



# Eavesdropping on the Mind

**COGS 17– Winter 2020**  
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**du**



# Announcements

- Midterm I is Tuesday, 1/28/20
  - Exam is worth 25% of your grade
  - Homework I is due before exam (worth 2.5% of grade)

# Technologies for Studying the Brain

Keep the following questions in mind:

- What does this technique tell us about the organization of the brain?
- What are the tradeoffs?
  - What can't this technique tell us?
  - Why might we choose a different method?
- What is the resolution of the data?

# Spatial vs. Temporal Resolution

- *Temporal Resolution*: Precision of a measurement with respect to **time**.
  - What scale of time can we measure at?
    - (s, us, ns)?
- *Spatial Resolution*: Precision of a measurement with respect to **space**.
  - What scale of distance can we measure at?
    - (m, cm, um, nm)?

# Outline

## Anatomical Exams

- Staining **Charts physical structures**
- Lesions **Invasive**
- Electrical Stimulation

## Recordings of Endogenous EM Radiation

**Measures electrical current**

- Single Cell Recording
- Multi-Cell Recording
- Electro-Encephalogram & ERPs
- Magneto-Encephalogram

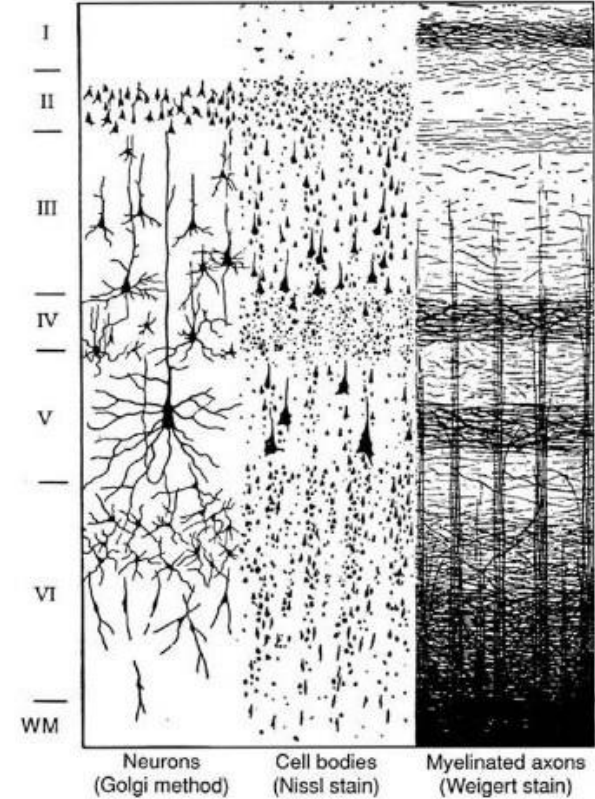
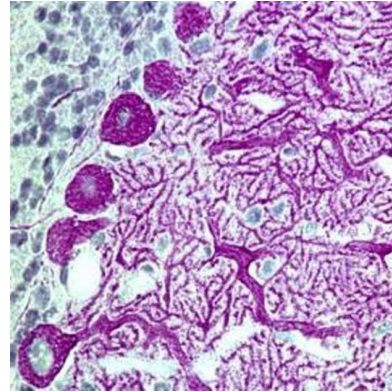
## Images Produced by Perturbation of System

- MRI
  - CAT
  - fMRI
  - PET
- Structure/non-invasive**
- Measure blood flow**

# Anatomical Exams

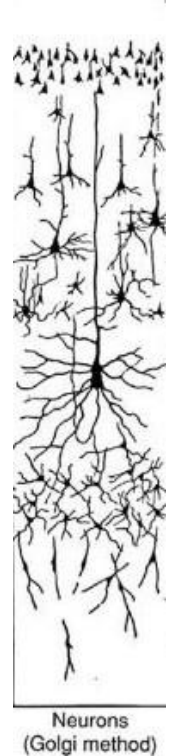
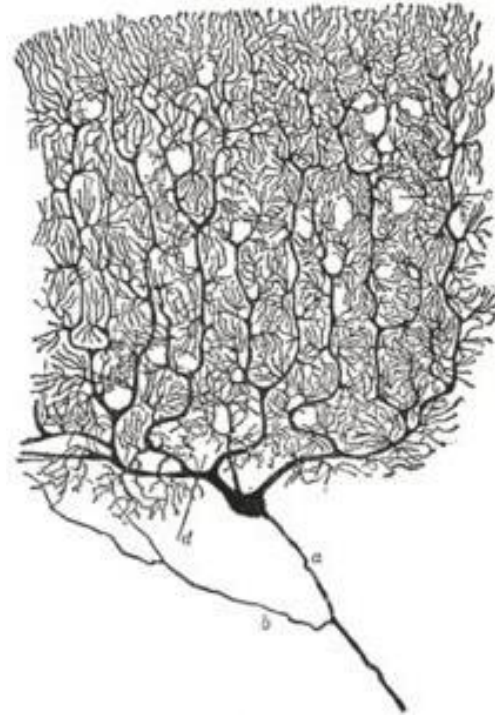
# Staining

- Allows for visualization of cellular and molecular organization in the brain.
- Requires tissue slices from *post-mortem brain*.
  - **Cost:** Must sacrifice subject.
- **Great** spatial resolution.
- **No** temporal information.



