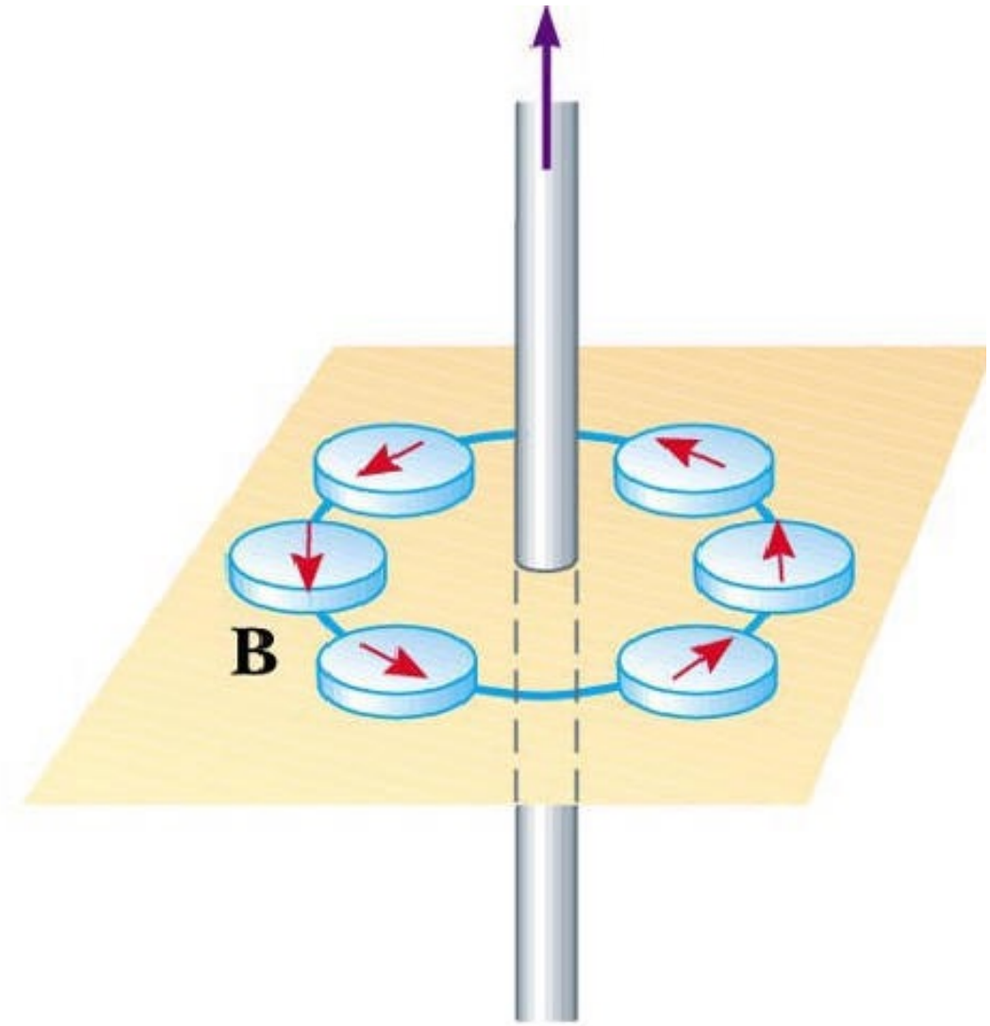

Electric Current On

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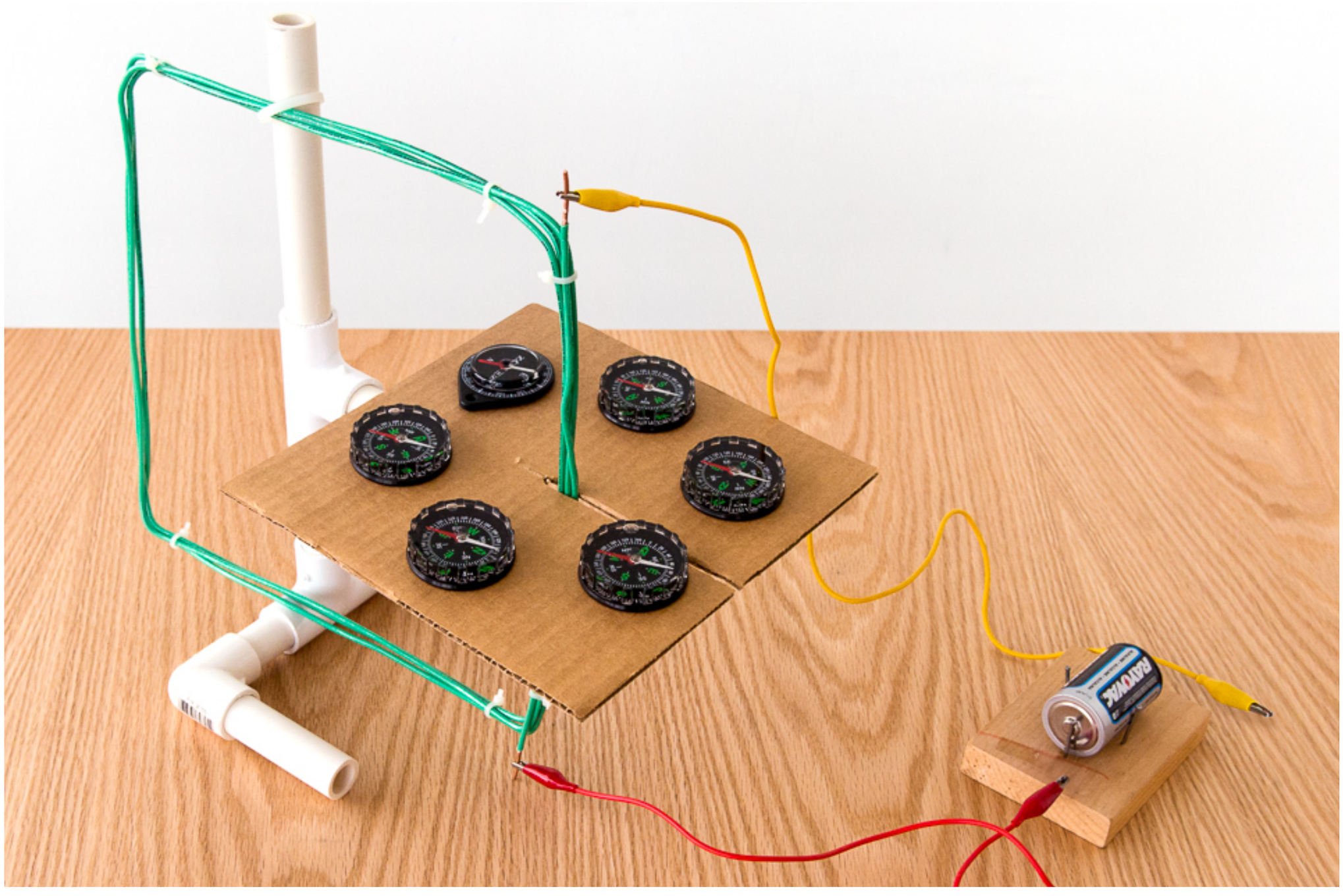
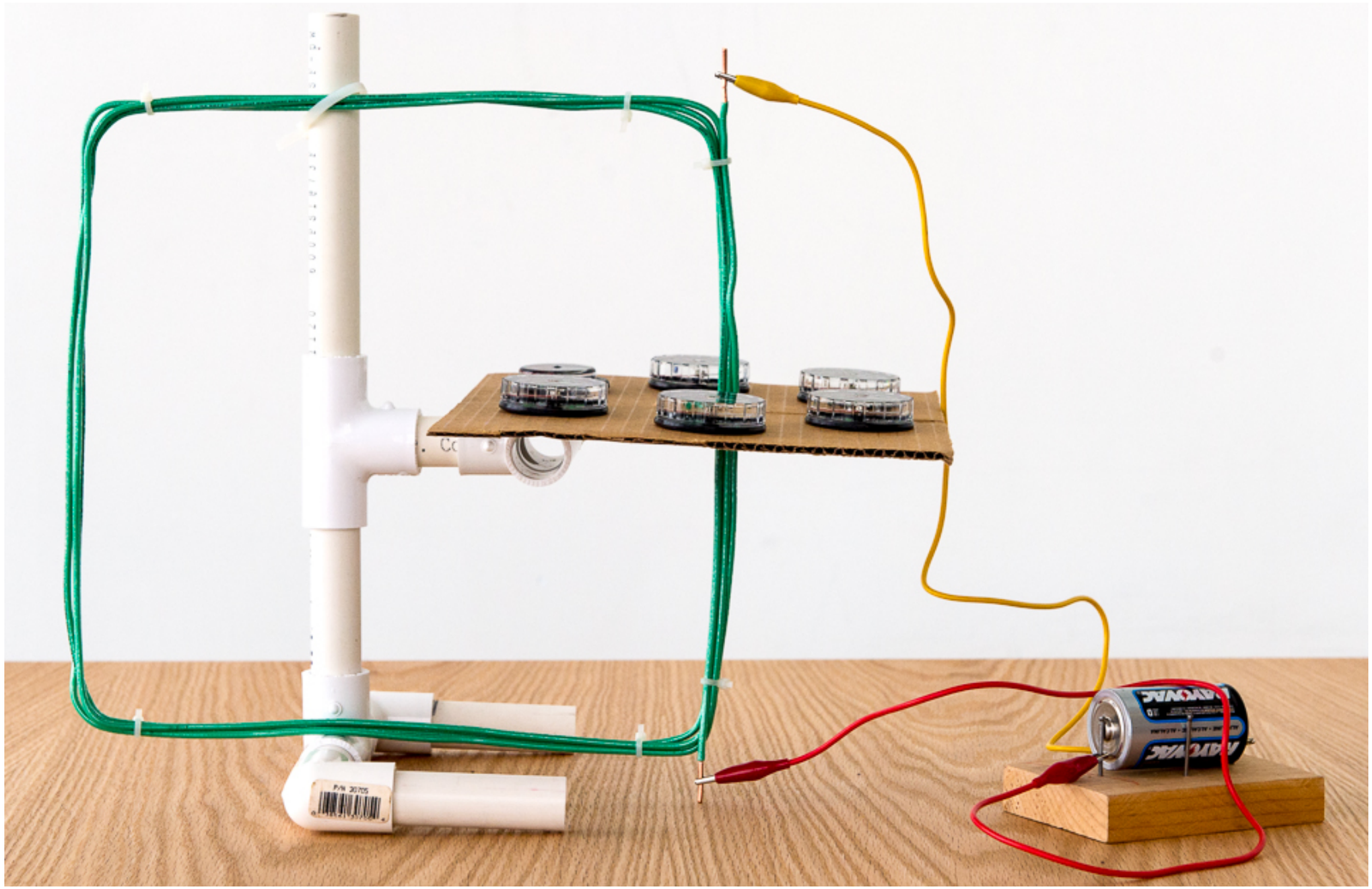


https://www.exploratorium.edu/snacks/circles-of-magnetism

Other Magnetic Fields



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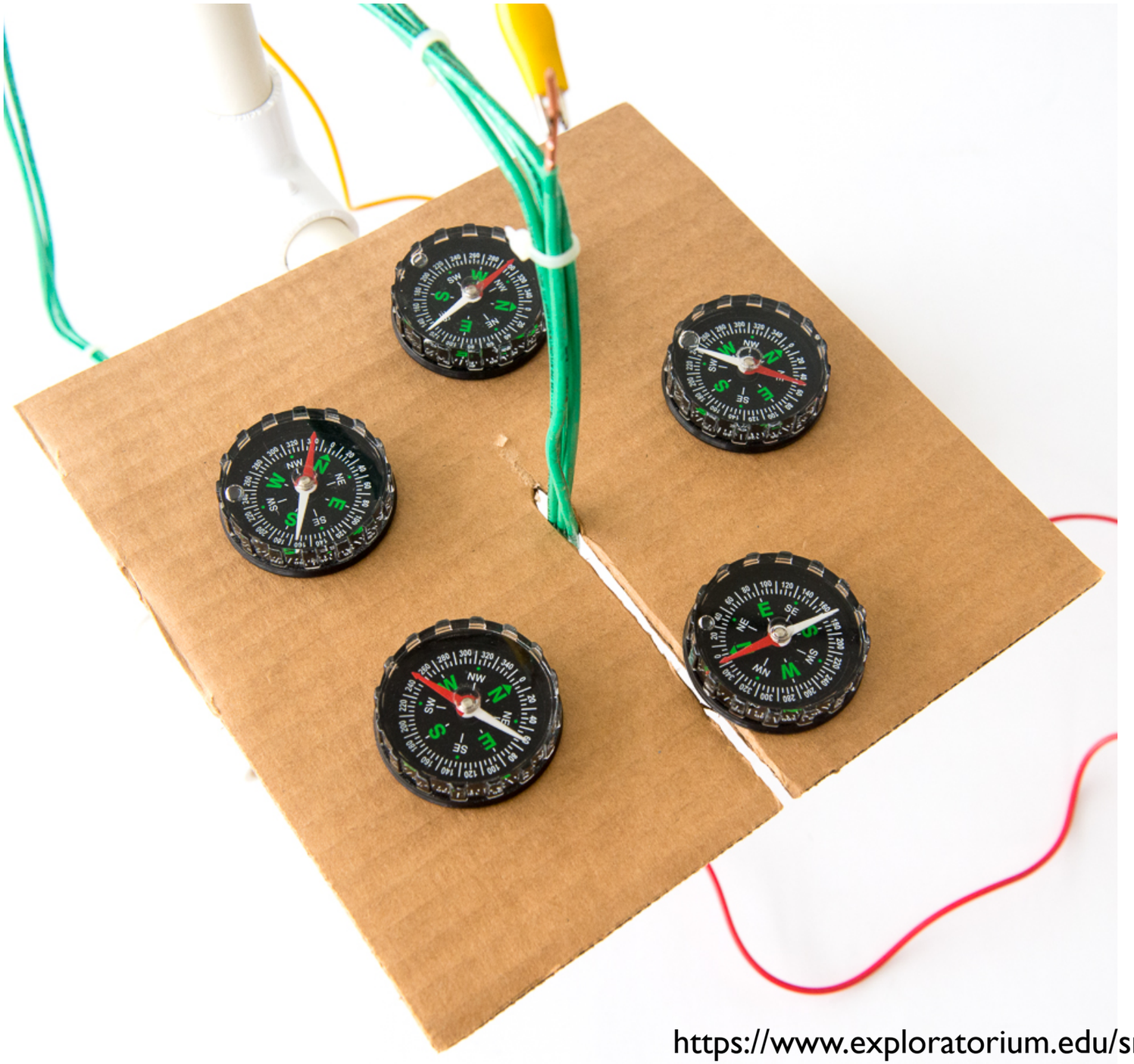
Measuring Magnetic Fields



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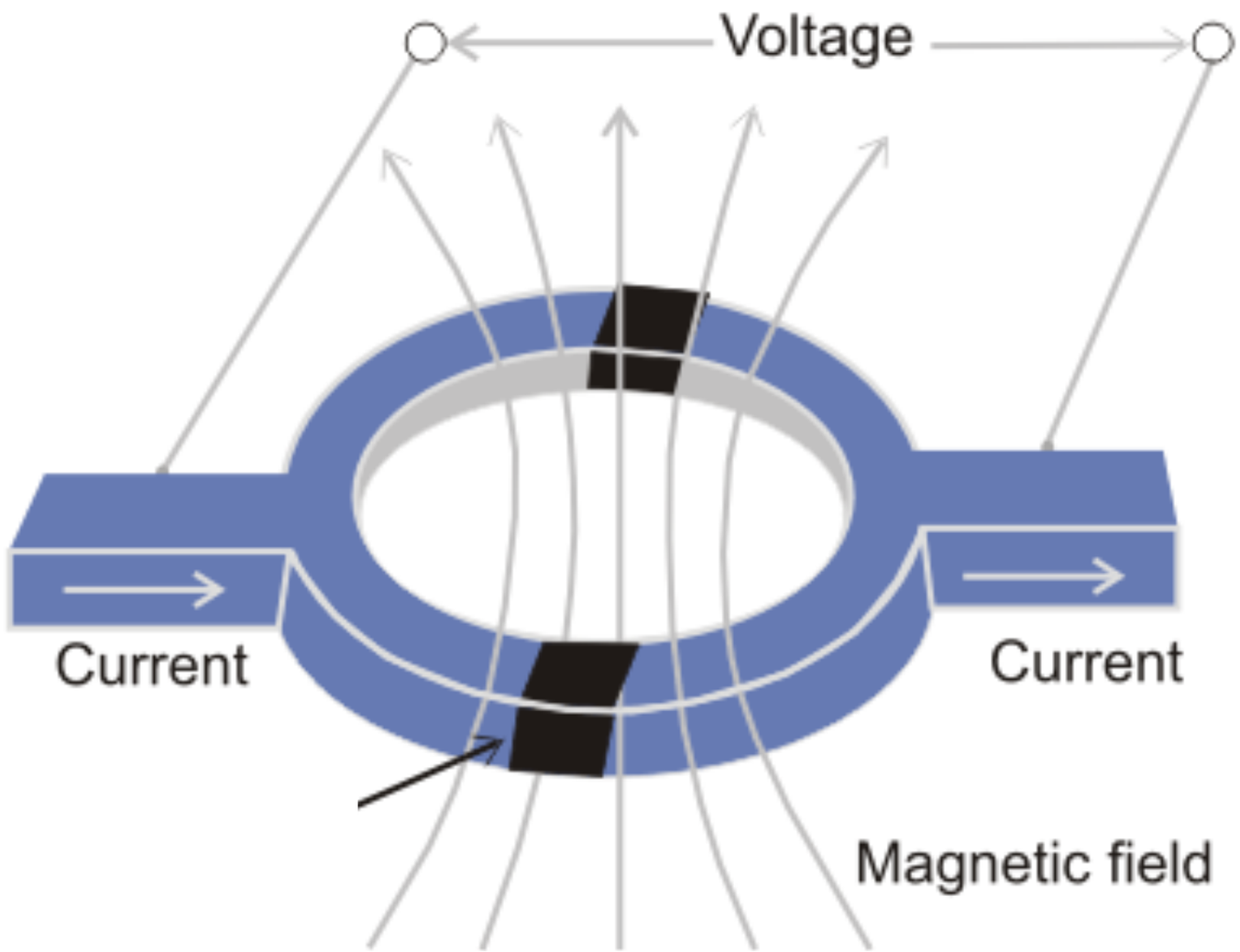
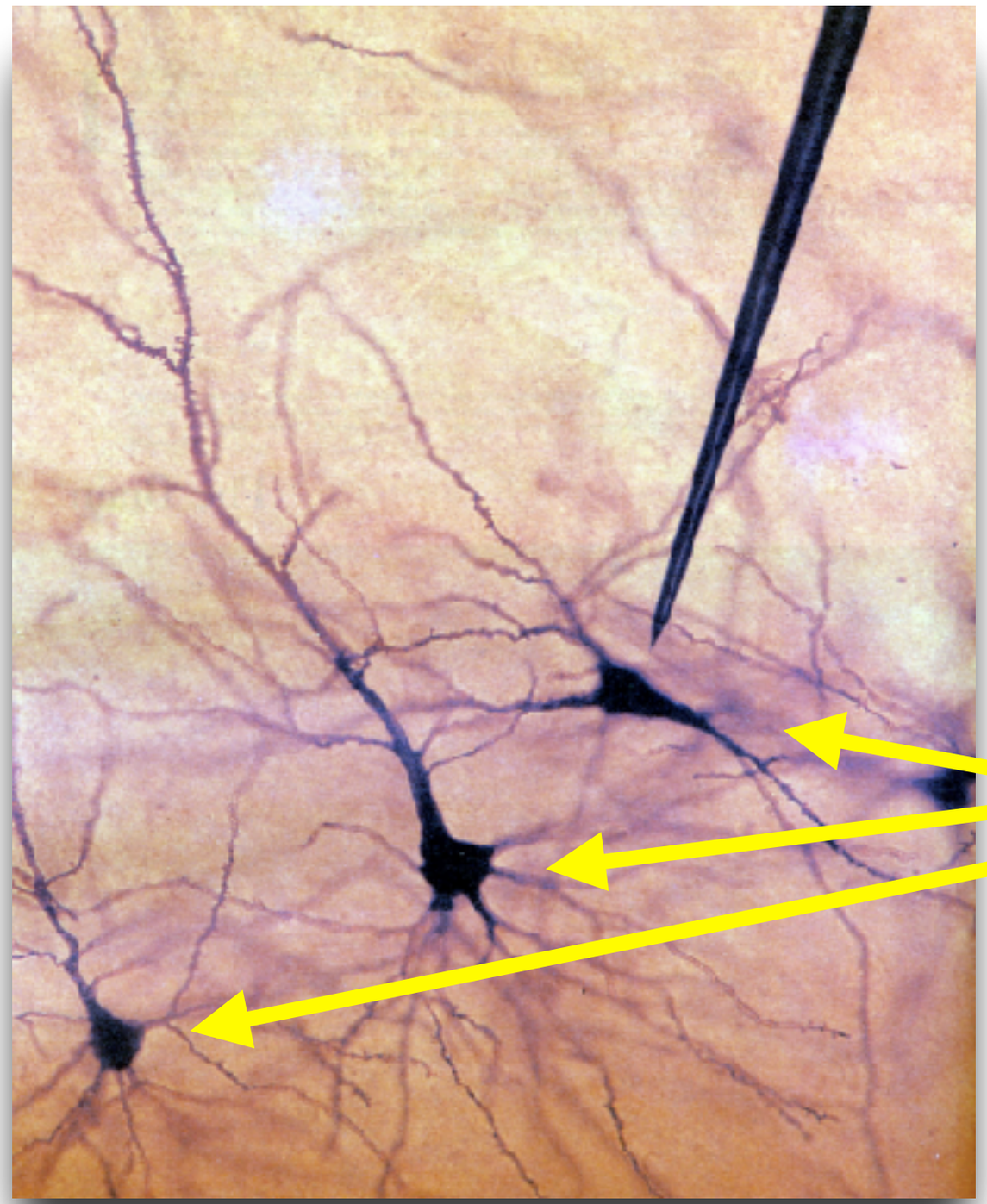
Measuring Magnetic Fields



