

Chapter 6 : Imaging The Brain

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Brain Imaging Techniques : Overview

- Electrical
 - Recording
 - Single Cell, Multiple Cell
 - EEG, ERP
 - Stimulation
- Magnetic
 - Recording - MEG
 - Stimulation - TMS
- Structural
 - X-ray, MRI
- Dynamic / Functional electrical activity
 - metabolism / glucose
 - blood flow, other

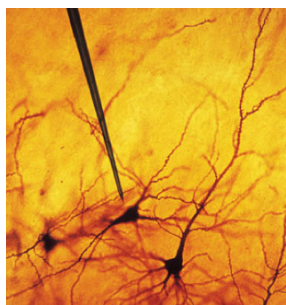
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Single-Cell recording

- Typically done in non-human animals
- Single electrode recording
- Arrays of electrodes
 - record from multiple cells

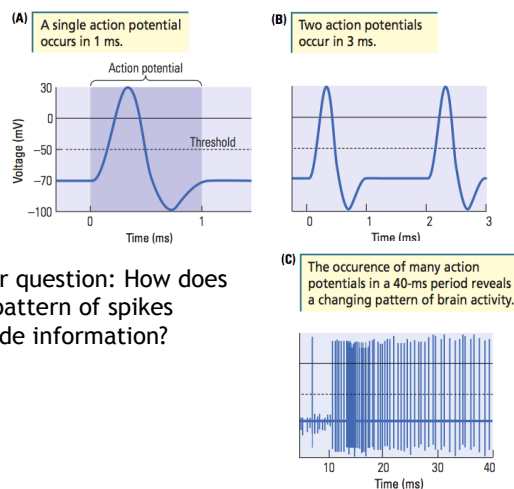


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Action potential trains



- Major question: How does the pattern of spikes encode information?

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Neuronal Code

- Patterns of neuronal firing
 - steady rate (e.g. "heartbeat" or time counter)
 - bursts, associated with behavior
 - rarely fire at all
 - daily, monthly, or yearly patterns
- How does the pattern of action potentials encode information?
- Example: Pain fibers in the PNS use frequency encoding:
 - low frequency : mild pain
 - high frequency : severe pain
- Example: color sensitive neurons
 - medium frequency : no color
 - low frequency : green
 - high frequency : red

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Findings re: Neuronal Code

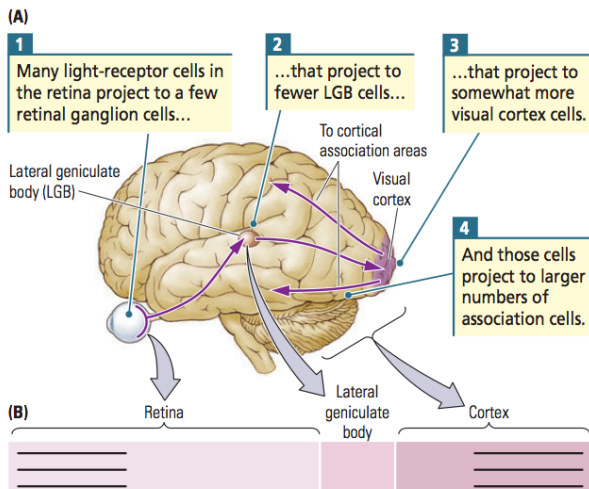
- Cortical neurons
 - fire about 3x/minute, up to 10x/minute when excited
- Adjacent Neurons may have completely different function
 - e.g. Broca's area: neuron for word perception next to one for word production
- Learning :
 - Newly learned information/skills - requires lots of neurons
 - Old information : more sparsely encoded

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Levels of Processing / # of neurons



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Levels of Processing / # of neurons

- Sensory input - few to many to few neurons
 - Retina
 - photo-sensitive cells : many, capture low level features (Light & Dark)
 - >
 - ganglion cells : fewer
 - >
 - LGB cells : even fewer
 - >
 - A17 (V1) Primary visual cortex : more cells, respond to visual features (line orientation)
 - >
 - association cortex : many more cells
 - "Grandmother!"