# Golgi Stain

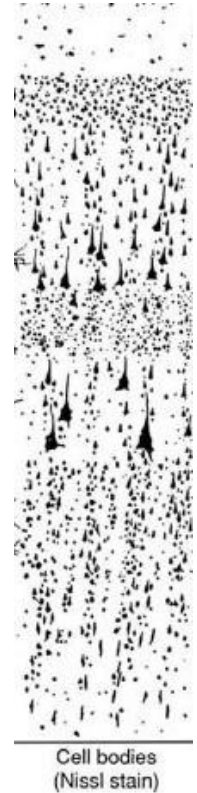
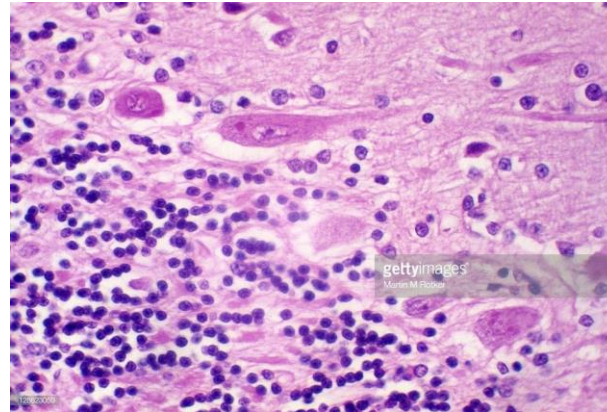
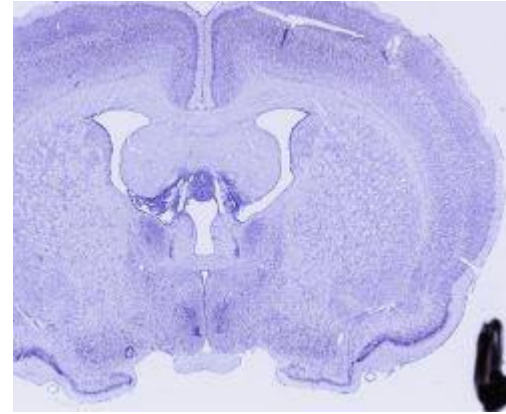
- Stains the entirety of a neuron: Soma, dendrites, and axon.
- Only dyes *some* of the cells in sample.
- Mechanism is still largely unknown.
- Used by Santiago Ramon y Cajal.
  - Neuron Doctrine: “Nervous system is made up of discrete individual cells (neurons).”
- **Good** spatial resolution.
- **No** temporal resolution.





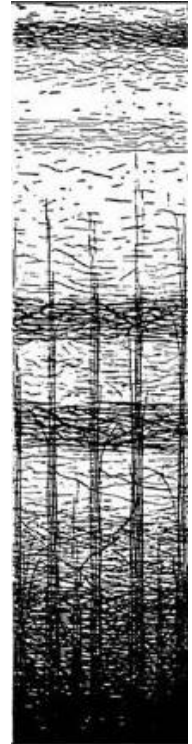
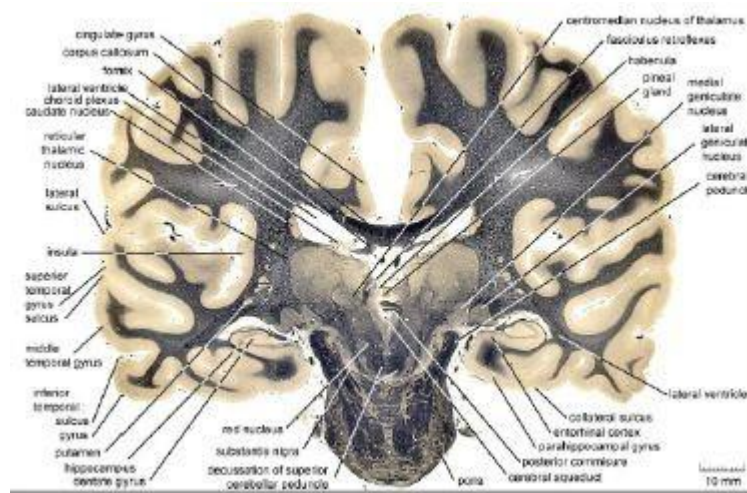
# Nissl Stain

- **Nissl Body:** Large granular body found in neurons, body composed of rough ER and free ribosomes.
  - Site of *protein synthesis*.
- Aniline stain dye binds to negatively charged nucleic acids and stains *extranuclear* RNA in cells.
- Stains the *cell body*, or **soma**.
  - Does **not** stain the dendrite and axons.