Superconducting Quantum Interference Device
= "SQUID"

http://www.geocities.ws/pranab_muduli/squid.html

Other Magnetic Fields



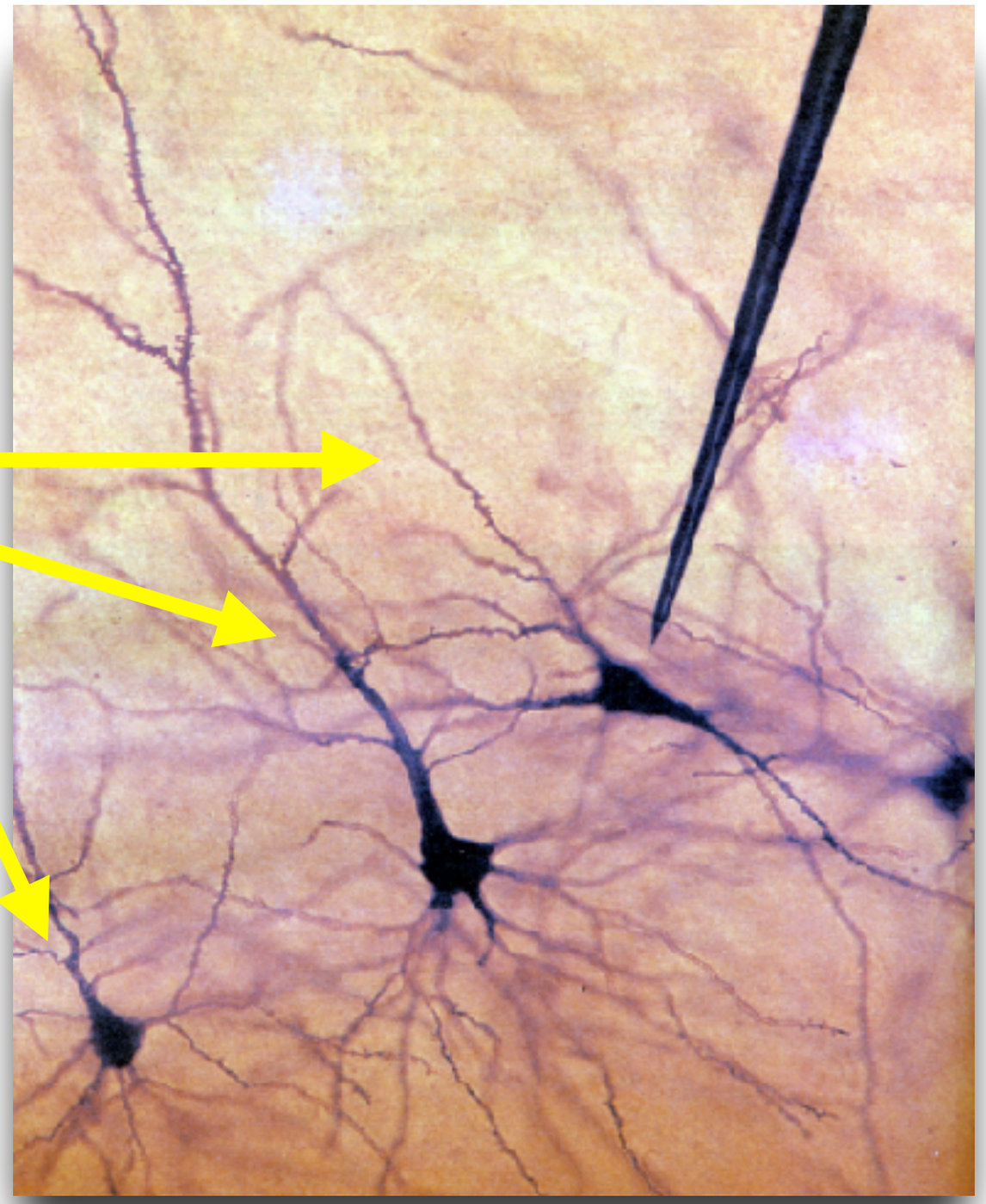
Inside your brain

Neurons

Photo by Fritz Goro

Other Magnetic Fields

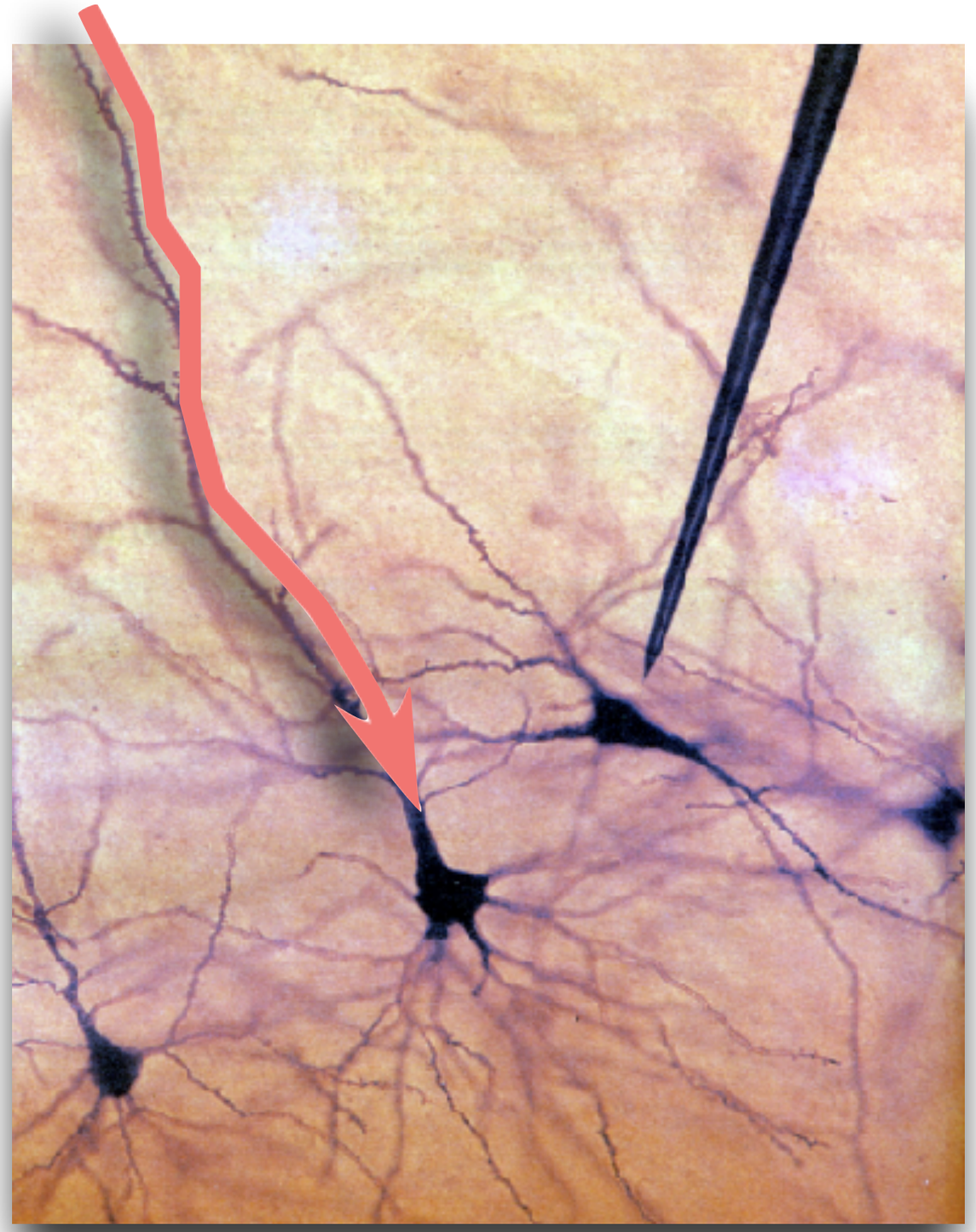
Neuron Wires
"Dendrites"