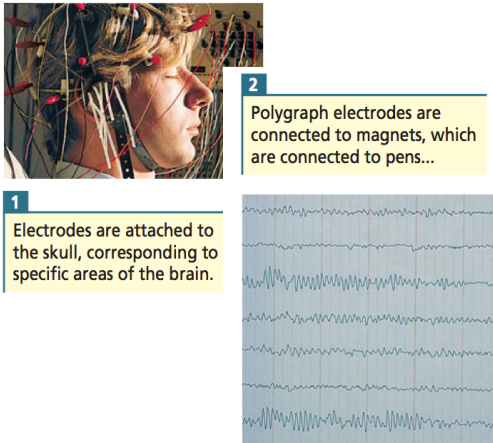
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Multiple Neuron Recording : EEG

- Neurons fire in synchrony
- Tiny voltages + many many neurons = measurable voltage on the scalp
- EEG : Electroencephalogram



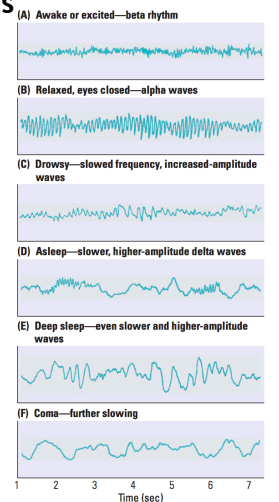
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EEG Patterns

- Majority of EEG signal comes from neurons in Layers V and VI
- Pacemaker cells keep these cells synchronized
- Frequency & pattern :
 - Faster, smaller, & more complicated with increasing arousal
 - Slower & larger amplitude in sleep, coma



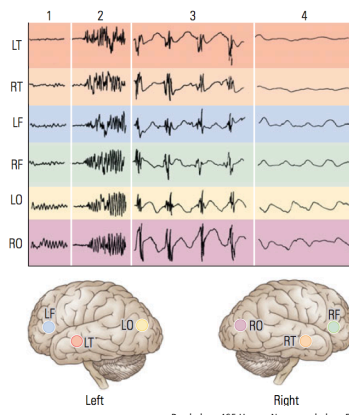
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Epilepsy

- Seizure
 - large groups of neurons firing all at once
 - out of control
 - pattern spreads
 - can involve entire brain
- Key
 - 1=pre
 - 2=onset
 - 3=clonic
 - 4=coma
- Note largest spikes in RO area - source of seizure?



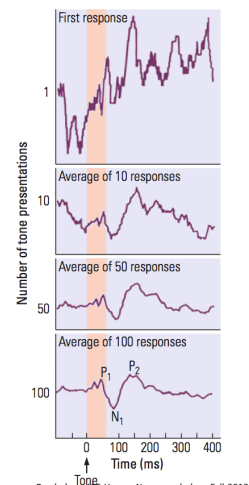
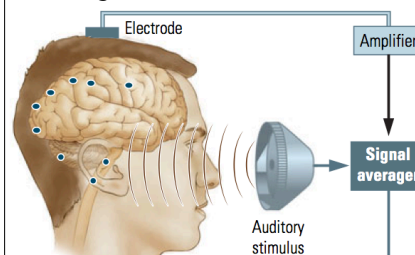
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ERP - Event-Related-Potentials

- Can you see "thinking" by watching EEG?
- In a single recording: No, it's too noisy
- By statistically averaging multiple events, a pattern emerges



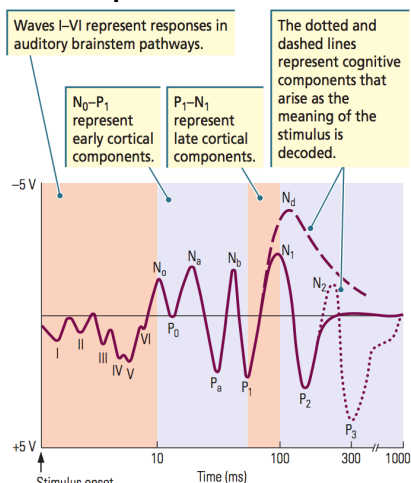
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Common ERP patterns