# Weigert Stain

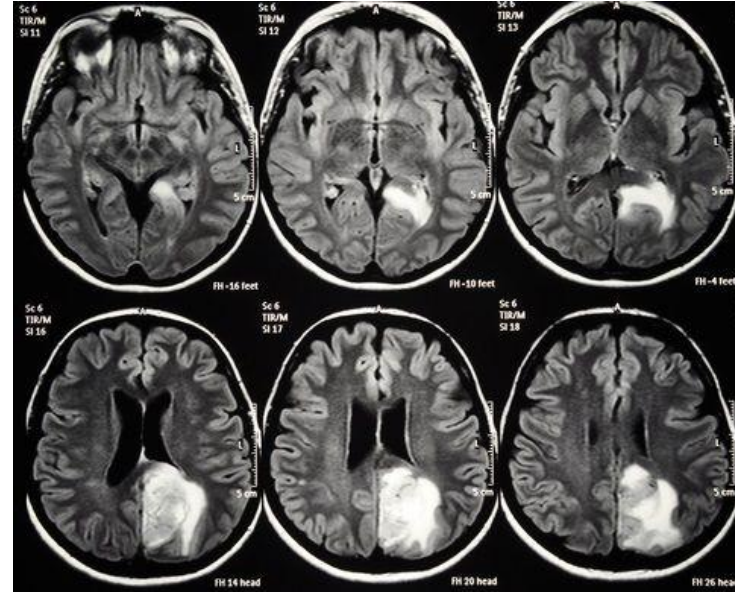
- Used to stain elastic fibers, more specifically **white matter** or *myelinated axons*.
- Useful for visualizing fiber pathways.



Myelinated axons  
(Weigert stain)

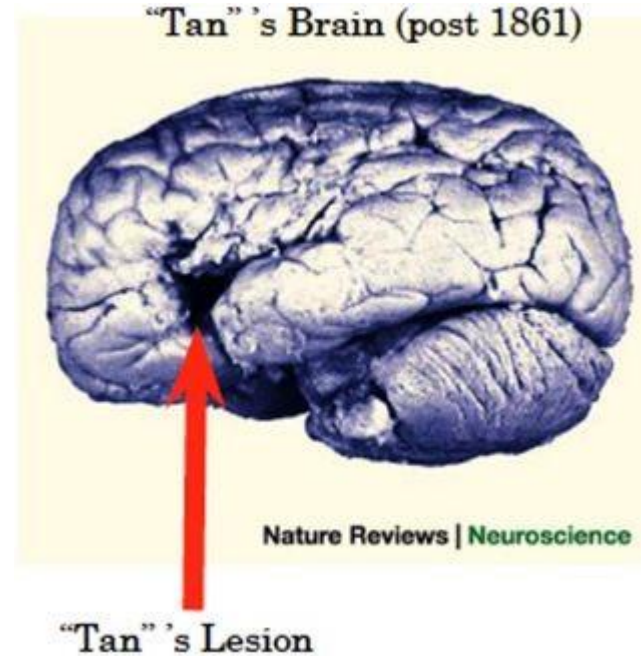
# Lesions

- Brain damaged naturally or experimentally.
- Observe behavior before/after *damage to neural tissue*.
- Later processing of post-mortem brain tissue allows for observation of damage.
- New techniques allow us to record in-vivo.
- **NO** temporal information.
- **GOOD** functional information.
- **GOOD** spatial resolution for damaged areas.
- Human Lesion Examples:
  - “Tan”
  - Phineas Gage
  - HM



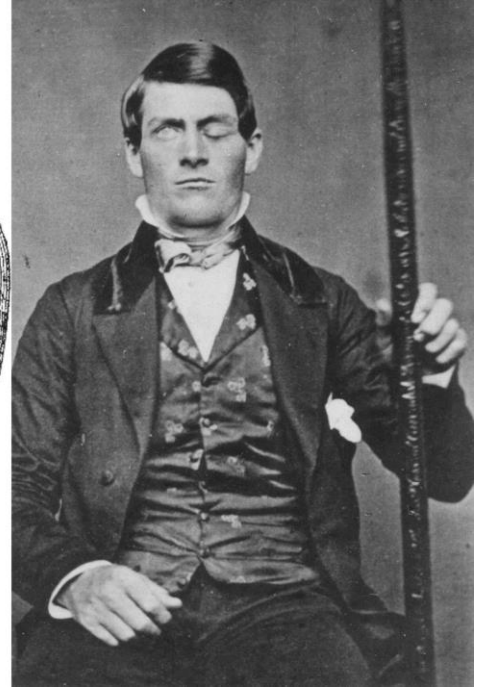
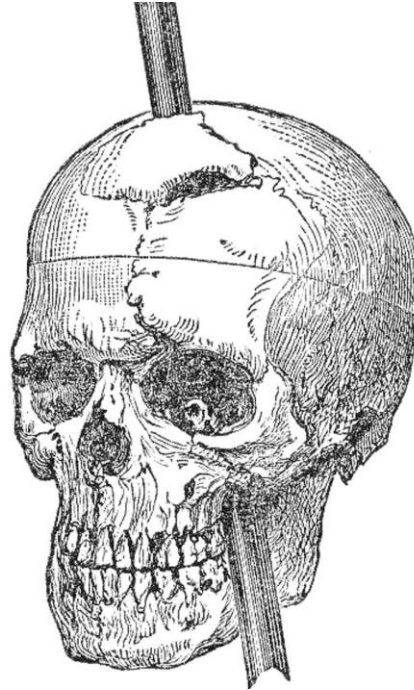
# “Tan”

- Patient of Paul Broca in 1861.
- Patient could only say “tan”.
- Brain analysis showed patient’s language comprehension was *unaffected*.
- Post-mortem exam found *lesion* in inferior *frontal cortex*.
- The area damaged was associated with language production.
  - Area known as **Broca’s Area**.