Inside
your
brain

Photo by Fritz Goro

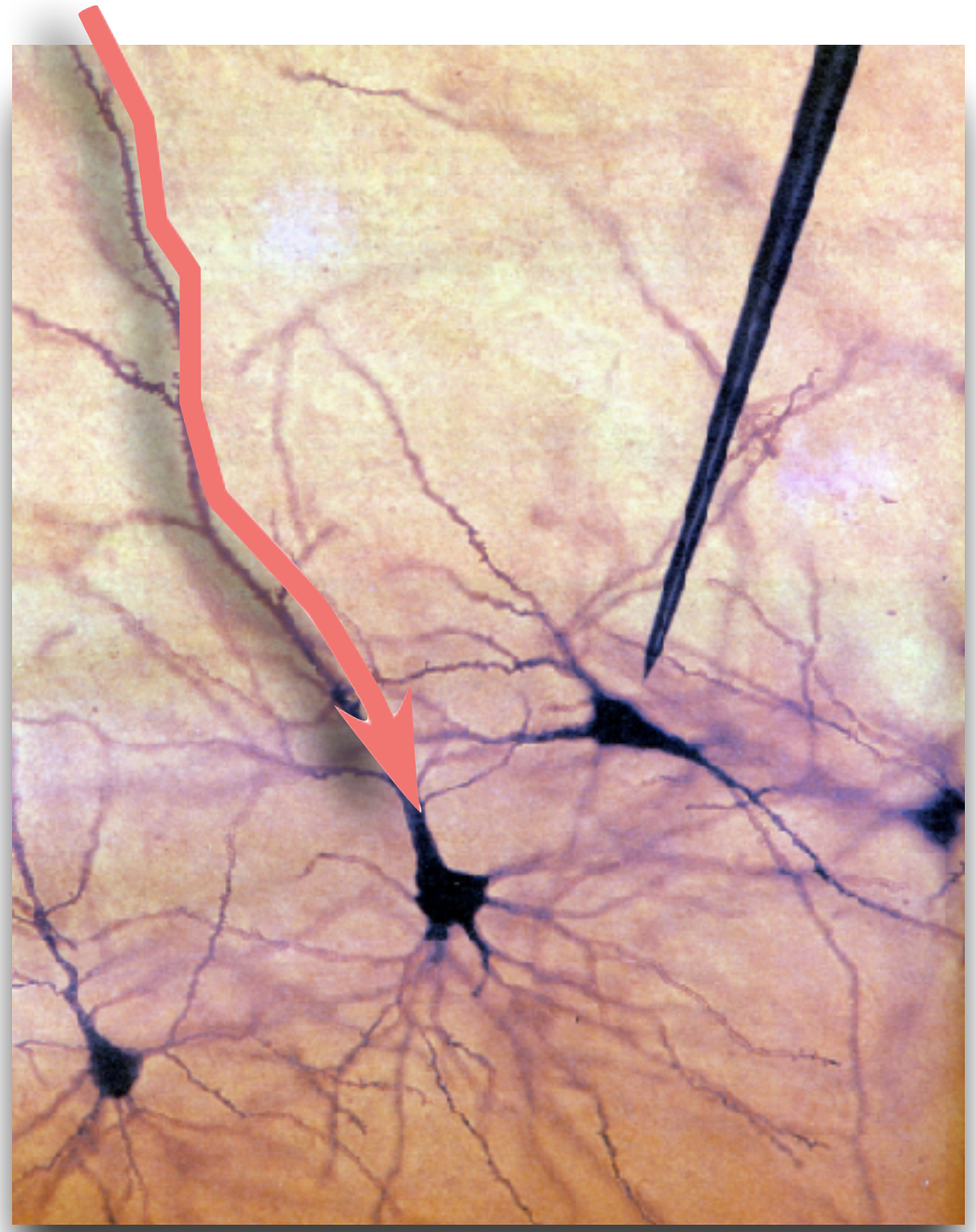
Other Magnetic Fields



Dendrites Carry Electrical Current

Photo by Fritz Goro

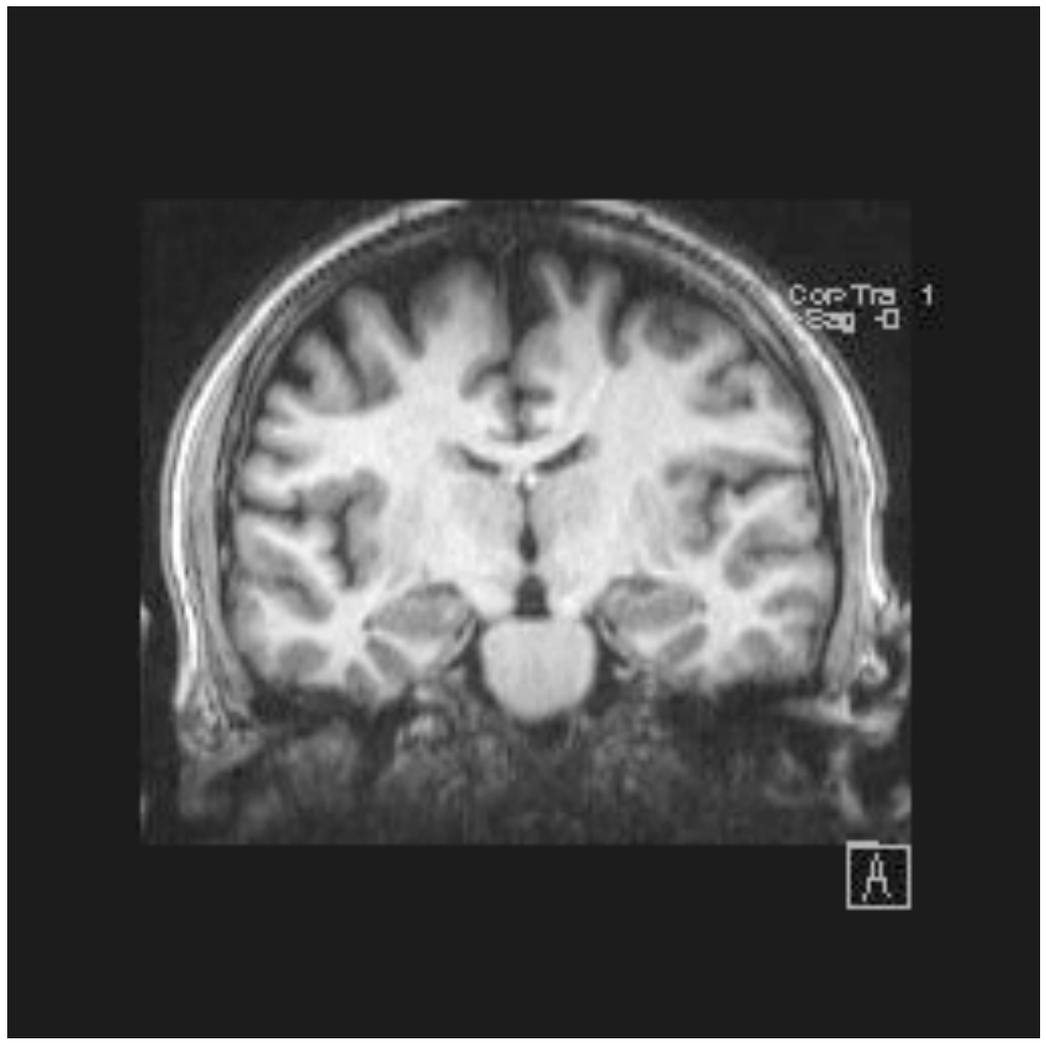
Other Magnetic Fields

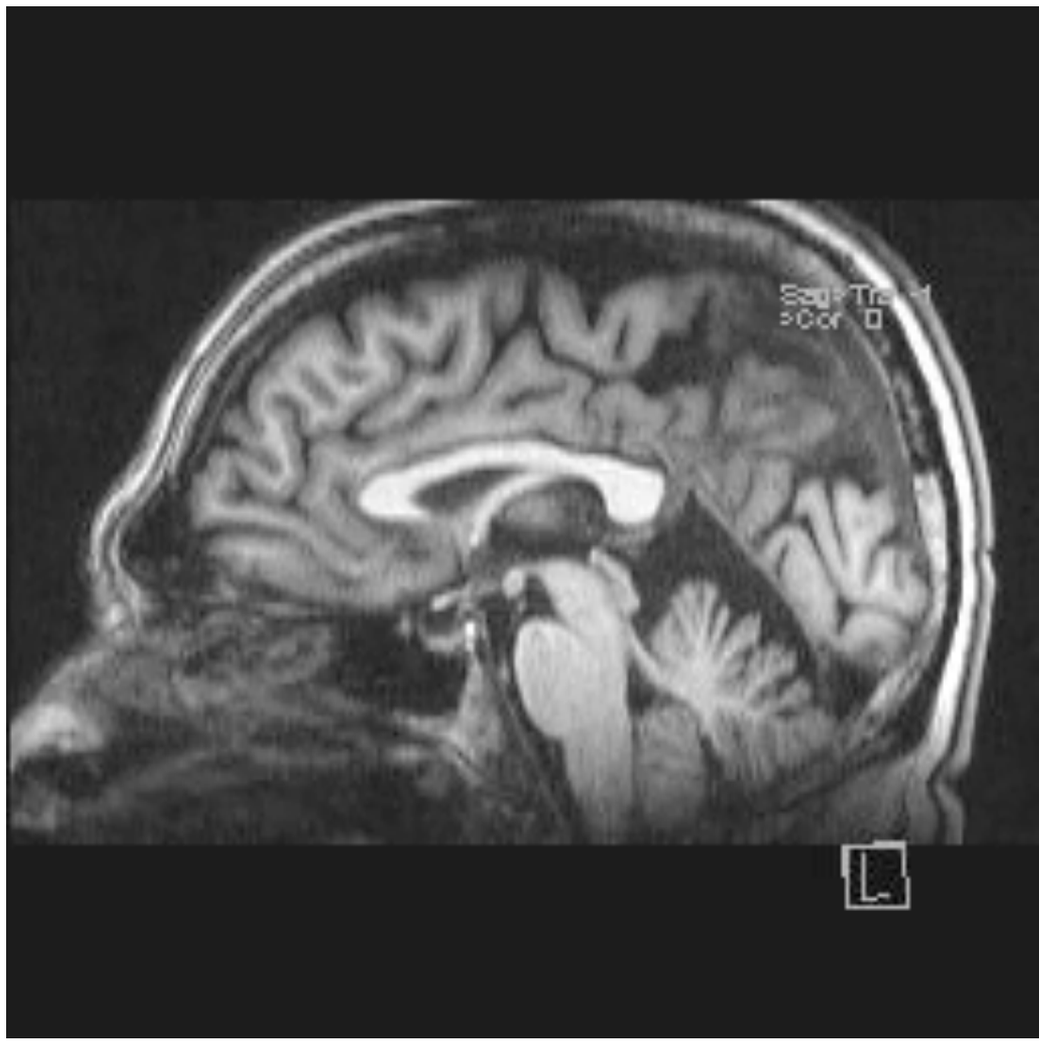


Dendrites Generate Magnetic Fields

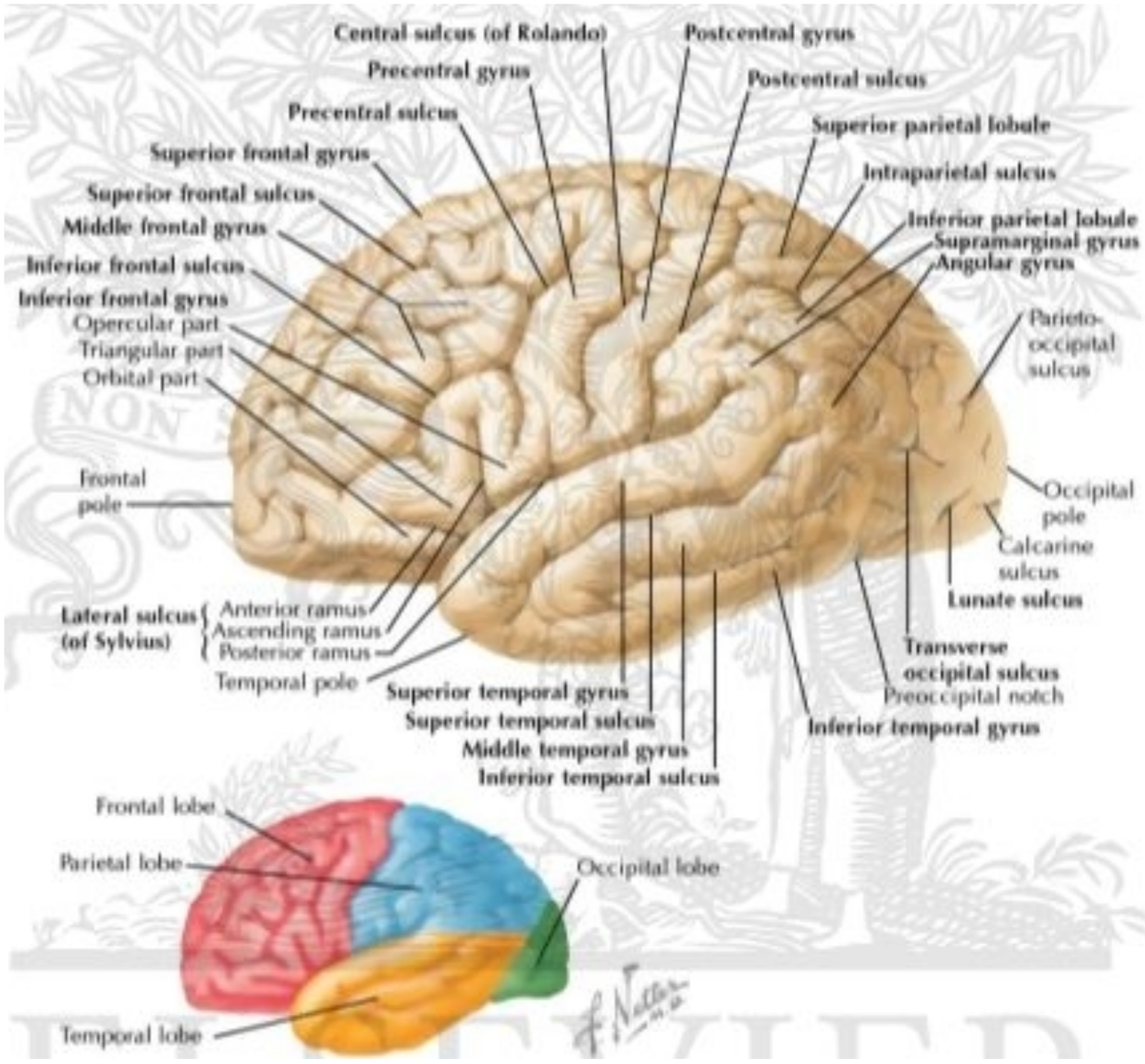
Photo by Fritz Goro

Neural Activity in the Brain Generates Magnetic Fields



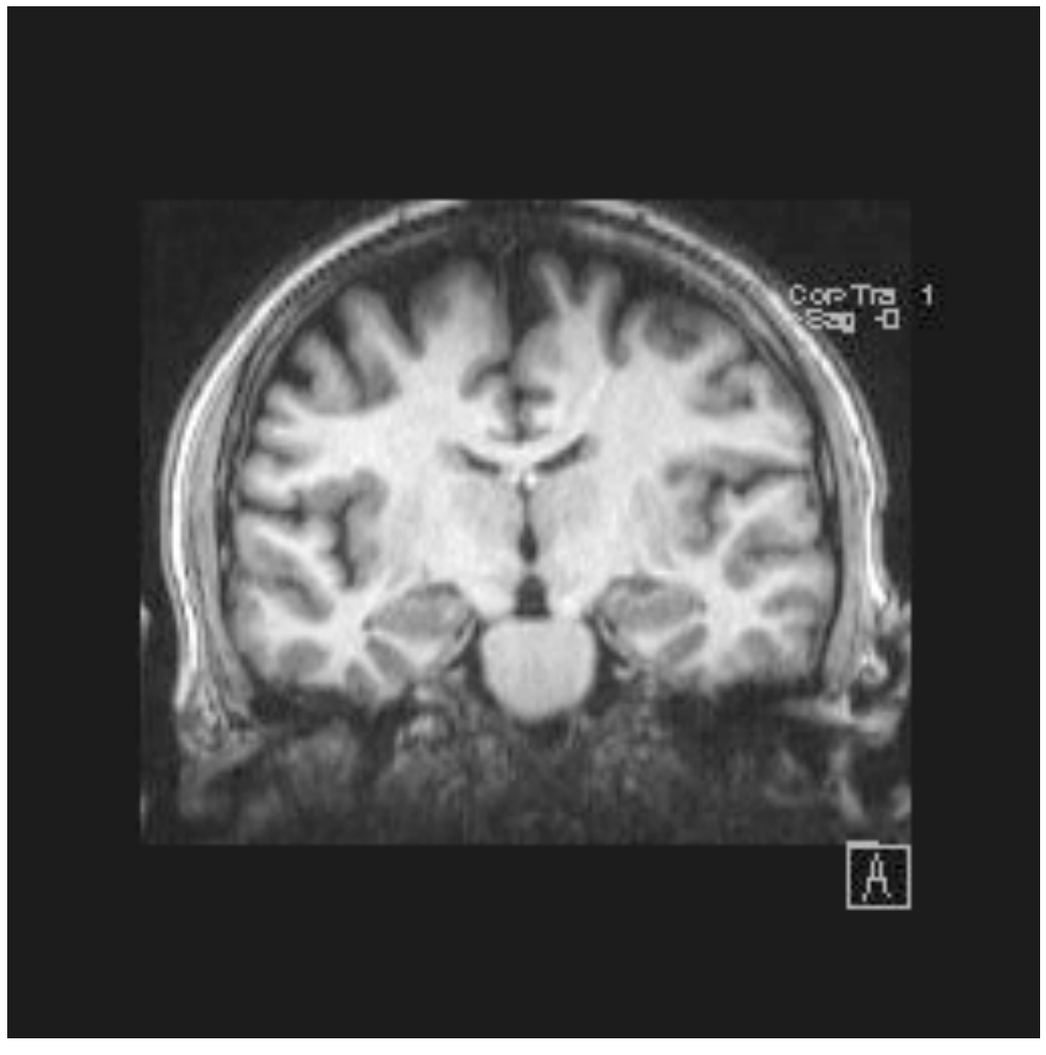


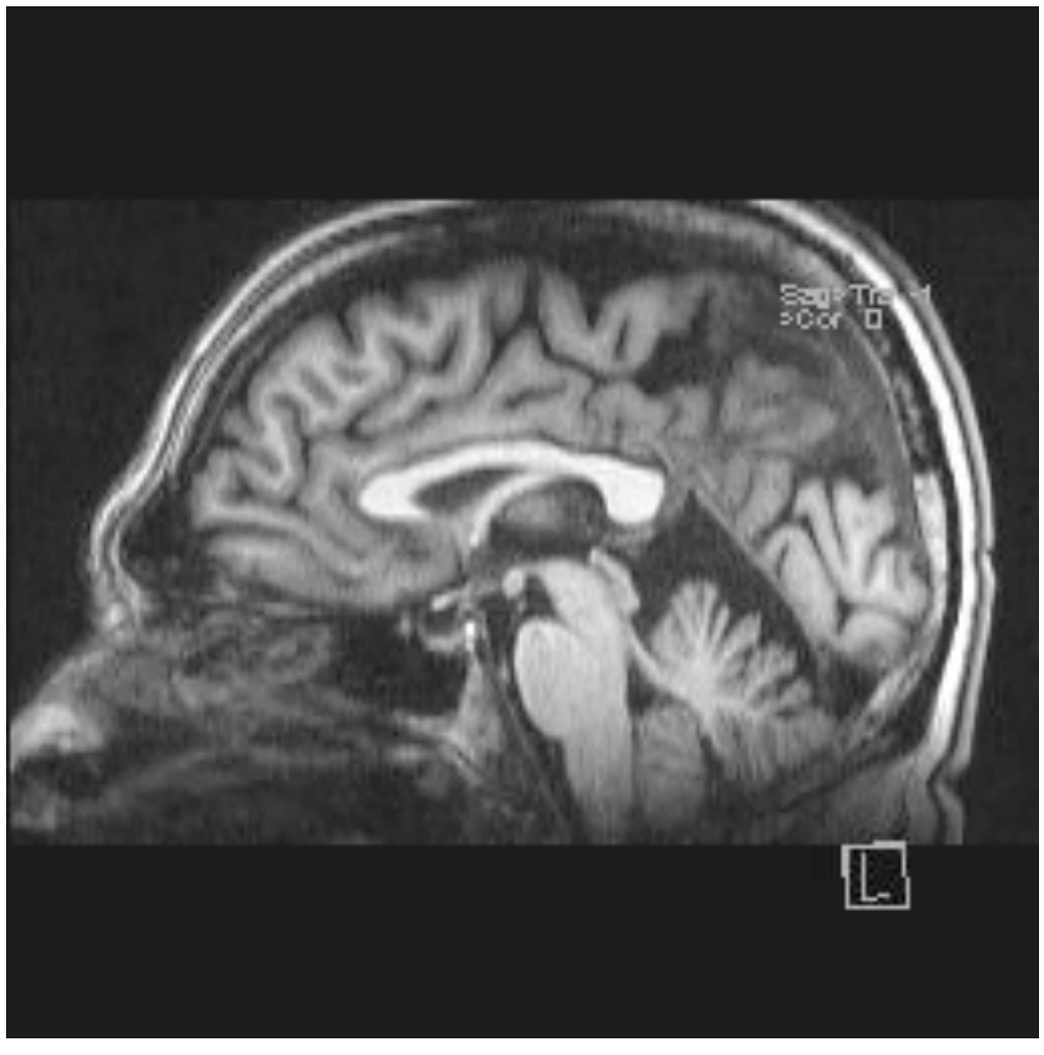
The Human Brain



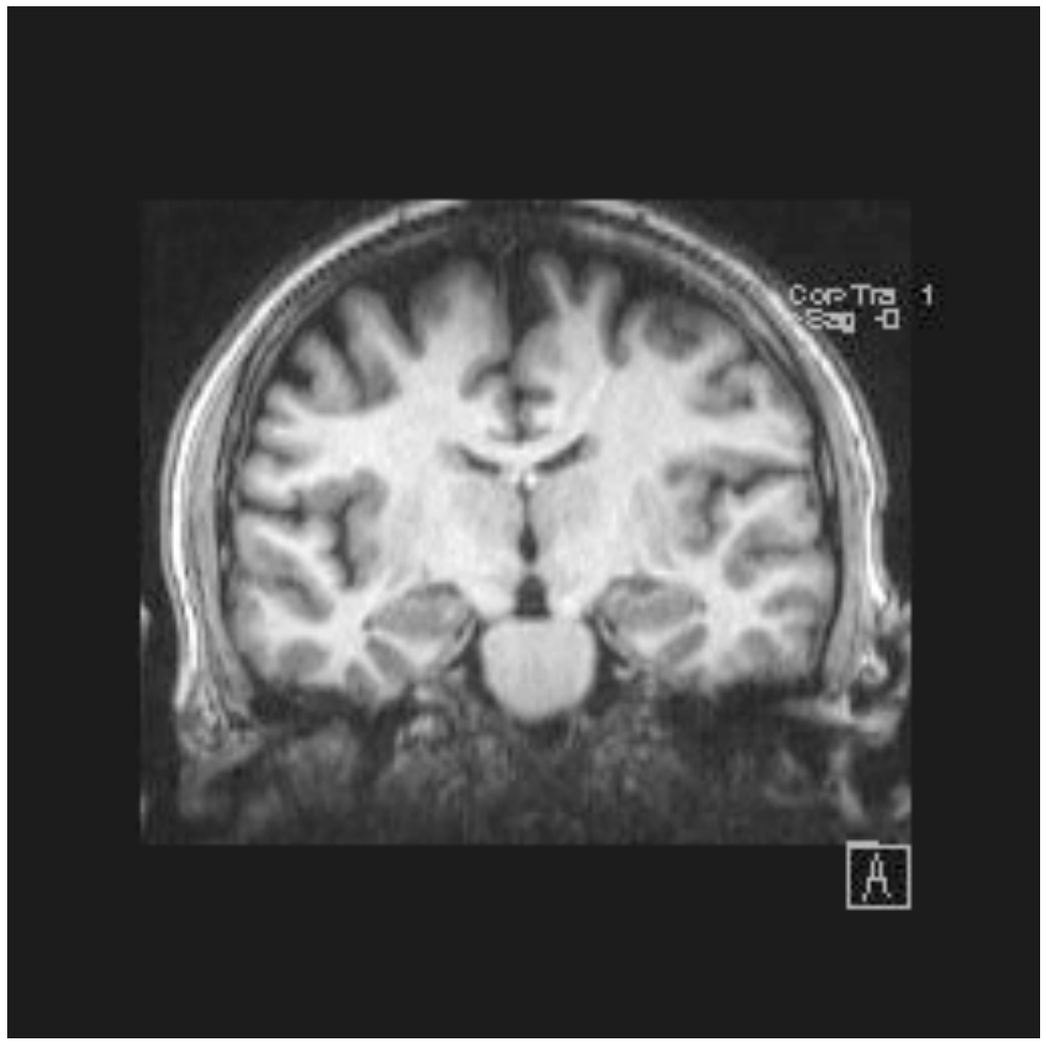
https://netterimages.com/images/vpv/000/000/056/56794-0550x0475.jpg