- (P)ositive and (N)egative waves
- Early waves in brainstem (I, II, III, IV, V, VI)
- Later waves in cortex (N0, P0...N3, P3)
- Image: ERP in Parietal Cortex in response to spoken word



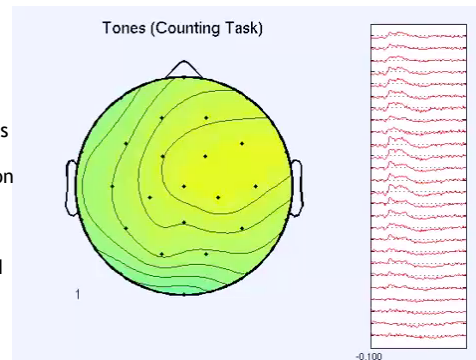
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Multi-electrode ERP

- An individual's event-related potentials (ERPs) to tones in a simple tone counting task. Right column plots ERPs at 26 scalp electrodes (negative is up). Voltage is represented in color on the cartoon head (cool=negative, warm=positive). Time (in seconds) is printed at the bottom of the column of ERPs. Most prominent ERP deflection is the auditory N1 that peaks around 100 ms post-stimulus.



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MEG : magnetoencephalography

- Maxwell-Faraday equation - relates change in Electrical potential (voltage) "E-field" to change in magnetic field "B-field"
- Electrical voltages : can be measured with cheap equipment
- Magnetic fields : measured with fancy equipment
 - SQUIDS : Superconducting quantum interference device
 - Requires liquid helium
 - \$\$\$
- Pro: higher resolution

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$



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Brain Stimulation

- Electrical
 - Surface
 - often used in brain surgery
 - Intracranial
 - DBS - Deep Brain Stimulation - mostly experimental, used for Parkinson's treatment
 - Very invasive - risks of infection, etc.
- Magnetic
 - TMS : transcranial magnetic stimulation

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Transcranial Magnetic Stimulation

- TMS - new, still being researched
- very strong magnetic fields are created in the brain
- magnetic fields cause electrical currents in brain tissue
- mechanism - unknown



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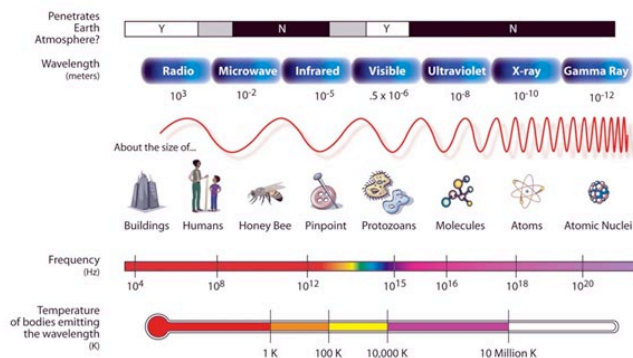
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X-Ray techniques

- X-rays : very high frequency (small wavelength) waves
- Ionizing!

THE ELECTROMAGNETIC SPECTRUM



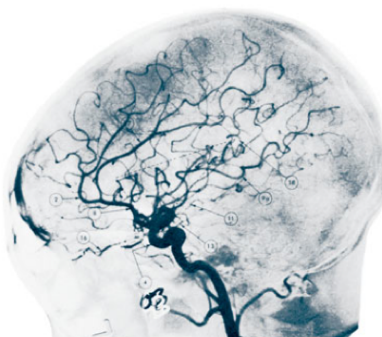
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X-Ray Procedures

- Conventional - simple xray of the skull - shows gross features
- Contrast techniques
 - Pneumoencephalography - *air-brain-graph* - inject air into csf for contrast
 - Angiography - inject material into blood which blocks xrays
- CT



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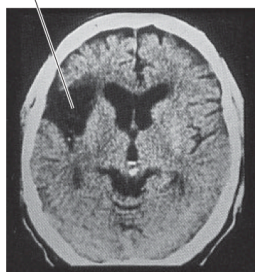
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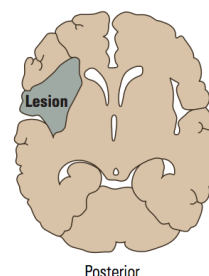
CT : Computed Tomography