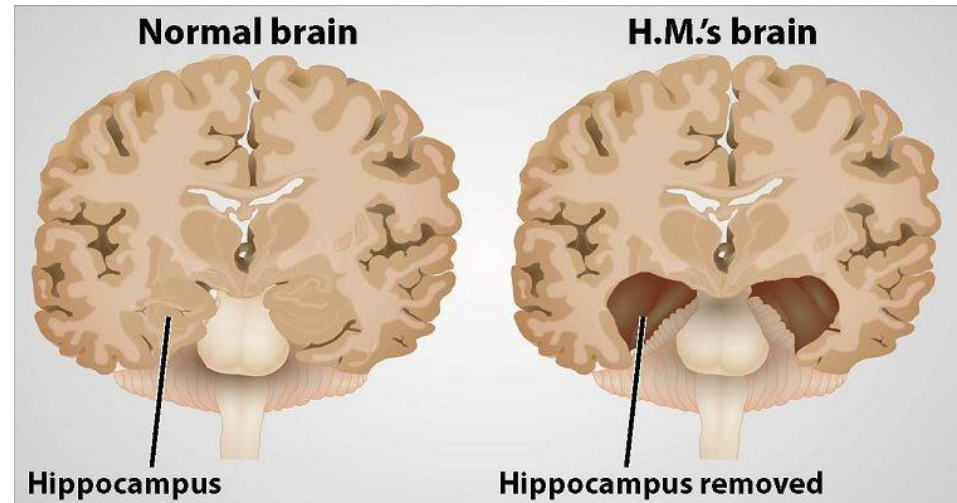
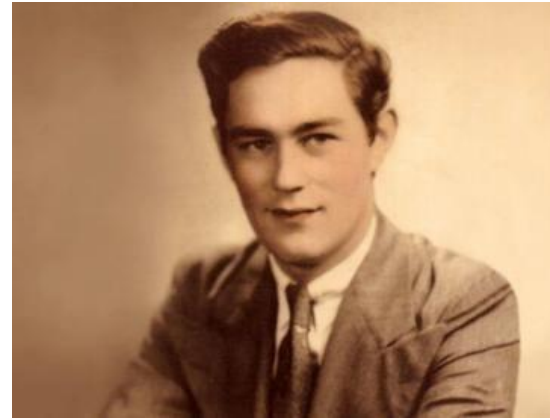
# Phineas Gage

- Railroad construction foreman.
- In 1848, accident resulted in a rod being lodged through head.
- Destroyed much of his left *prefrontal cortex*.
- Changes in his mood and personality.
  - Foul-mouthed.
  - Flakey.
  - Irritable.



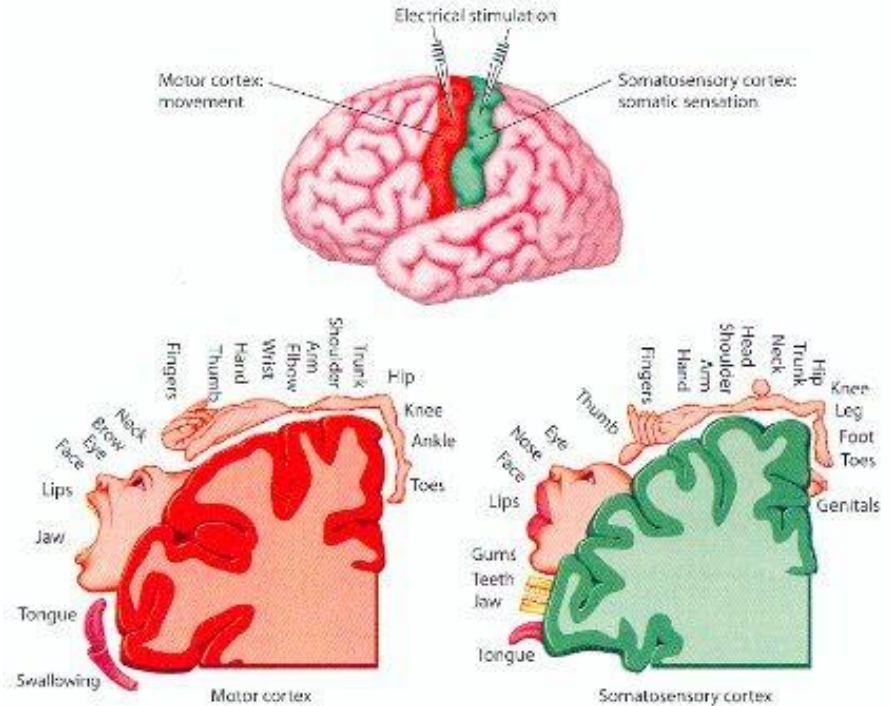
# H.M

- Knocked down in bicycle accident at young age, resulting in seizures throughout life.
- Unresponsive to medication.
- Bilateral medial temporal lobectomy to correct **epilepsy**.
- Intact procedural memory, short-term memory, and priming effects.
- Unable to create new *episodic* memories.



# Electrical Stimulation

- Electrical probe placed on surface or inserted into specific brain area.
- Stimulate particular parts of the brain and see how it affects the body.
- Live subjects, invasive.
- **NO** temporal resolution.
- **GOOD** spatial resolution for the stimulation site.
- Functional information comes from subject responses.
- Revealed parts of brain used for processing motor functions, or sensory functions, for different parts of the body.