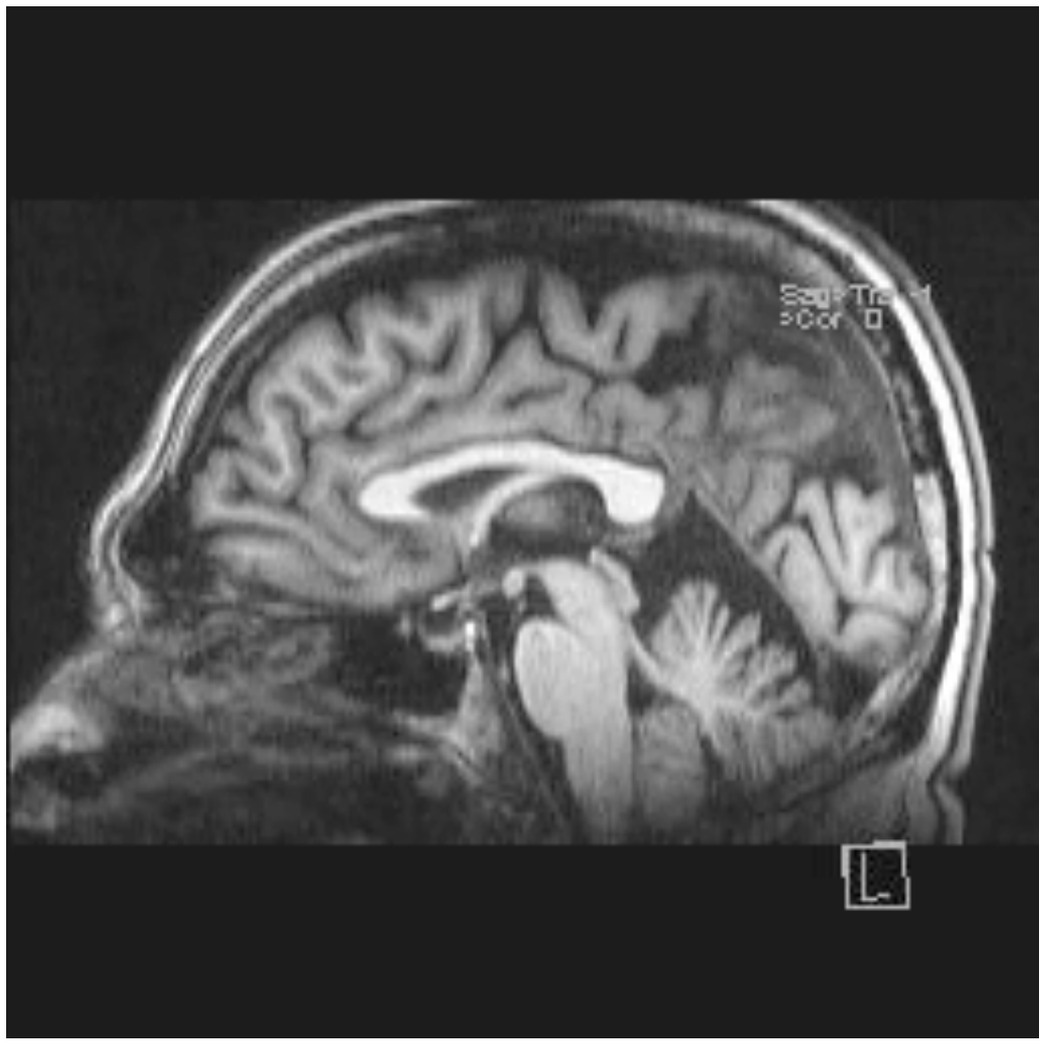
A Human Brain



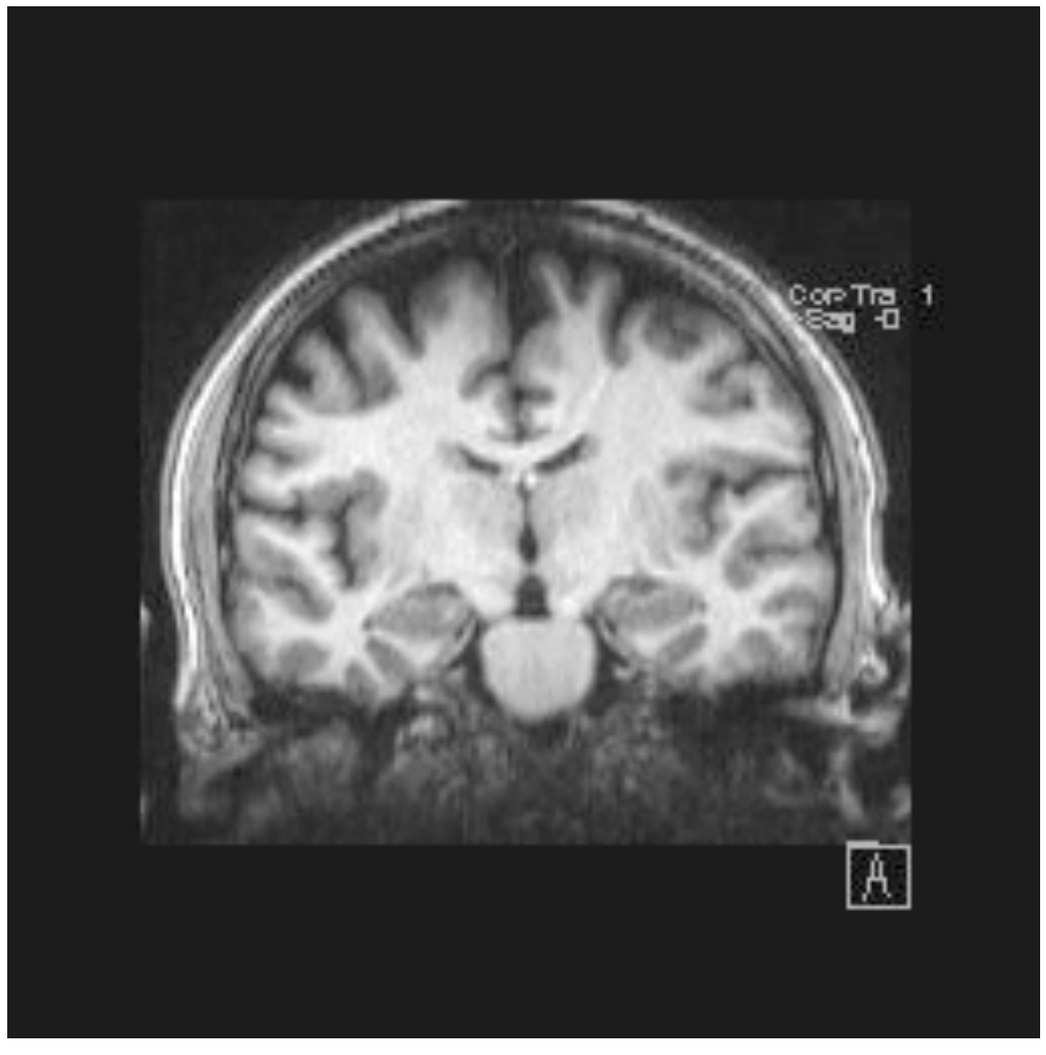


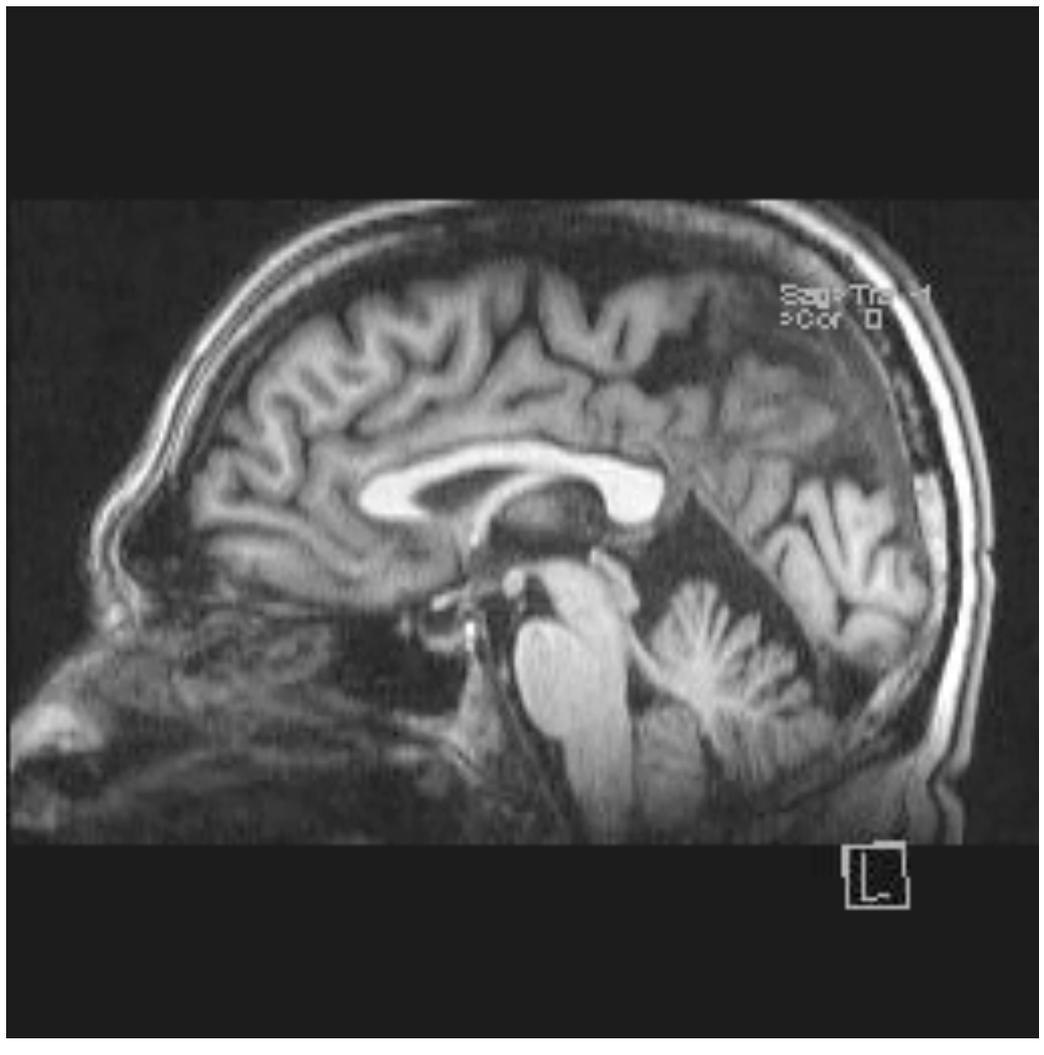
A Human Brain



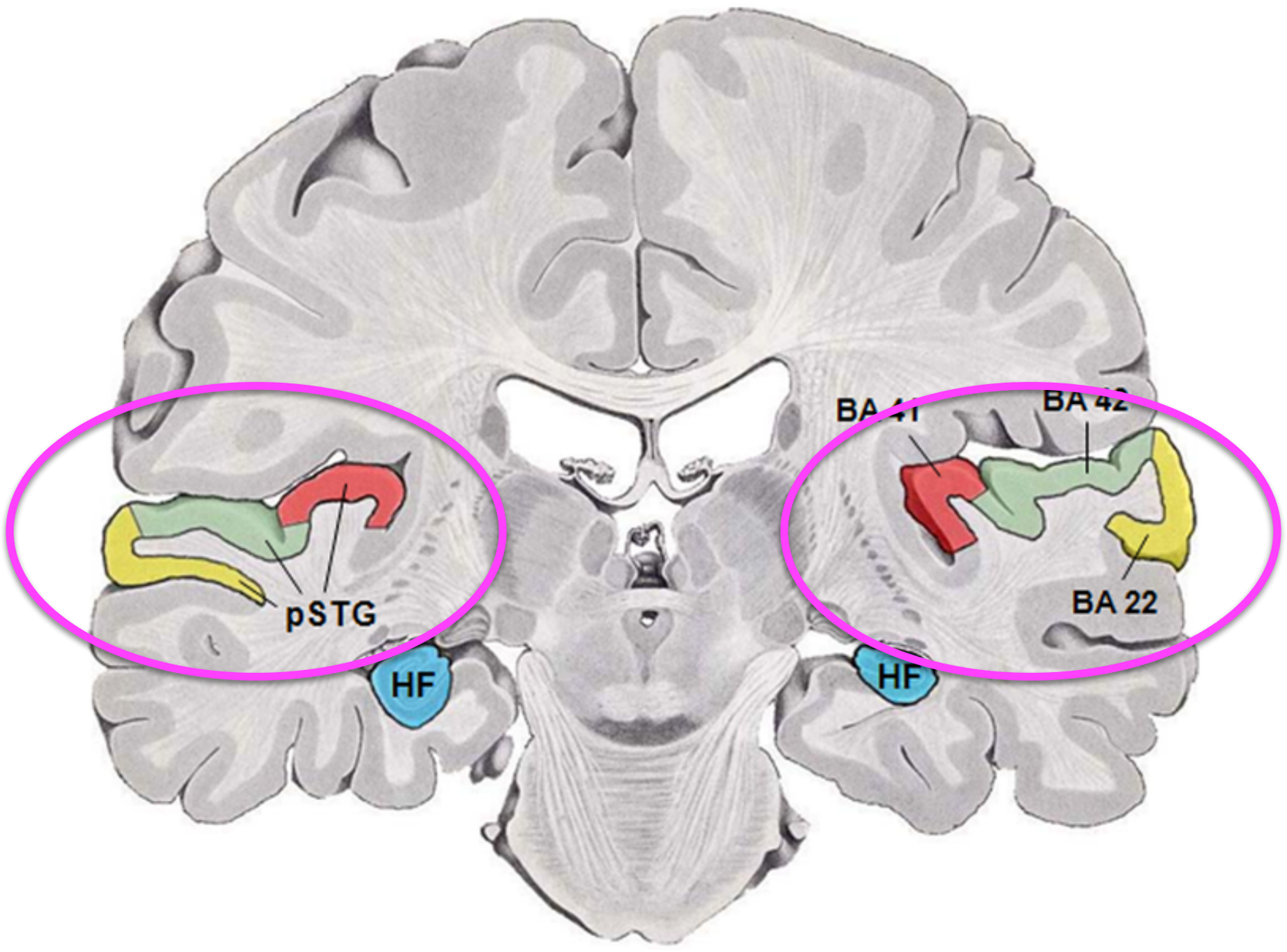


A Human Brain





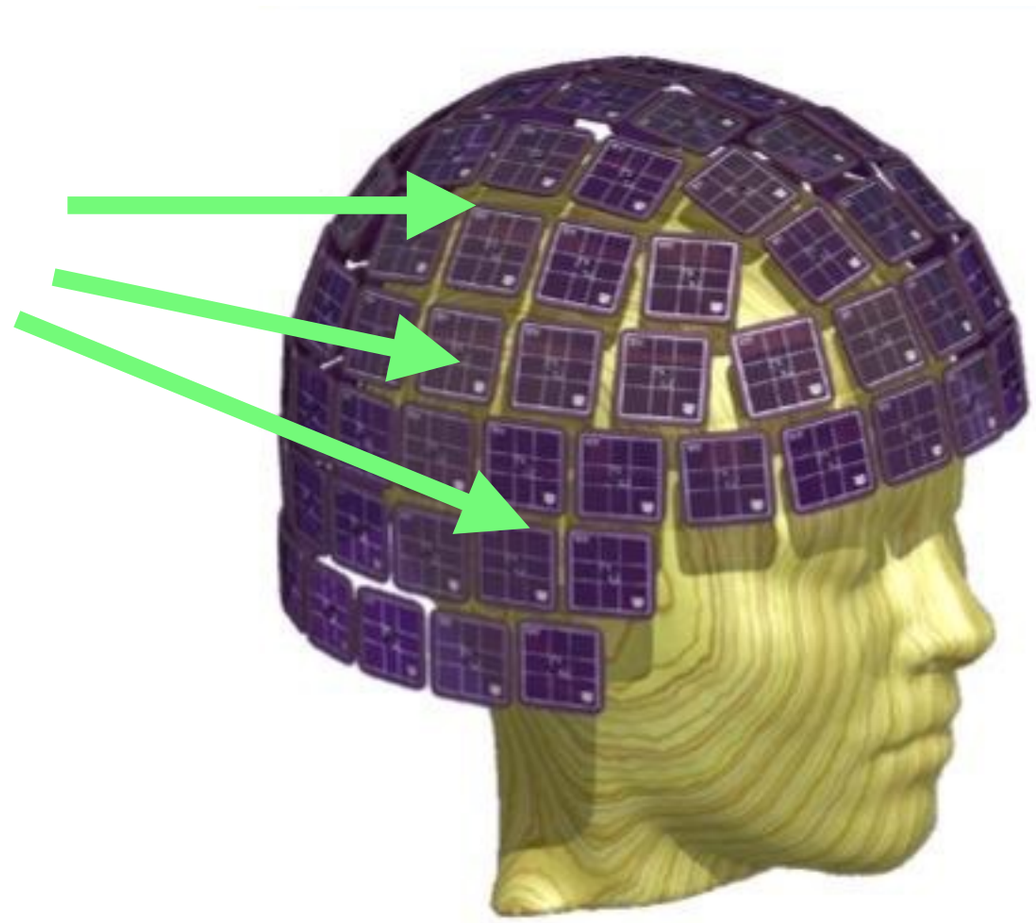
Human Auditory Cortex



https://upload.wikimedia.org/wikipedia/commons/c/c0/Human_temporal_lobe_areas.png

Measuring Magnetism in the Brain

SQUIDs

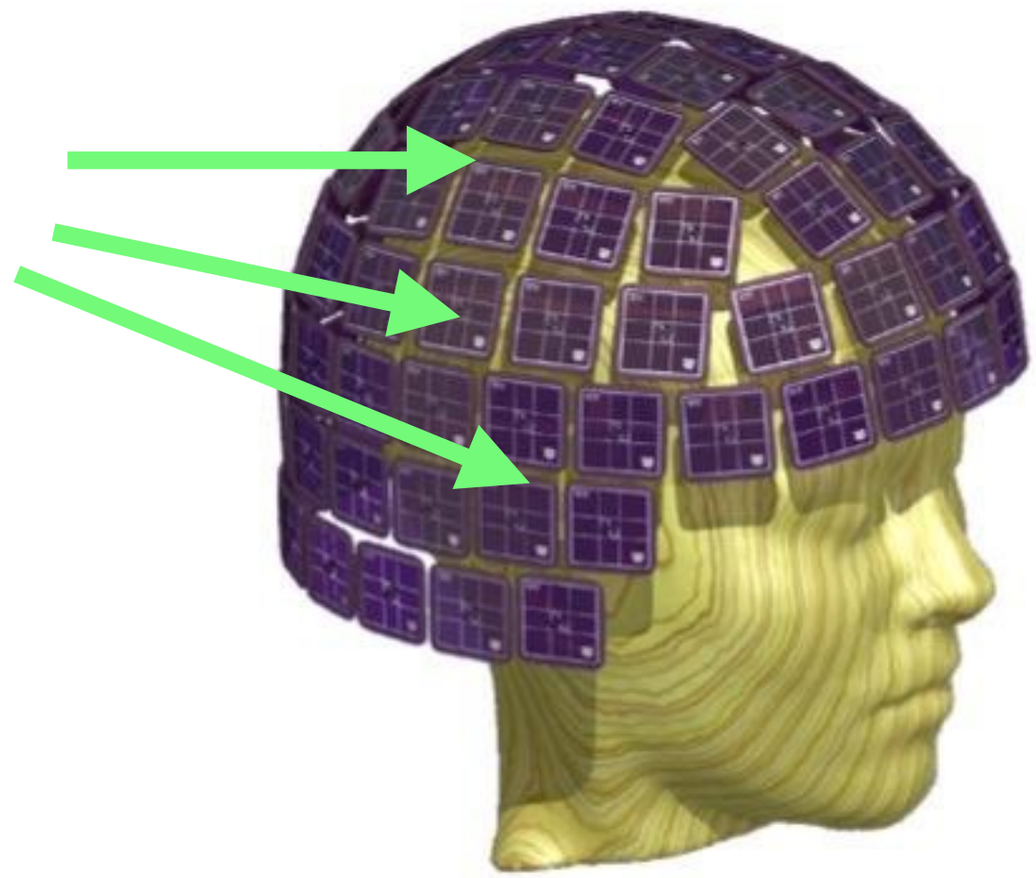


http://ilabs.washington.edu/what-magnetoencephalography-meg

Measuring Magnetism in the Brain

Magnetoencephalography = "MEG"