- Xrays are sent through head from all angles
- Computer reconstructs data into 3-D image
- Aka "Computed Axial Tomography" or CAT scan

(A) CT scan
Lesion



(B) Horizontal section
Anterior



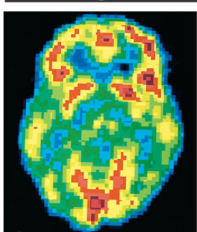
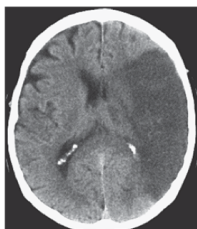
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Neuroimaging

- Visualizing the brain *in vivo*
- CT : Computed Tomography
 - xray
 - cheap(er), quick
 - low resolution
- PET : Positron Emission Tomography
 - radioactive injection
 - tag chemicals to image



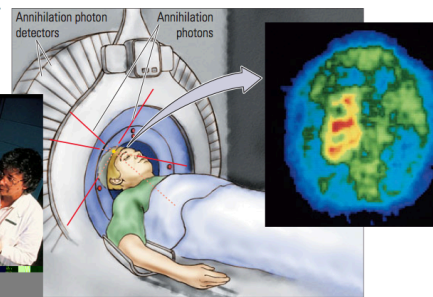
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PET Scanner

A small amount of radioactively labeled water is injected into a subject. Active areas of the brain use more blood and thus have more radioactive labels.



Positrons from the radioactivity are released; they collide with electrons in the brain, and photons (a form of energy) are produced, exit the head, and are detected.

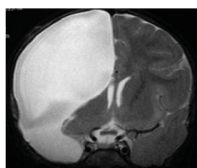
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MRI

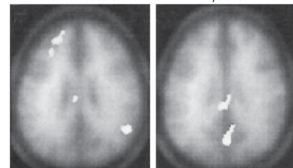
- MRI : Magnetic Resonance Imaging
 - magnetic fields
 - detailed
 - expensive
- fMRI : Functional MRI
 - metabolism in real time



(B) fMRI responses

Normal readers

Dyslexics



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MR - Spectroscopy

- MRI normally images hydrogen molecules in water (80% of the brain) - Can't see other 20%
- MR Spectroscopy - uses different RF frequency to image non-water chemicals
- Experimental
 - e.g. can detect choline (precursor to Acetylcholine)

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MR - DTI - Diffusion Tensor Imaging

- measures directional movements of H₂O molecules
- in ventricles & cell bodies: water molecules are random
- in nerve fibers, water moves along axis of fiber

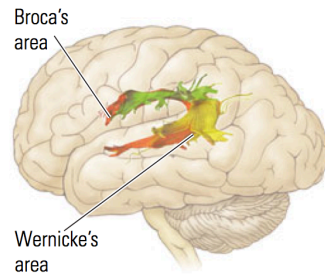


Figure 6.24

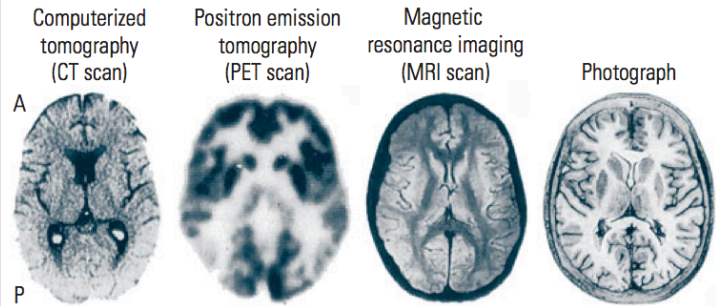
Diffusion Tensor Images of the Language Pathways Connecting Broca's and Wernicke's Regions

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Comparison of Neuroimaging images



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Imaging Comparison

Kind	Time	Resolution	Cost	Risk	Detect Function?
Xray - Conventional	fast	very low	\$	☠	✗
Xray angiography	slow	high	\$\$	☠ ☠	✗
Xray - CAT	medium	medium	\$\$	☠ ☠	✗
PET	slow	low	\$\$\$	☠ ☠	✓
MRI	slow	high	\$\$		✗
fMRI	slow	high	\$\$\$		✓

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