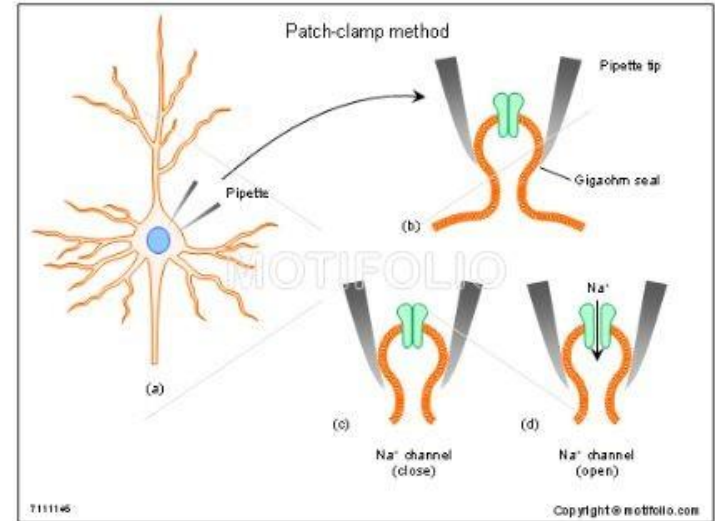
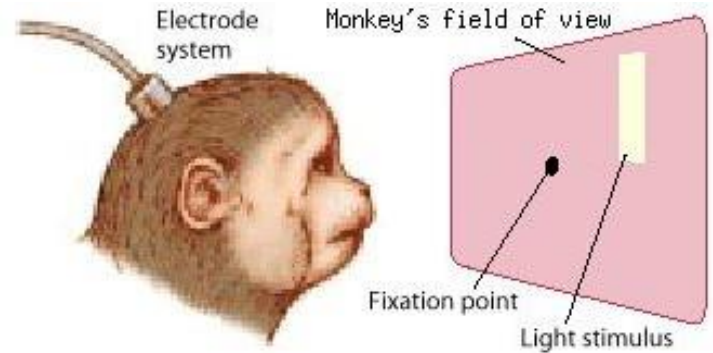


# Recordings of Endogenous EM Radiation



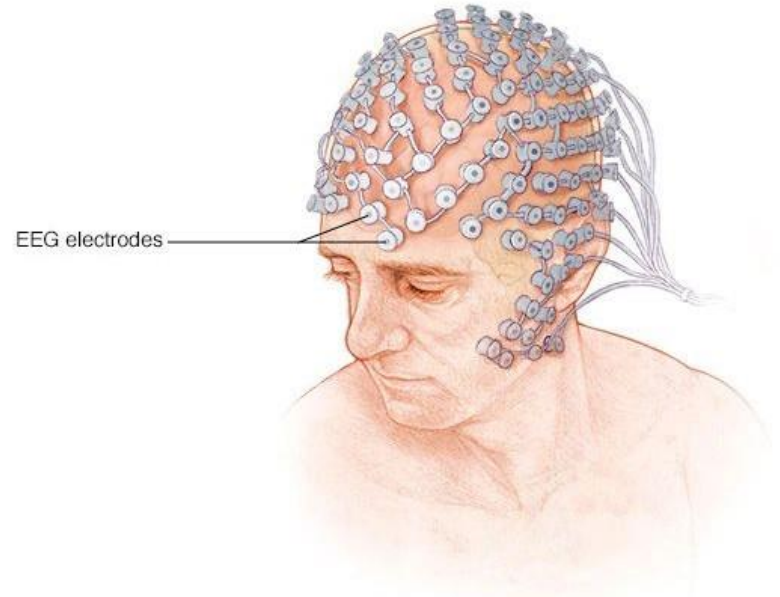
# Single Cell Recording

- Recording probe inserted in brain.
- Micro-electrode measures voltage differences between inside and outside of a single cell.
- Live subject is engaged in a task.
- **VERY GOOD** temporal, spatial and functional resolution, but only for the single cell (highly localized).



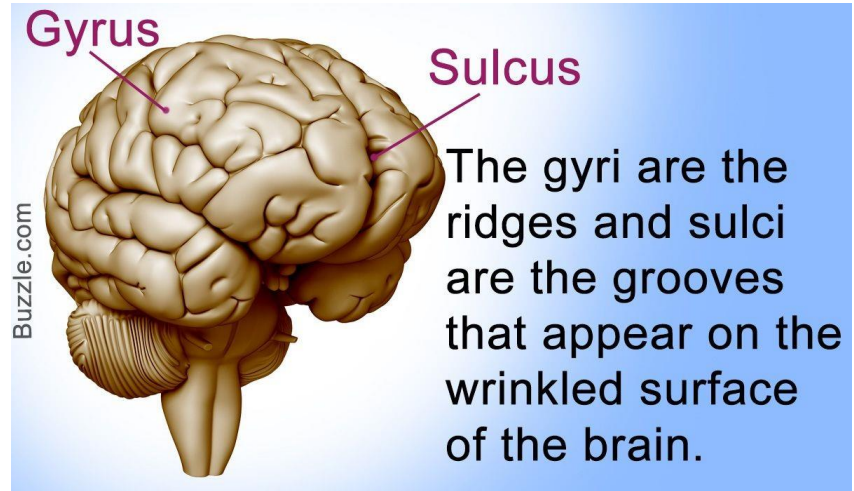
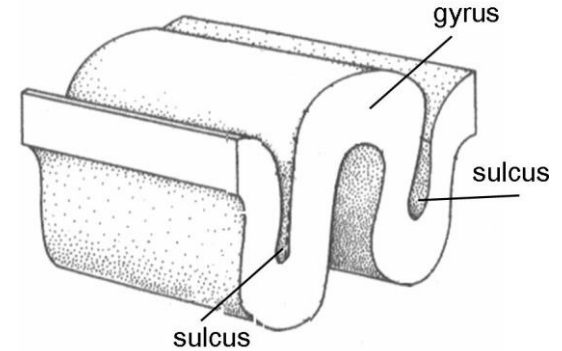
# Electroencephalogram (EEG)