SQUIDs



http://ilabs.washington.edu/what-magnetoencephalography-meg

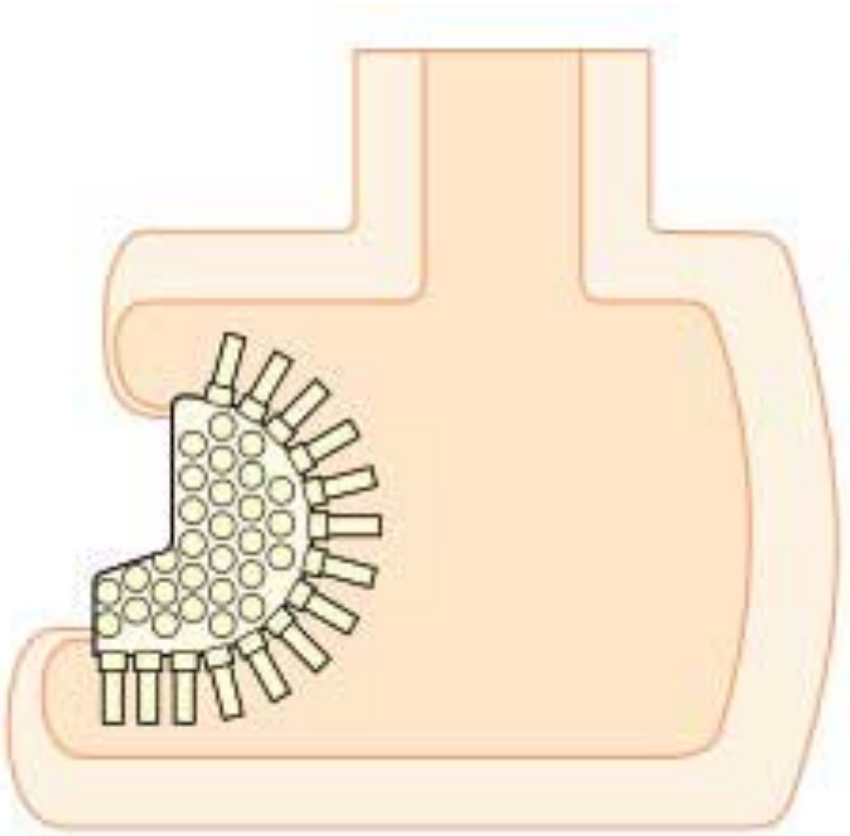
Magnetoencephalography

= MEG

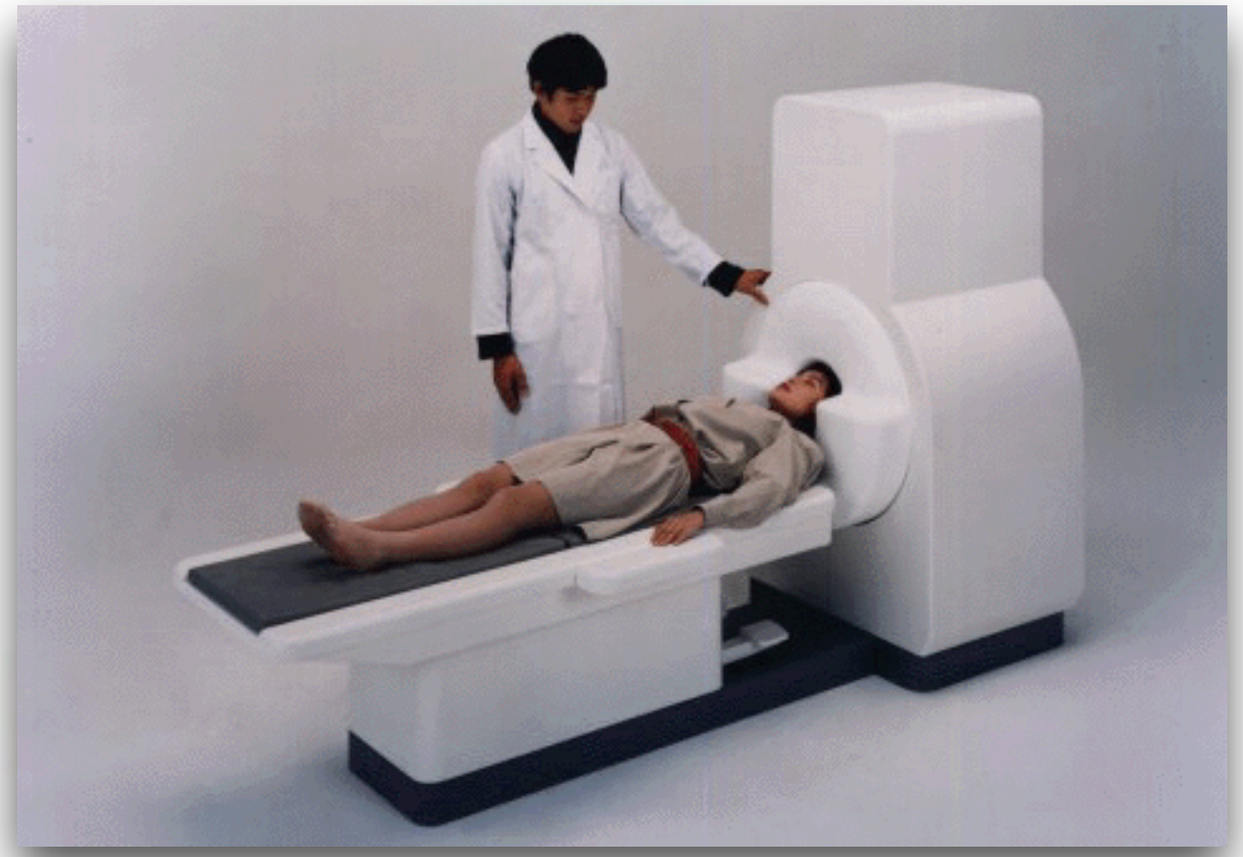
= magnetism from the brain

http://www.darkroastedblend.com/2007/05/mystery-devices-issue-2.html

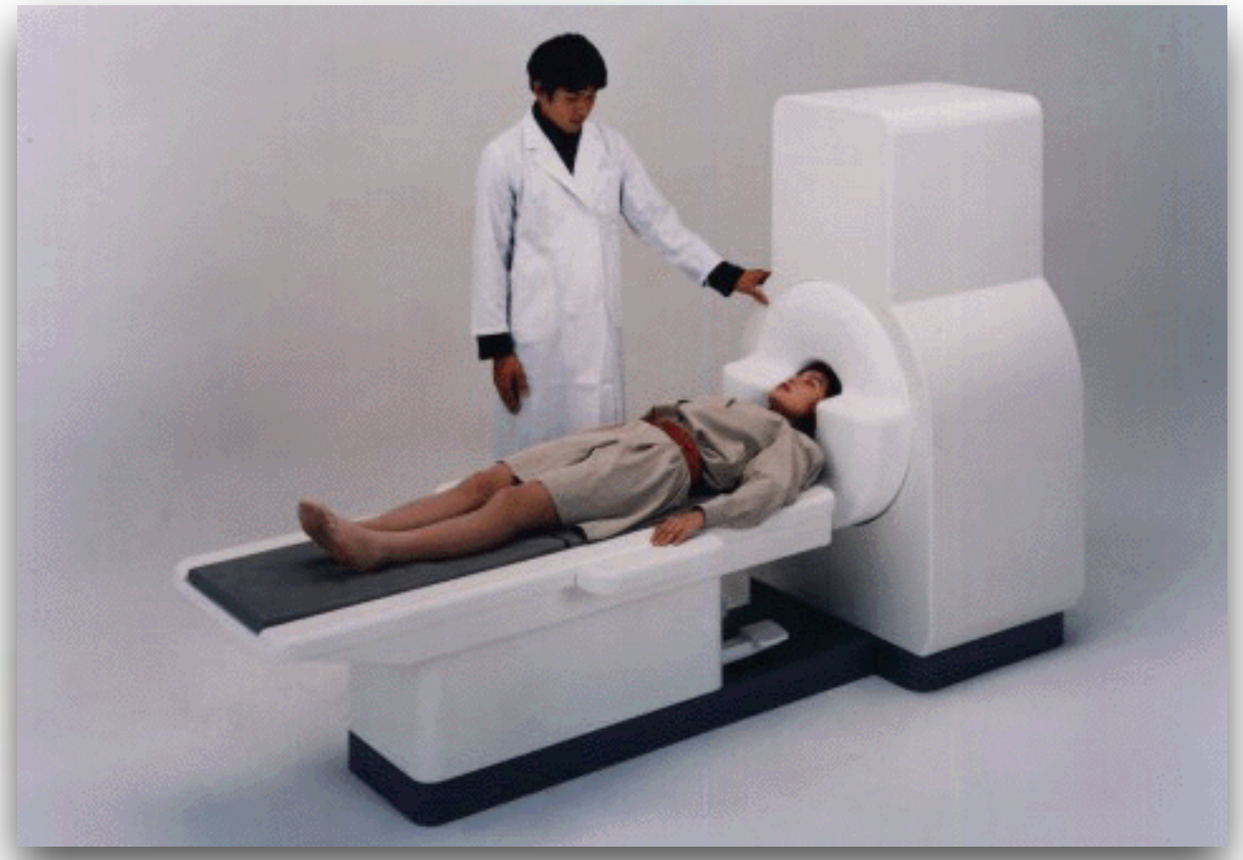
MEG For Real



MEG For Real



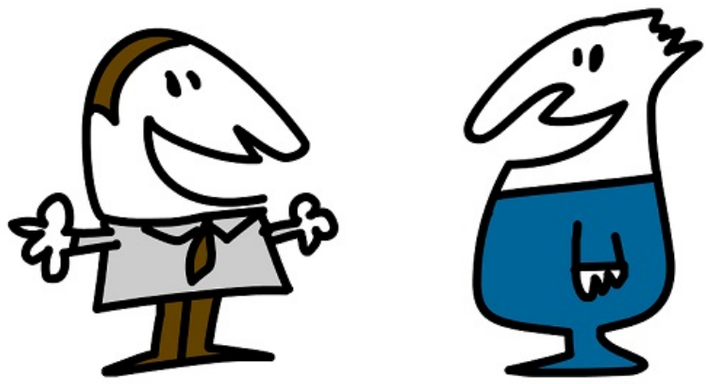
MEG For Real



MEG For Real

http://www.international.mq.edu.au/globe/2008-52/breaking-news

MEG For Real



http://www.international.mq.edu.au/globe/2008-52/breaking-news

Neural Signals & MEG

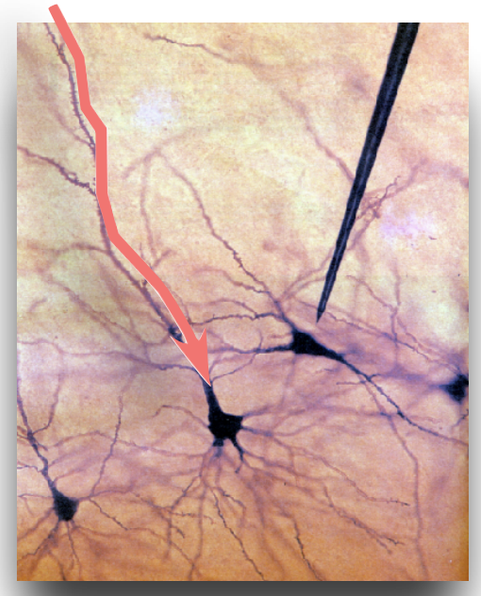
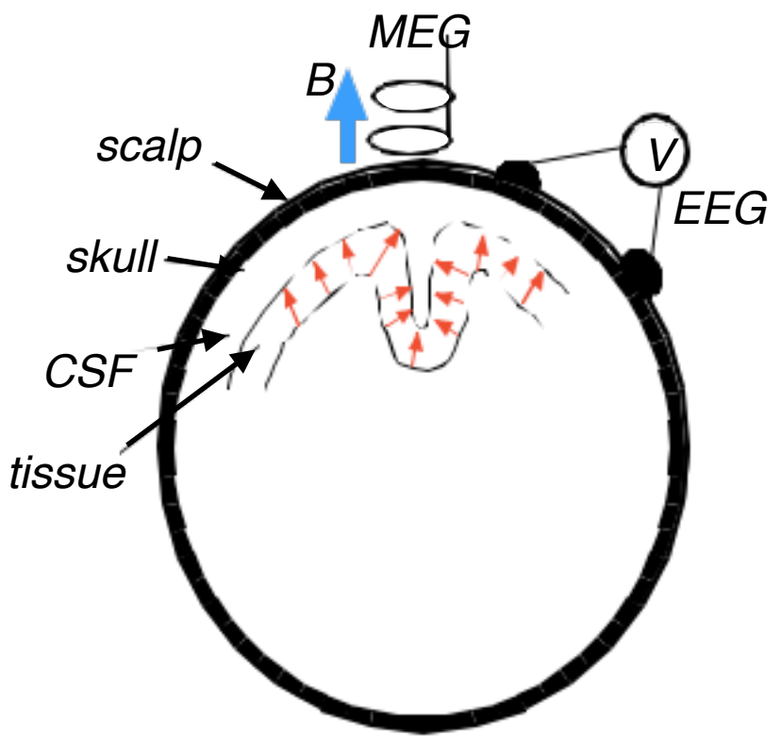
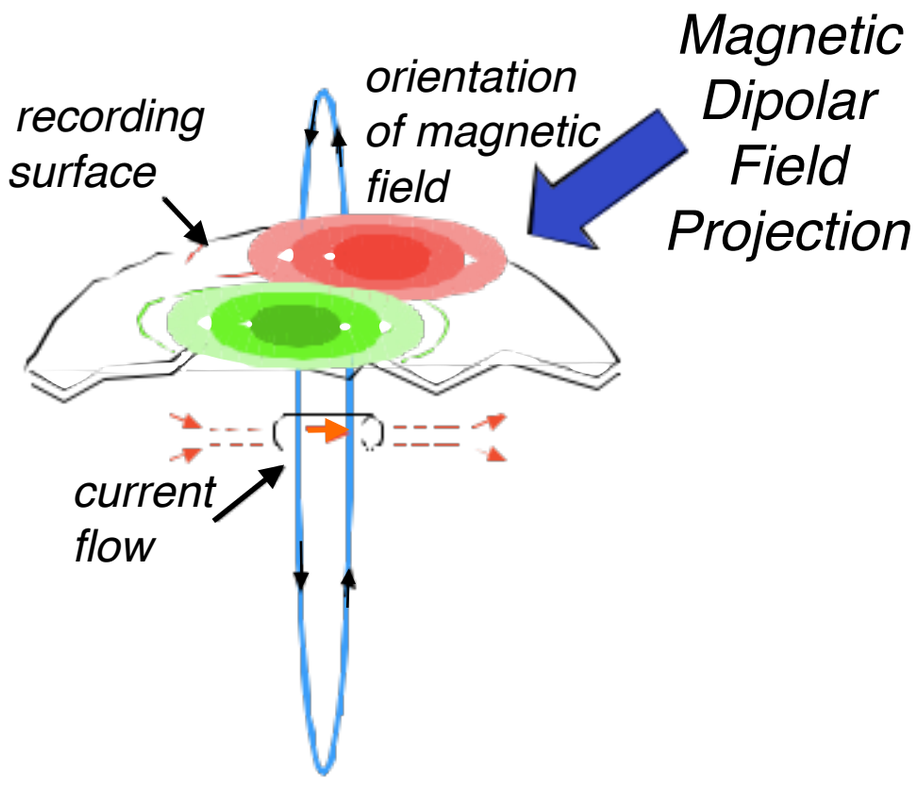


Photo by Fritz Goro

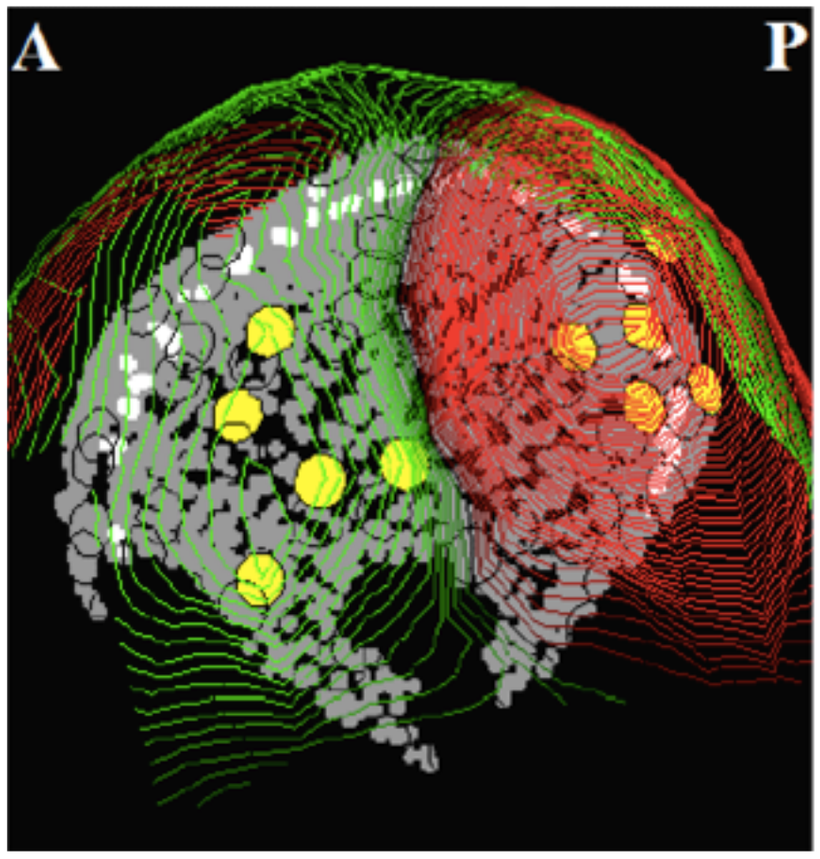




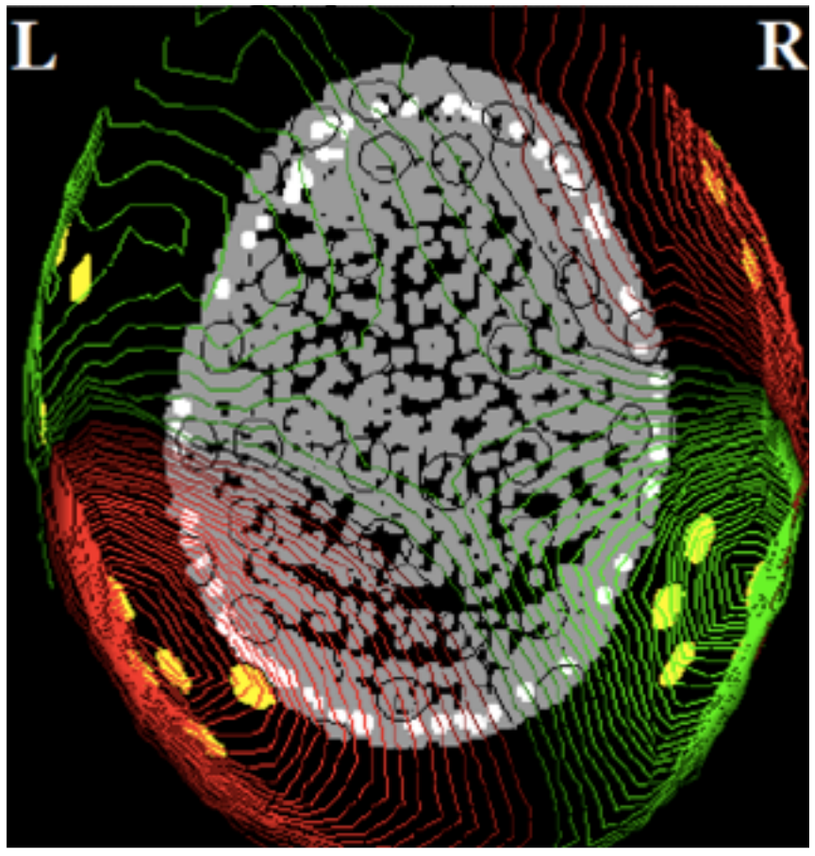
- Direct electrophysiological measurement
  - not hemodynamic
  - real-time
- No unique solution for distributed source