- Recording of brain's **electrical activity**.
- Records *electric dipole*, or the separation of a positive and negative charges found in an electromagnetic system.
  - Dipole generated by changes in electrical potential of cells at the scalp.
- Non-invasive, inexpensive.
- **GOOD** temporal resolution, but **POOR** spatial resolution.



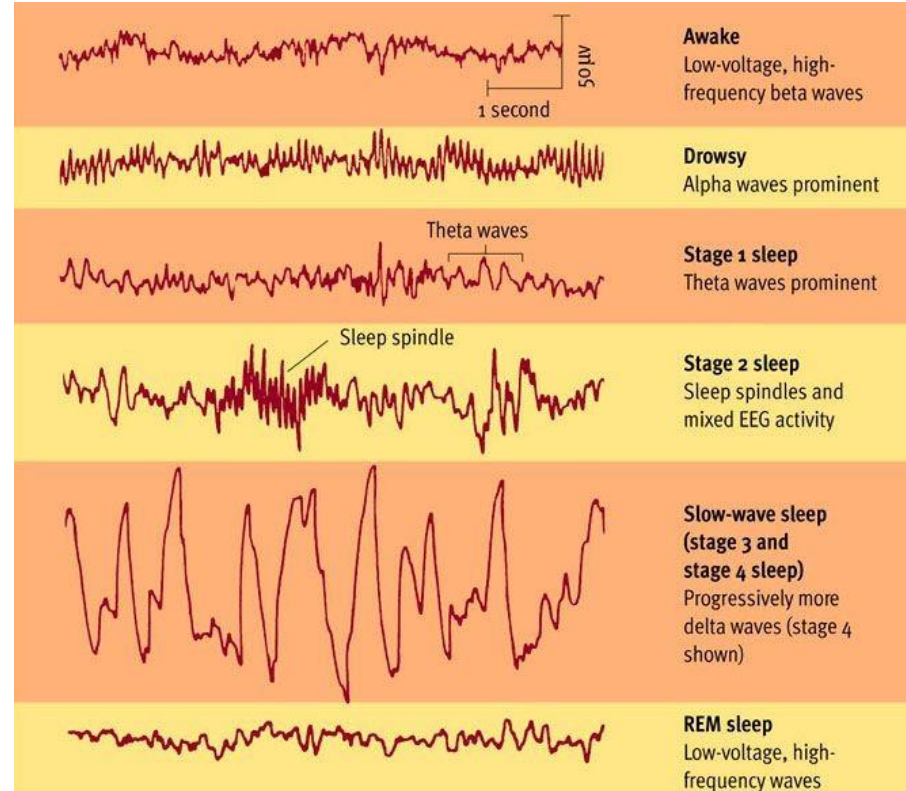
# Electroencephalogram (EEG)

- *Electric field* created by neurons is detected on the **gyri** of the cortex.
- The electric fields measured in EEG are **perpendicular** to the cortex.



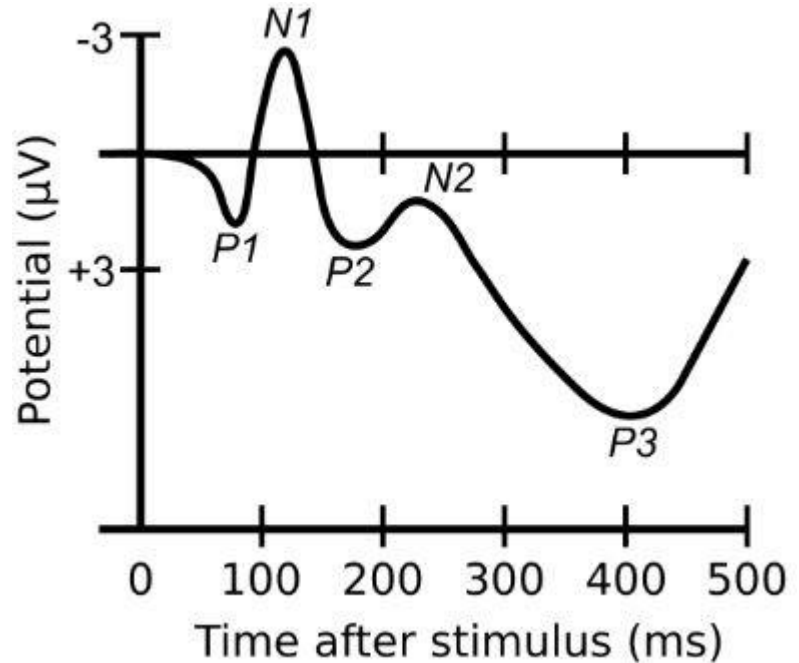
# Electroencephalogram (EEG)

- Can be used to measure brain activity during a task or during a particular state, such as sleep.