- Measures spatially synchronized cortical activity
- Fine temporal resolution (~ 1 ms)
- Moderate spatial resolution (~ 1 cm)

Auditory Magnetic Field



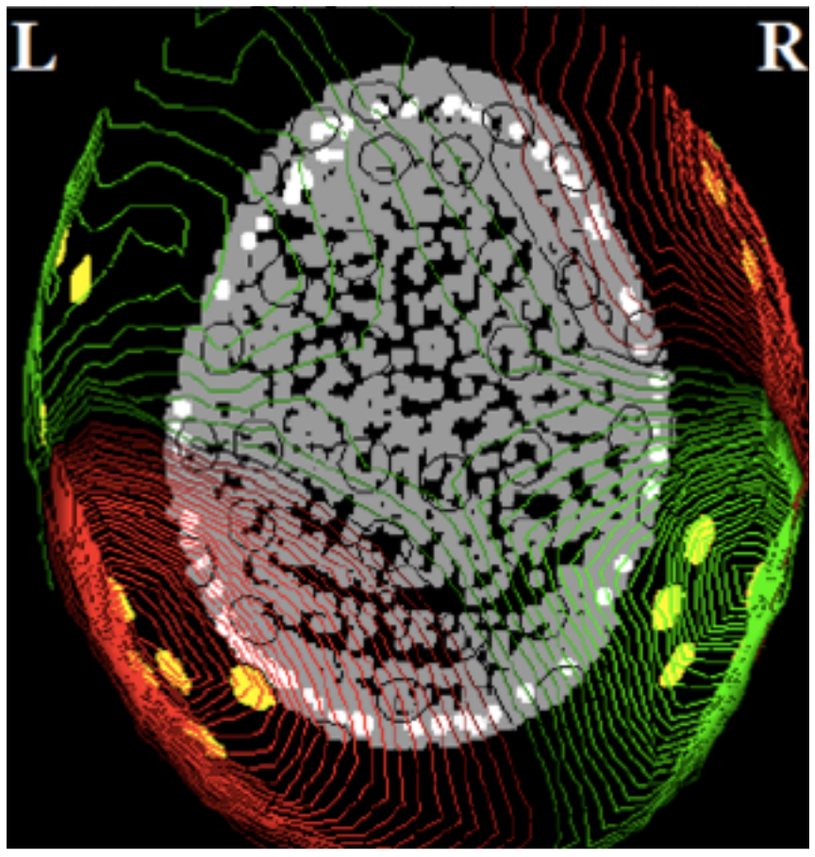
Side View



Top View

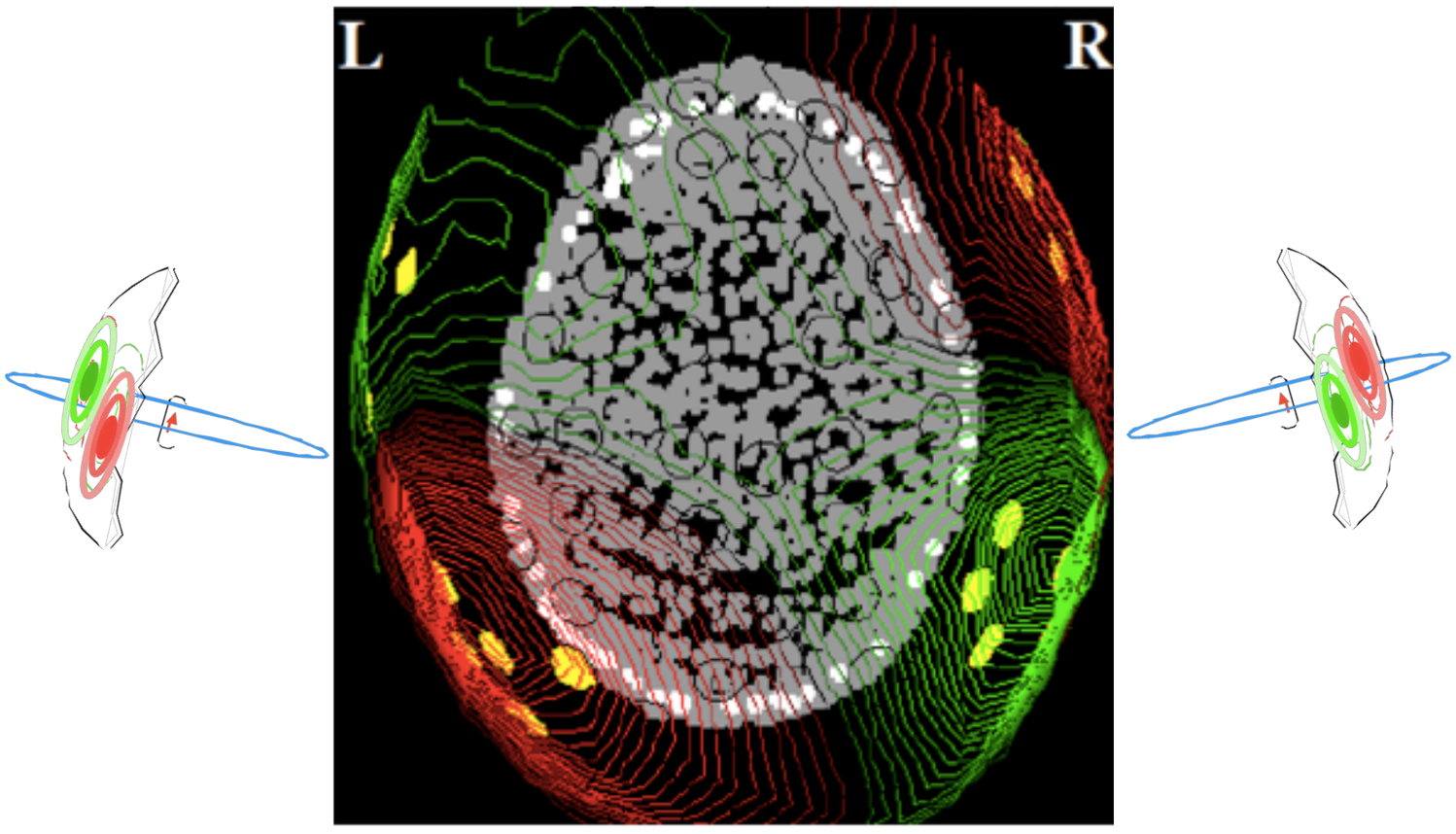
Chait, Poeppel and Simon, Cerebral Cortex (2006)

Auditory Magnetic Field



Chait et al., Cerebral Cortex (2006)

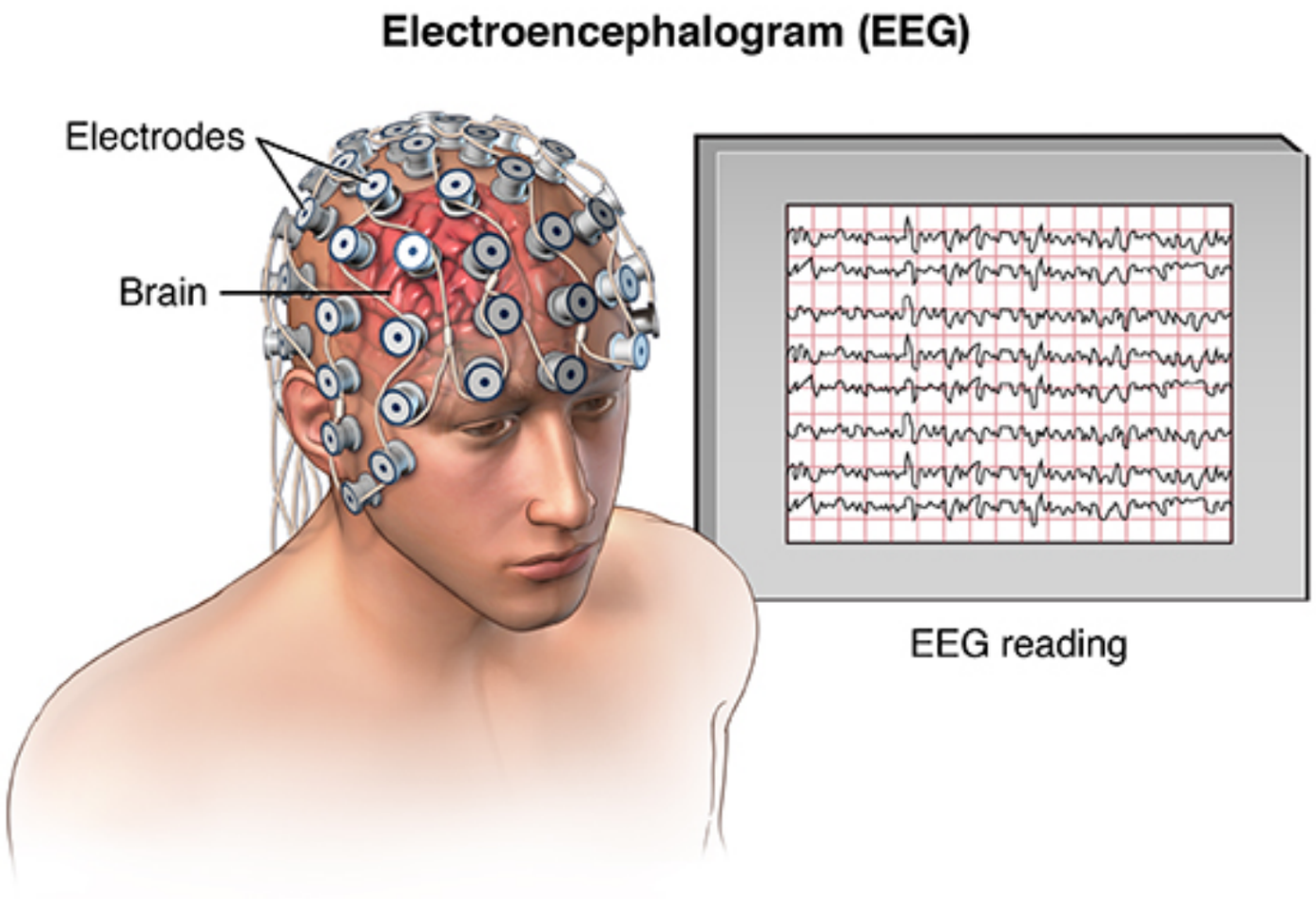
Auditory Magnetic Field



Chait et al., Cerebral Cortex (2006)

EEG

Electroencephalography



http://www.saintlukeshealthsystem.org/health-library/electroencephalogram-eeg

MRI

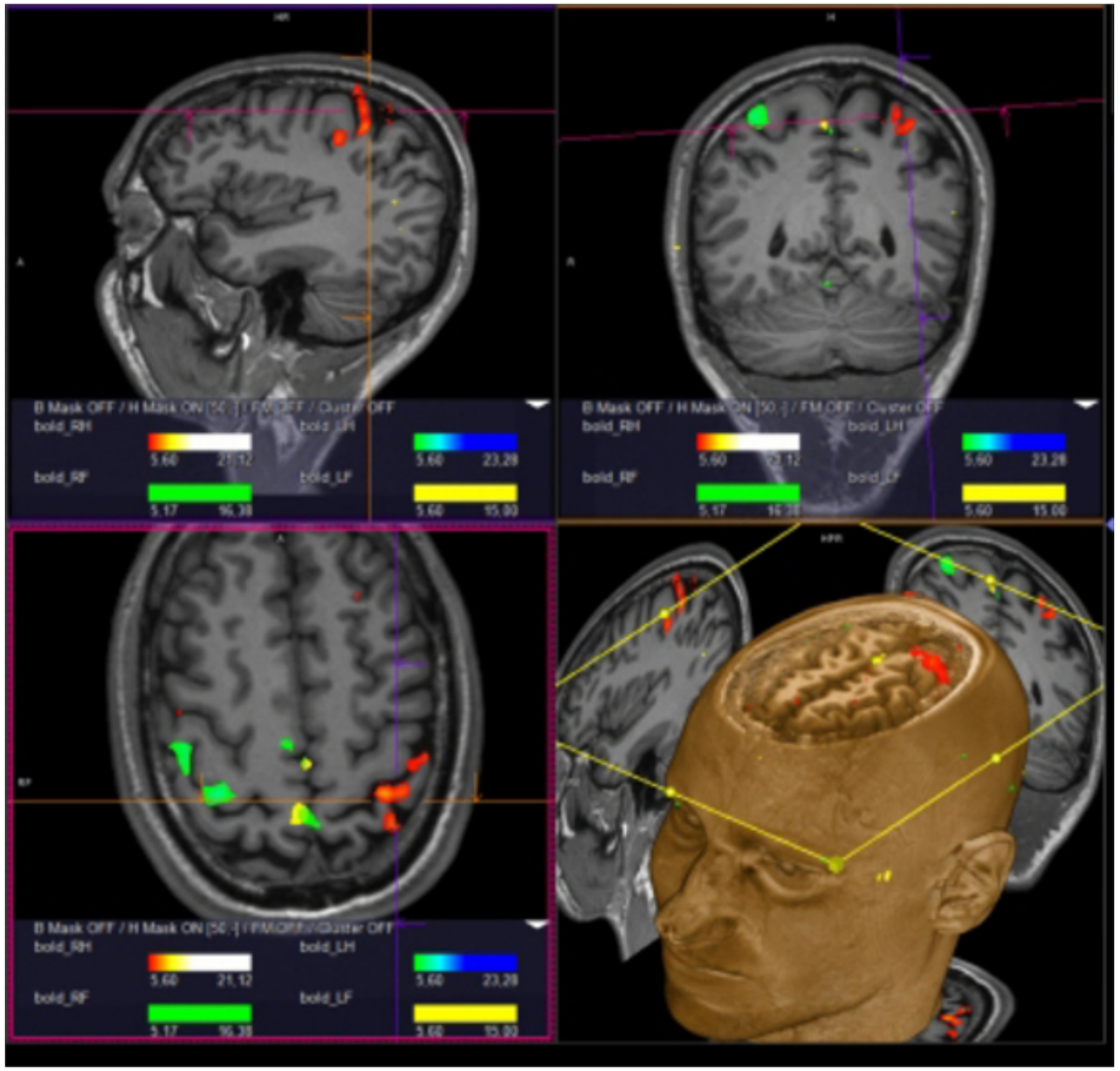
Magnetic Resonance Imaging

https://giving.hillcountrymemorial.org/campaign/magnetic-resonance-imaging-mri/

http://www.extremetech.com/wp-content/uploads/2013/10/scan.jpg

fMRI

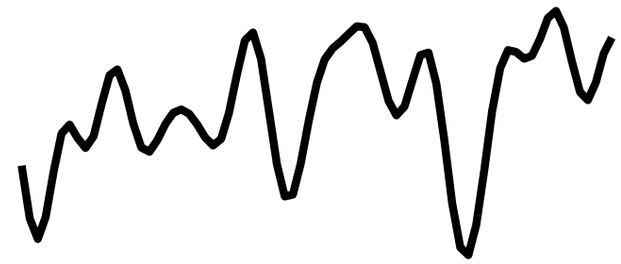
functional Magnetic Resonance Imaging

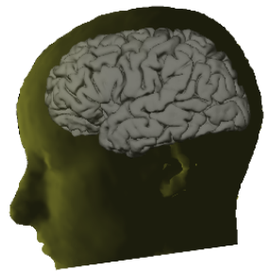


https://www.healthcare.siemens.com/magnetic-resonance-imaging/options-and-upgrades/clinical-applications/syngo-mr-neuro-fmri

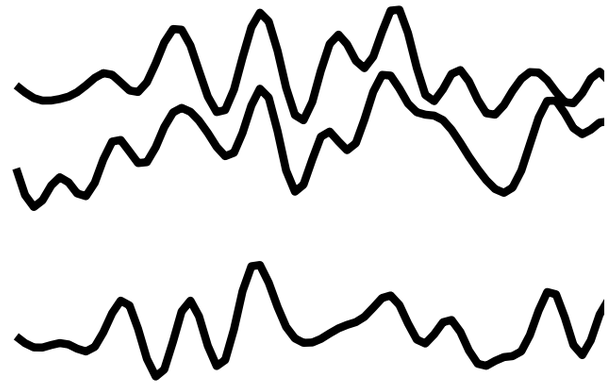
Cortical Processing of Speech

Speech Envelope

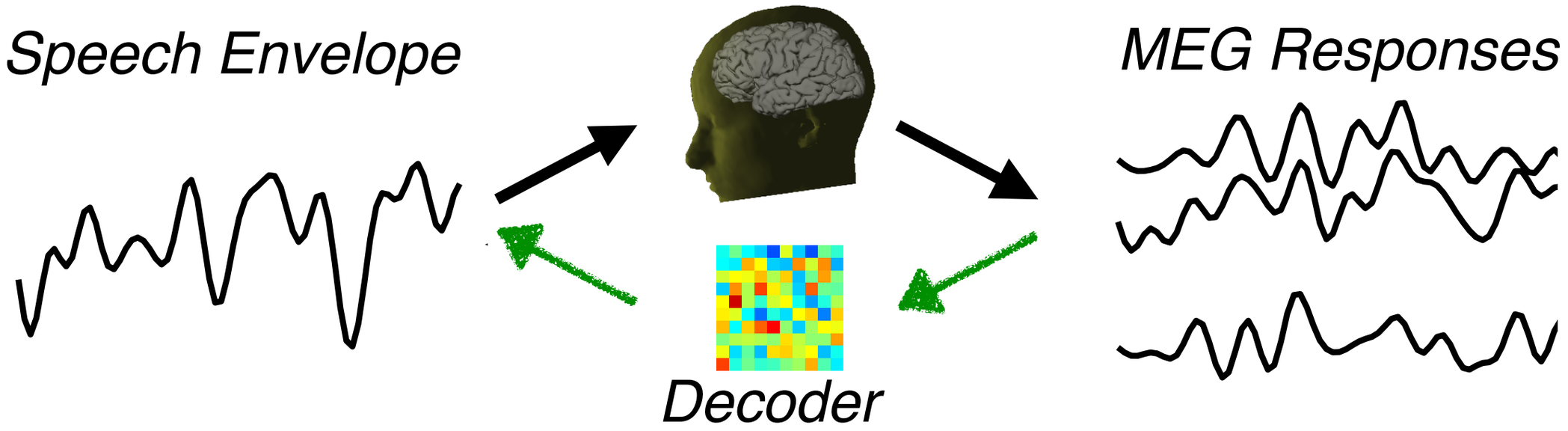




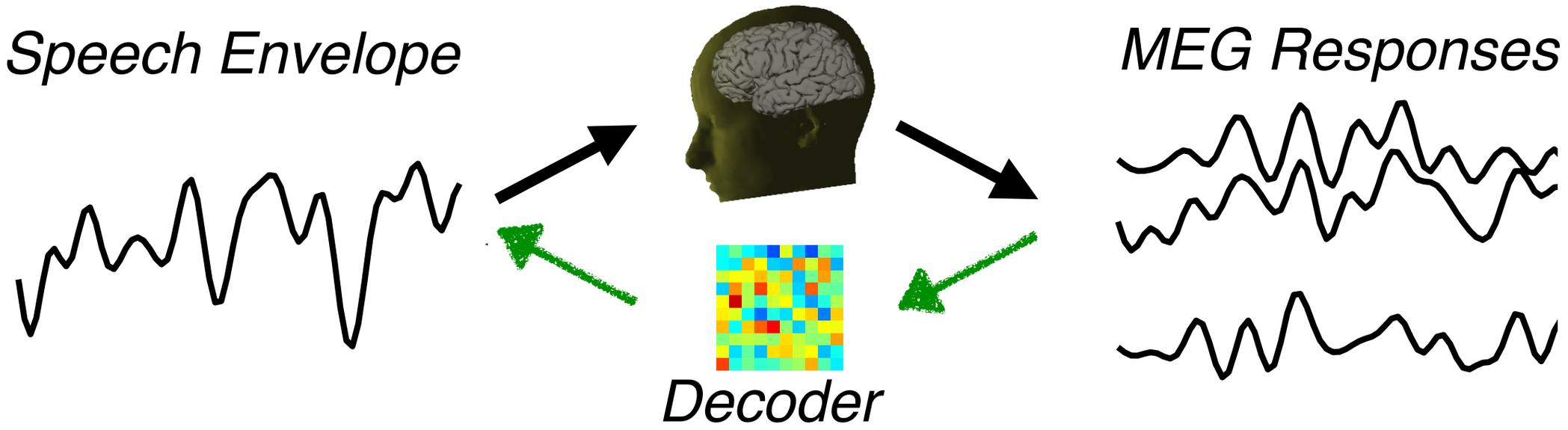
MEG Responses

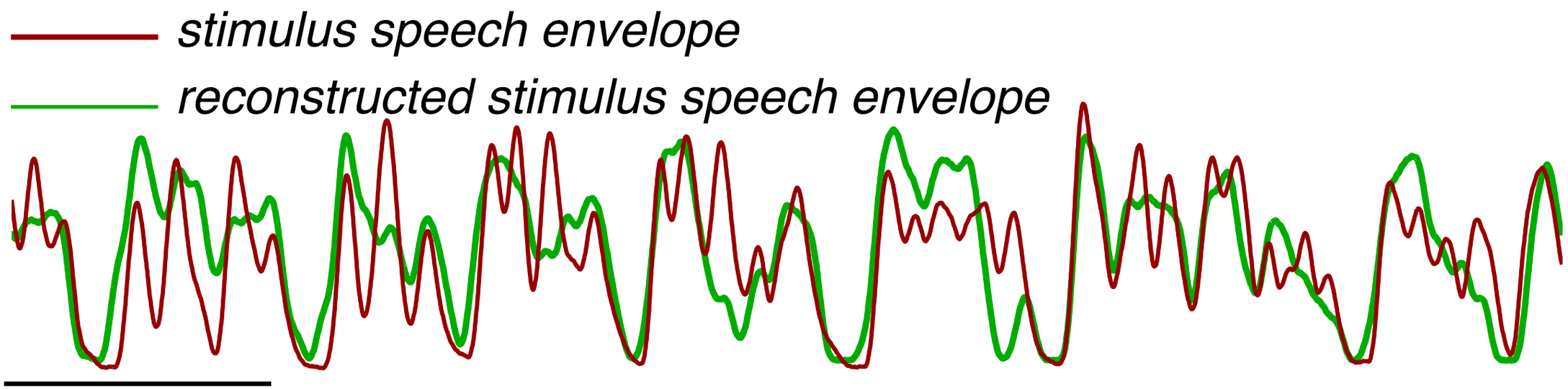


Cortical Processing of Speech



Cortical Processing of Speech

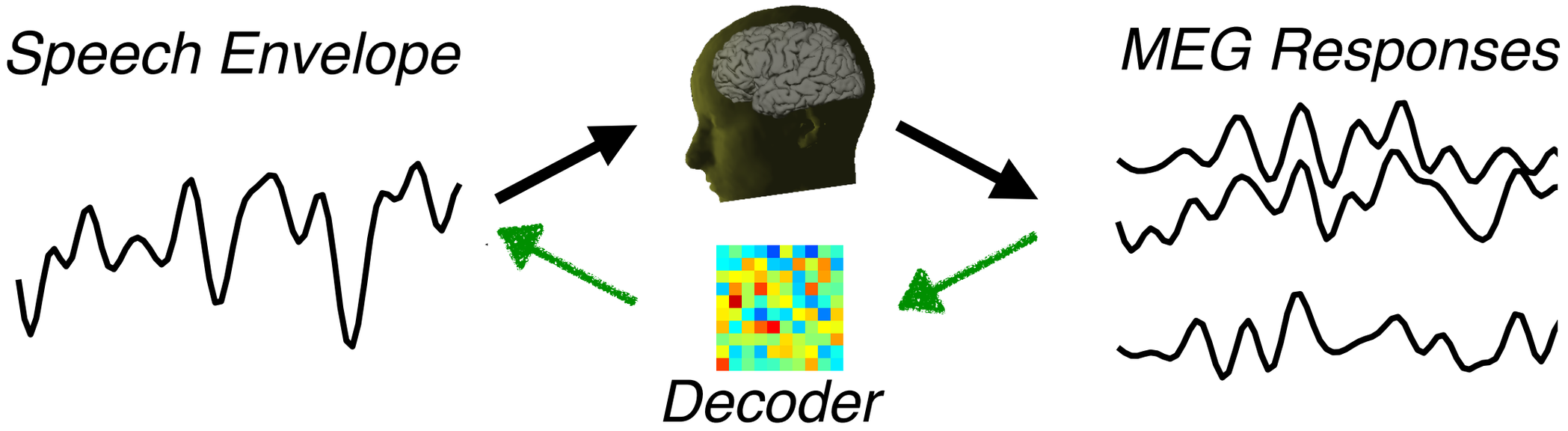




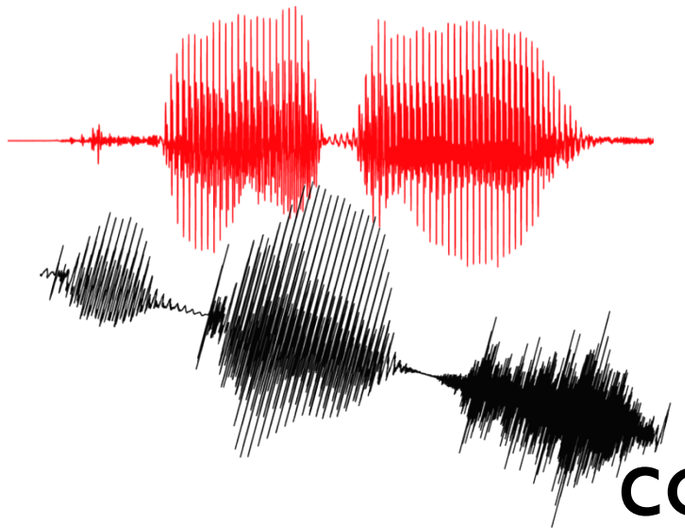
Ding & Simon, J Neurophysiol (2012)
Zion-Golumbic et al., Neuron (2013)