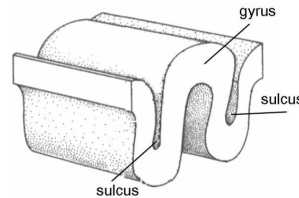
# Event-Related Potential (ERP)

- Measured brain response that is direct result of a specific sensory, cognitive, or motor event.
- Examines averaged EEG response.
- **Time-locked** to stimulus/task exposure to multiple trials.
- Detect fast changes in electrical activity elicited by a stimulus.
- **GOOD** Temporal Resolution.
- **POOR** Spatial Resolution.
- **STRONG** functional information related to a specific stimulus-response pairing.



# Magnetoencephalogram (MEG)

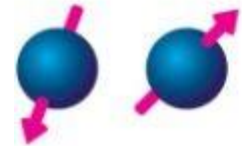
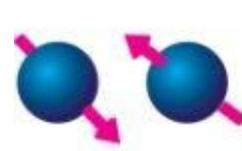
- Records magnetic fields produced by electrical currents occurring naturally in brain.
- **No** magnet used.
- More expensive than EEG.
  - Uses Superconducting Quantum Interference Devices (SQUIDs)
- Measures activity **parallel** to the brain surface (from sulci).
- **GOOD** temporal resolution.
- **GOOD** spatial resolution.
- **WEAK** functional information.



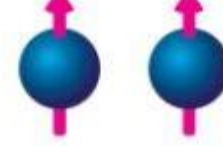
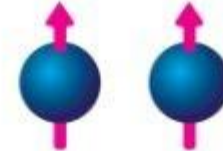
# Images Produced by Perturbation of the System

# Magnetic Resonance Imaging (MRI)

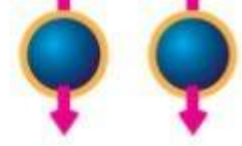
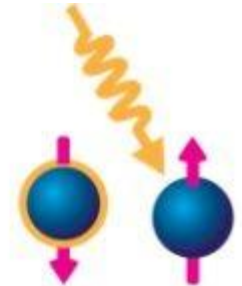
- Utilizes strong magnets to generate images of organs in the body. *Structural info!*
- Machine applies a strong magnetic field.
- Hydrogen protons in tissues containing water react by aligning with the magnetic field.
- Once aligned, MRI is turned off.
- Energy released from protons in form of radio frequency signal can be recorded to create an image.
- **NO** temporal information.
- **BEST** spatial resolution.
- **NO** functional information.