Reconstruction accuracy comparable to single unit & ECoG recordings

Cortical Processing of Speech



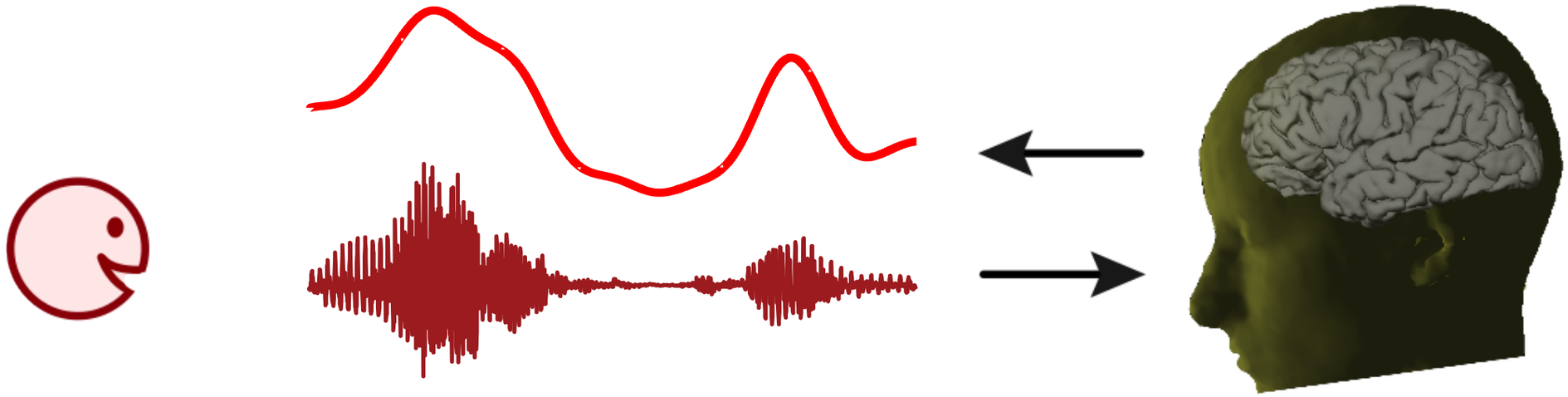
Competing Speech Streams



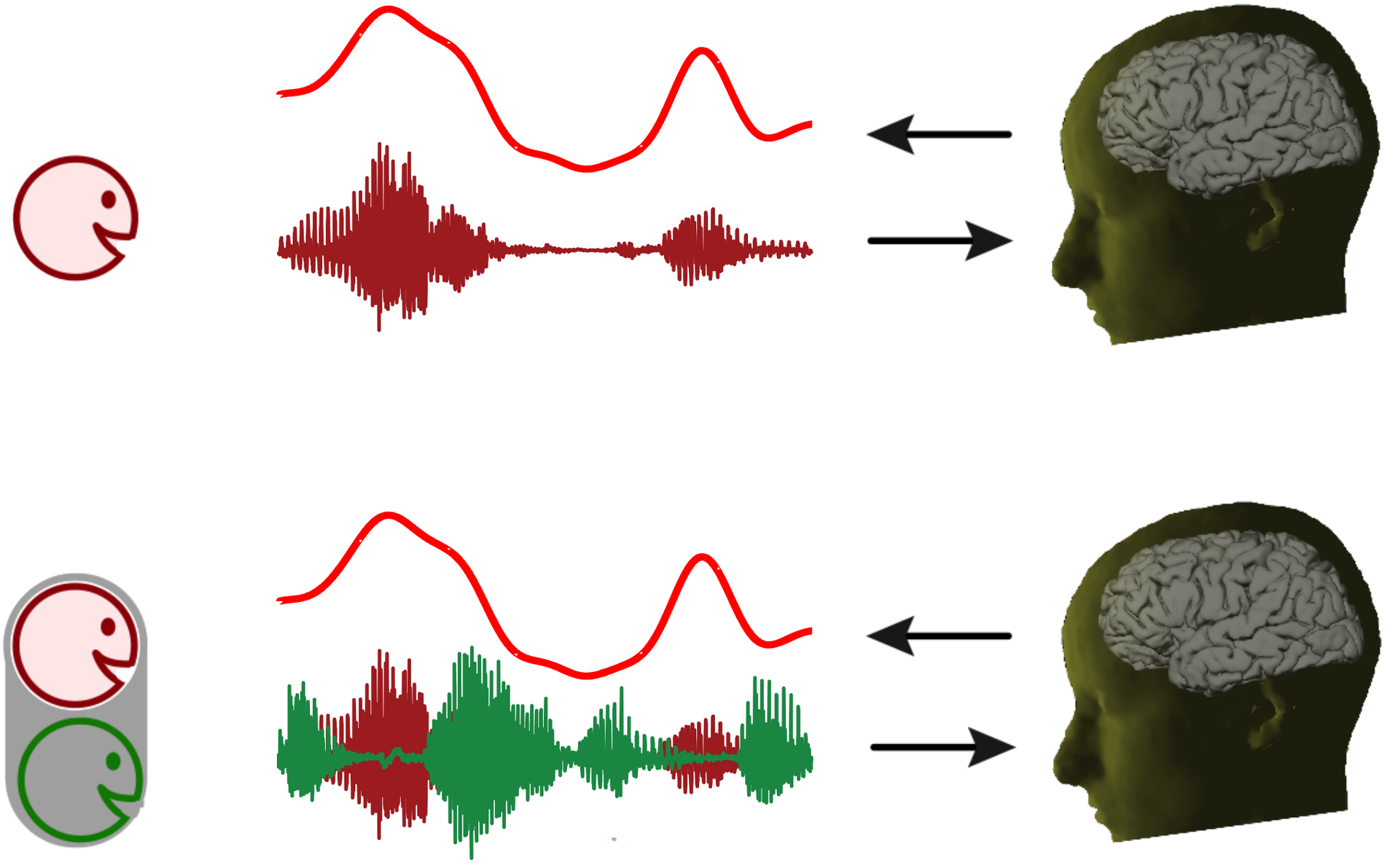
speech

competing speech

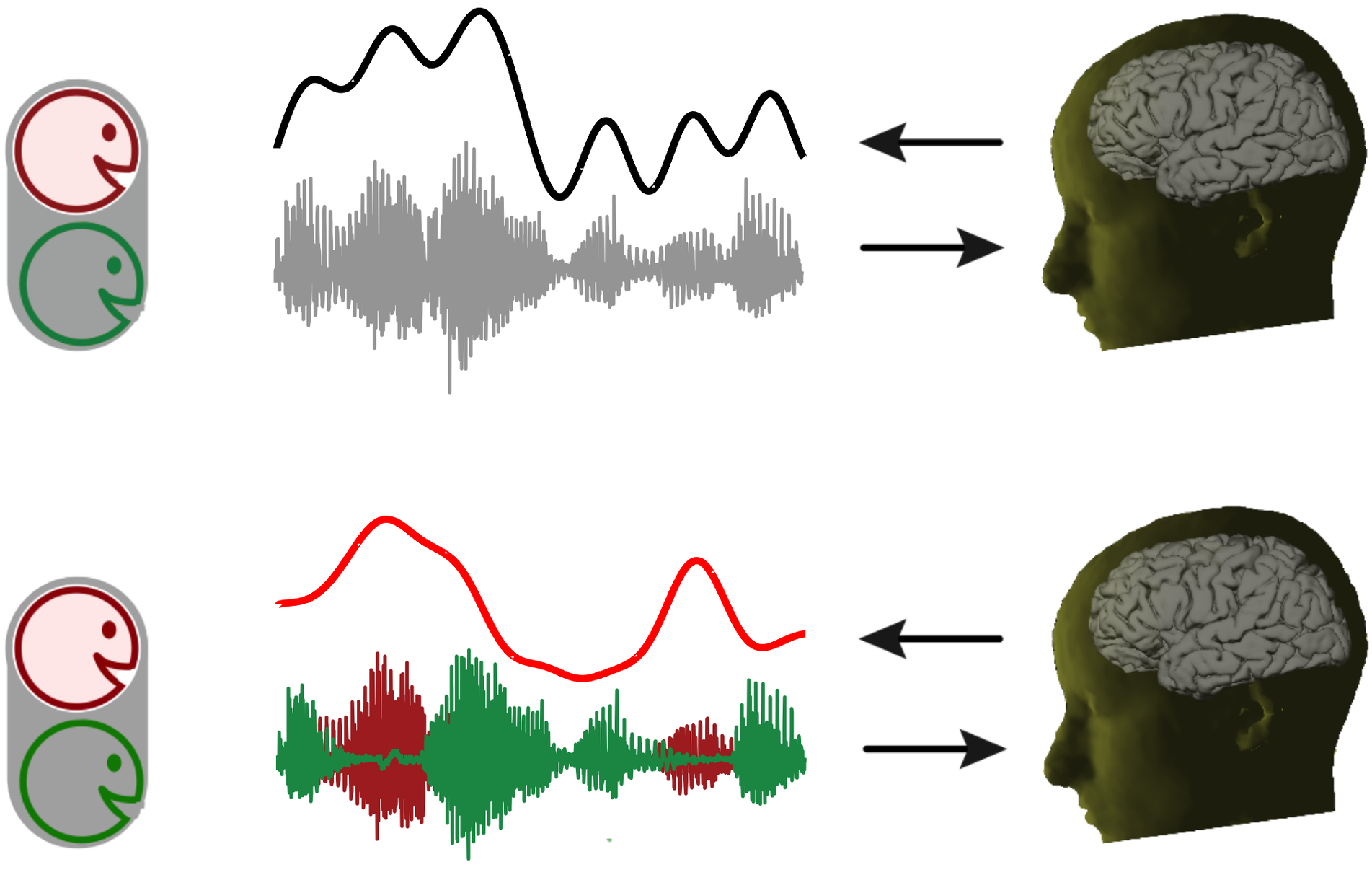
Selective Neural Encoding



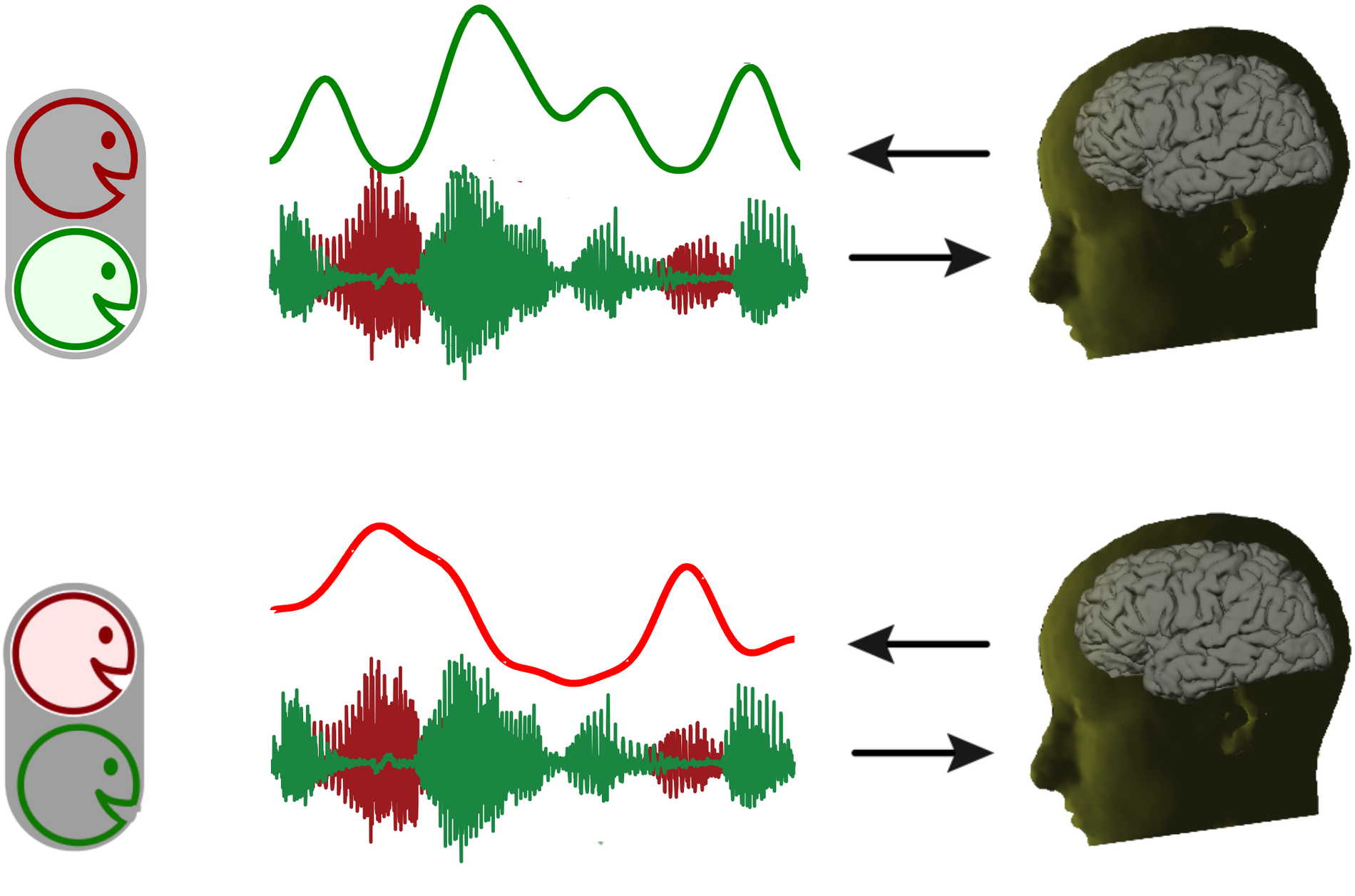
Selective Neural Encoding



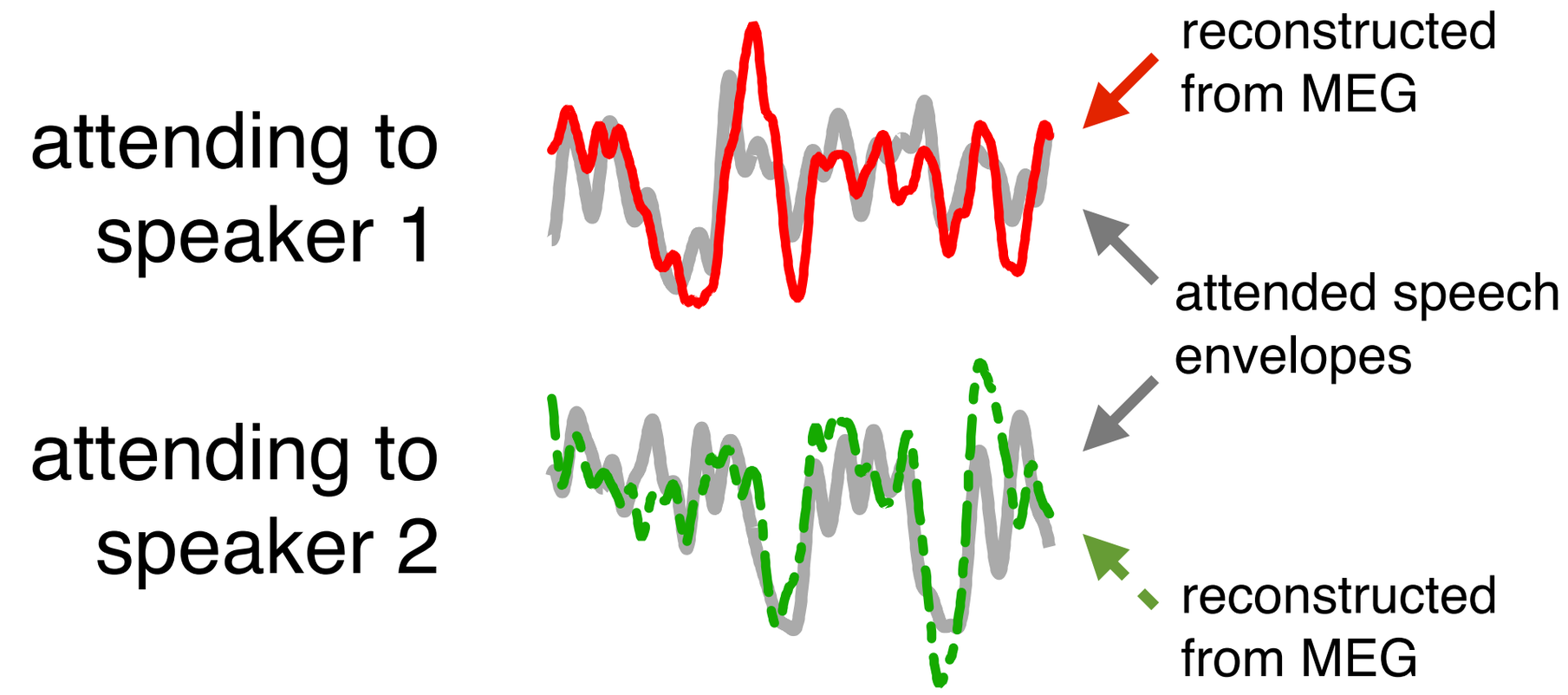
Unselective vs. Selective Neural Encoding



Selective Neural Encoding



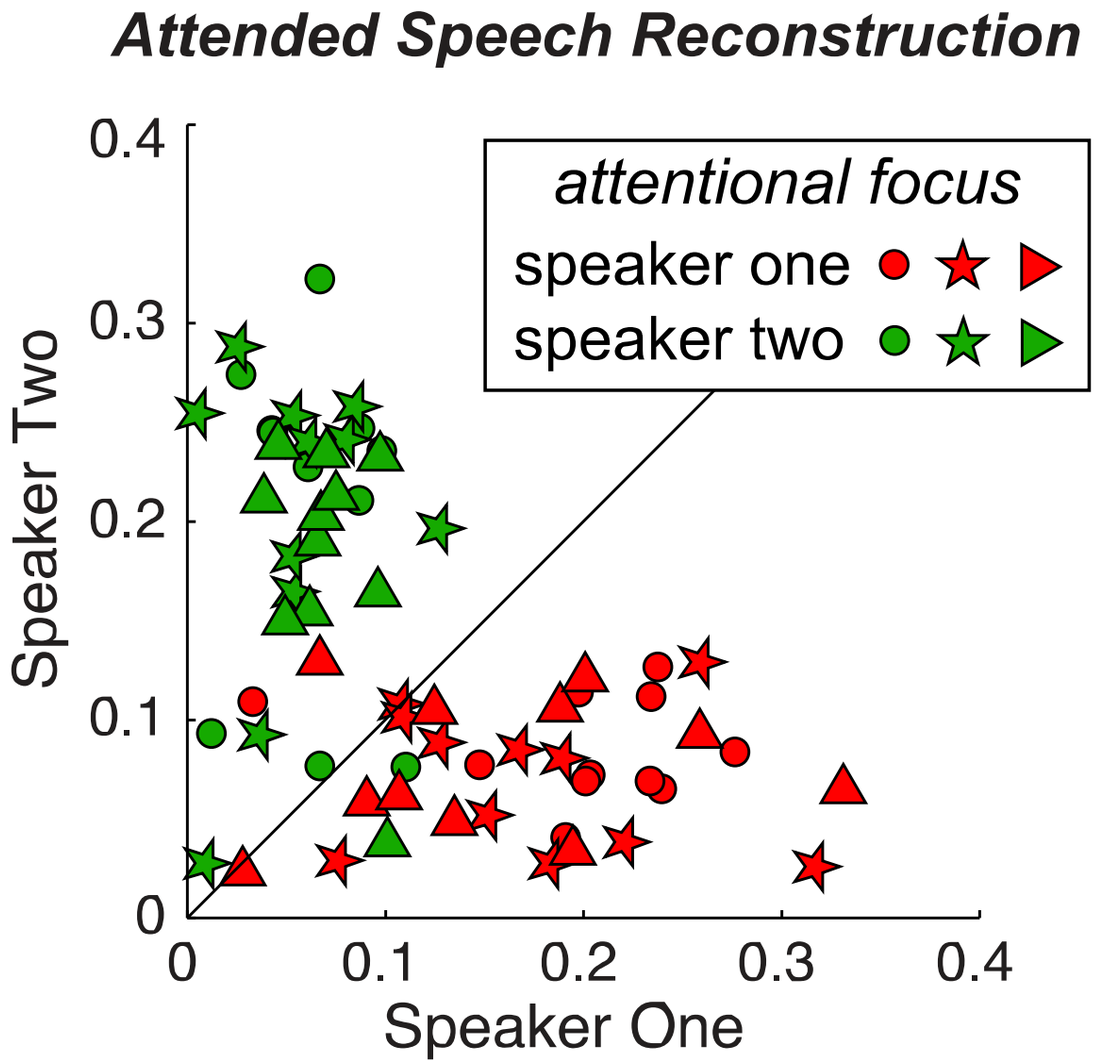
Selective Encoding: Results



Identical Stimuli!

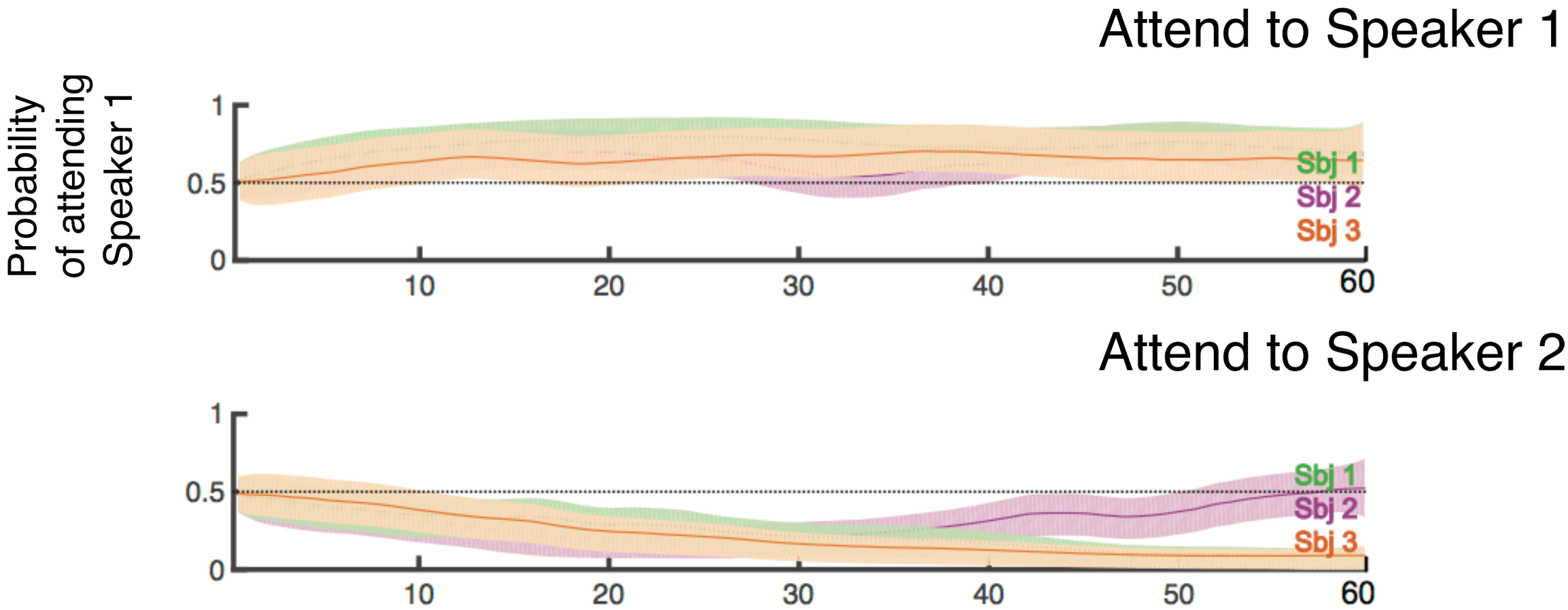
Ding & Simon, PNAS (2012)

Single Trial Speech Reconstruction



Ding & Simon, PNAS (2012)

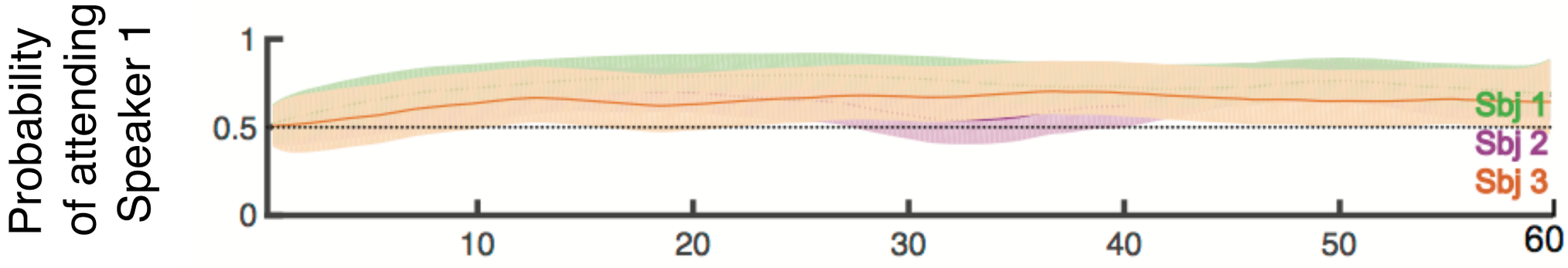
Attentional Dynamics



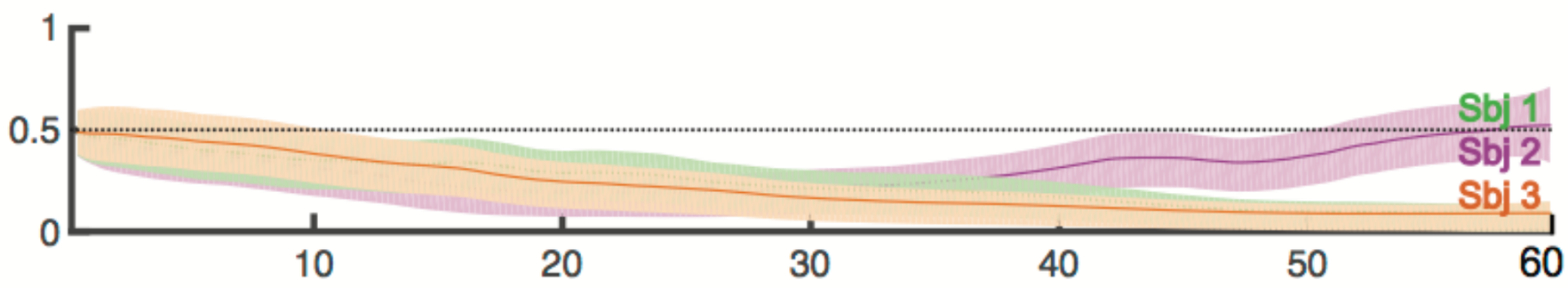
Akram et al., NeuroImage (2016)

Attentional Dynamics

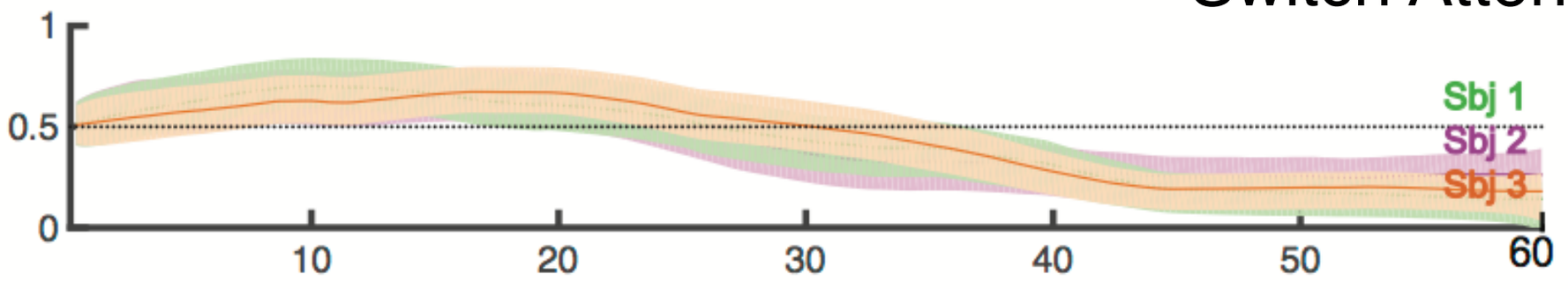
Attend to Speaker 1



Attend to Speaker 2



Switch Attention



Akram et al., NeuroImage (2016)

Summary

- Neural Currents generate Magnetic Fields
  - Weak but measurable with SQUIDs
- Neural Processing of Speech in Time generates Neural Currents that change in Time
- Neural Currents that change in Time generate Magnetic Fields that change in Time
  - Changing Magnetic Fields reflect Dynamic Neural Processing
- When Processing Multiple Sounds, we can see Auditory Cortex separate out the Attended Sounds

Thank You