No magnetic field



magnetic field

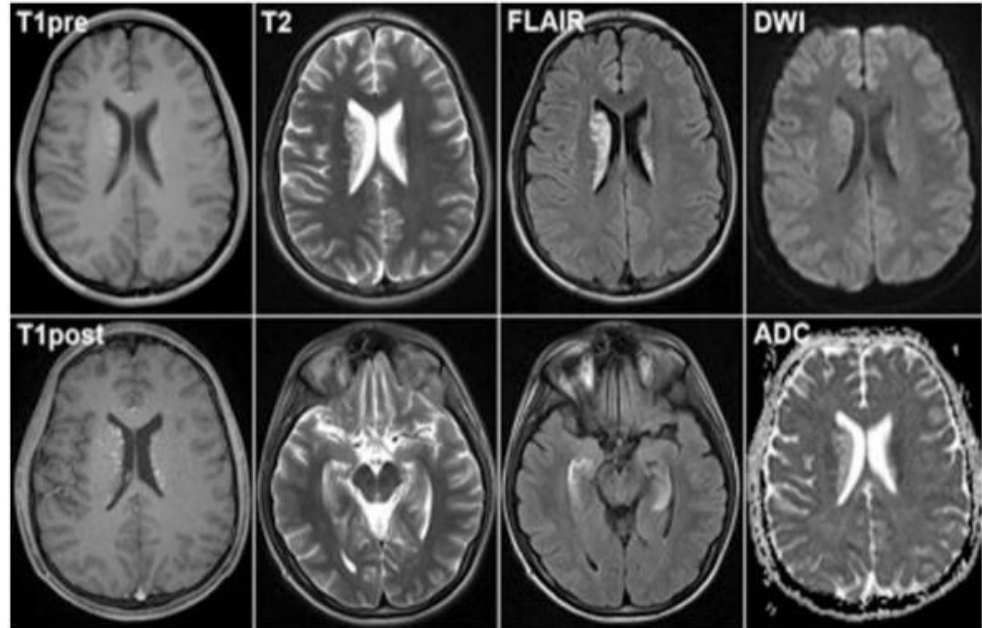


magnetic field and applied radio waves



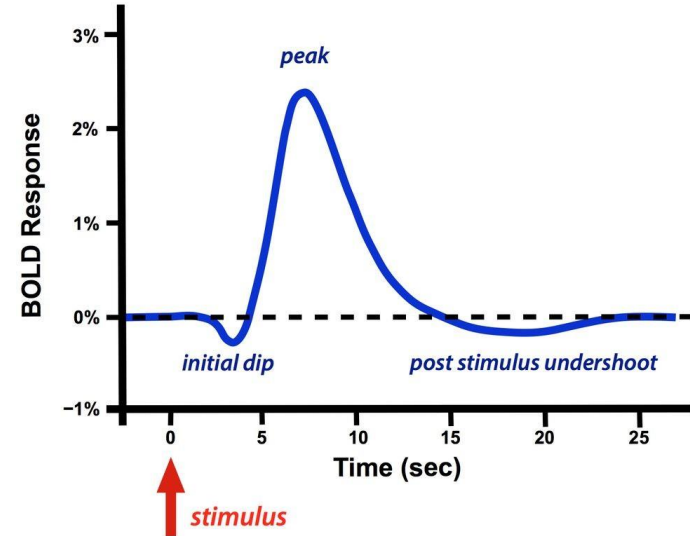
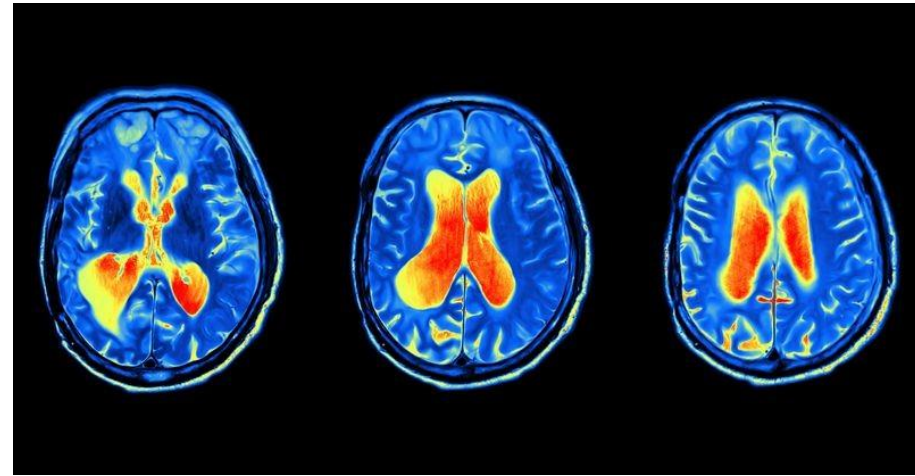
# Magnetic Resonance Imaging (MRI)

- MRI vs. MEG?
  - MRI collects *structural information*.
  - MEG collects *magnetic activity* from neurons, visualized as brain waves.
  - MRI uses magnets, MEG does not.



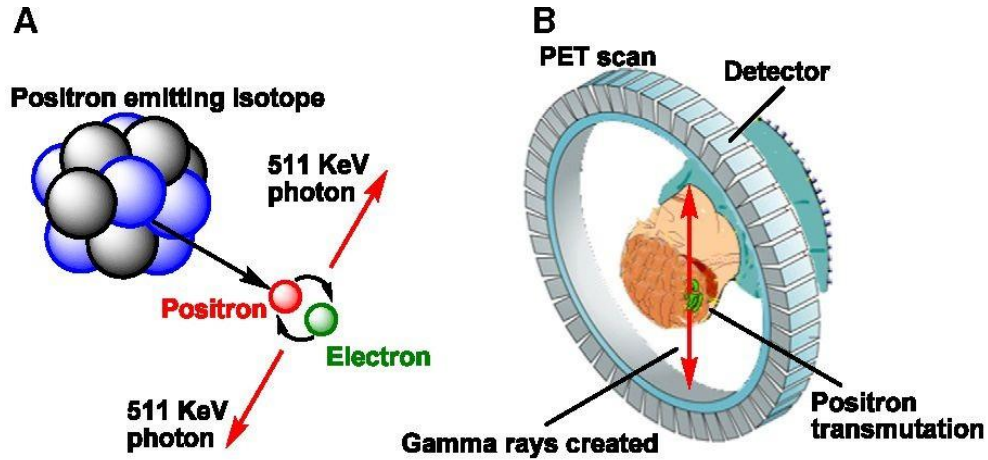
# Functional MRI (fMRI)

- Indirect measurement of neural activity by detecting changes in *blood flow*.
- **BOLD** = “**B**lood **O**xxygen **L**evel **D**ependent” signal
- Blood flow *increases* when a region is **active**. Noninvasive!
- Oxygenated and Deoxygenated blood differ magnetically
- **GOOD** Functional Info
- **Okay** Temporal Resolution
  - ~ seconds
- **VERY GOOD** Spatial Resolution
  - ~ Within millimeters



# Positron Emission Tomography (PET)

- Technique used to observe metabolic processes in body.
- Introduction of **radioactive tracers** into body to detect areas of *blood flow*.
  - Example: Fludeoxyglucose.
- Gamma waves emitted are detected.
- PET can detect molecular changes even prior to structural changes, such as as in Alzheimer's.
  - Ex: Brain metabolism is slower (and so less blood flow).
- **POOR** Temporal Resolution.
- **GOOD** Spatial Resolution.
- **GOOD** Functional Information.



# Computed Axial Tomography (CAT)

- Utilizes **x-rays** to get a quick and rough image of brain structure.
- Detect abnormalities such as tumors or areas affected by a stroke.
- Construction of *3D image* from multiple *2D x-ray* images.
- **NO** Temporal Information.
- **OK** Spatial Resolution.
  - Not as good as MRI.
- **NO** Functional Information.

