

## Chapter 6 : Imaging The Brain

Saturday, September 22, 2012

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1

## 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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2

### Single-Cell recording

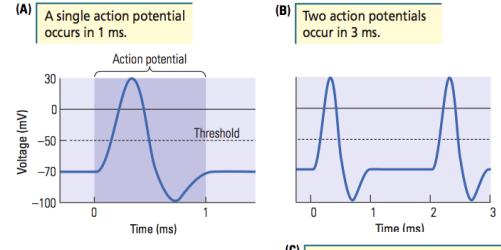
- Typically done in non-human animals
- Single electrode recording
- Arrays of electrodes
  - record from multiple cells



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3

### 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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5

### 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

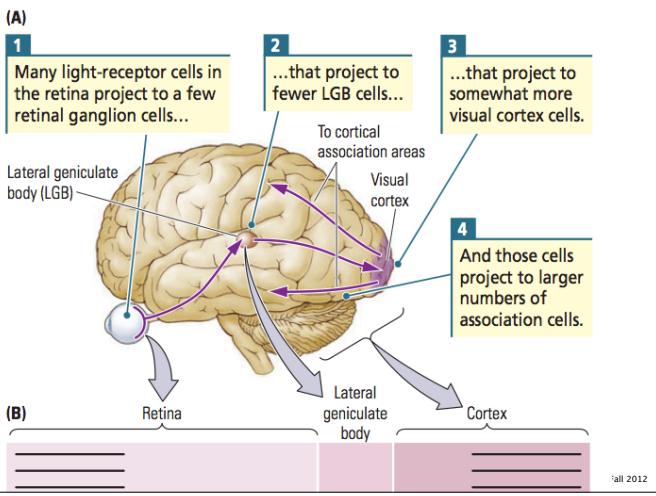
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6

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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!"

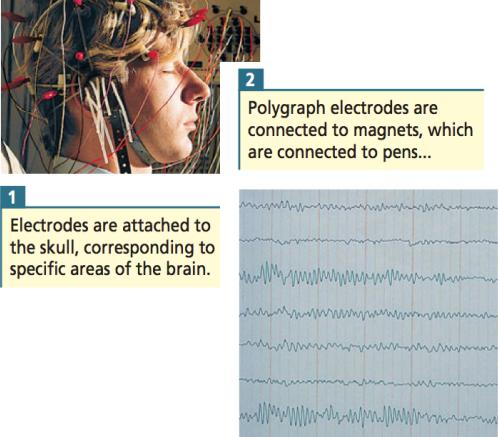
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8

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## Multiple Neuron Recording : EEG

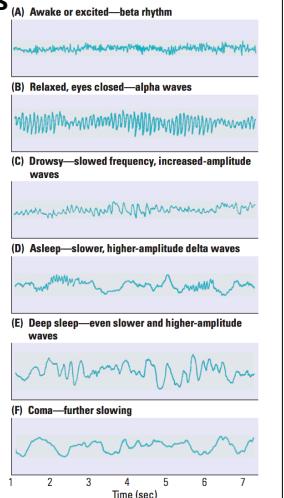
- Neurons fire in synchrony
- Tiny voltages + many many neurons = measurable voltage on the scalp
- EEG : Electroencephalogram



9

## 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

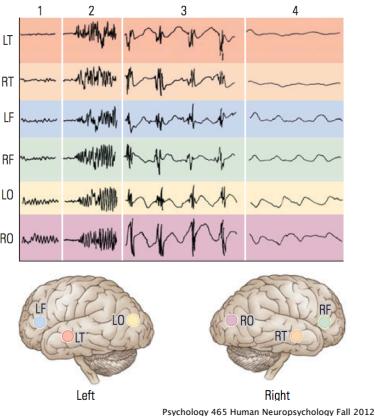


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10

## Epilepsy

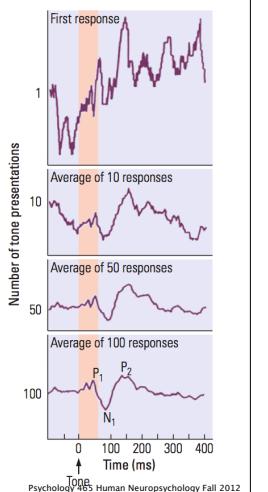
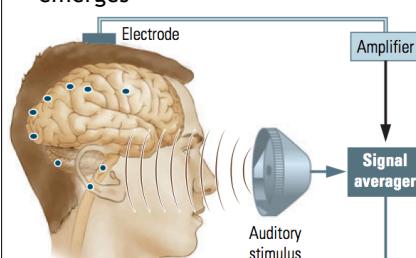
- Seizure
  - large groups of neurons firing all at once
  - out of control
  - pattern spreads
  - can involve entire brain
- Key
  - 1=pre
  - 2=onset
  - 3=clonic
  - 4=coma
- Note largest spikes in RO area - source of seizure?



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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

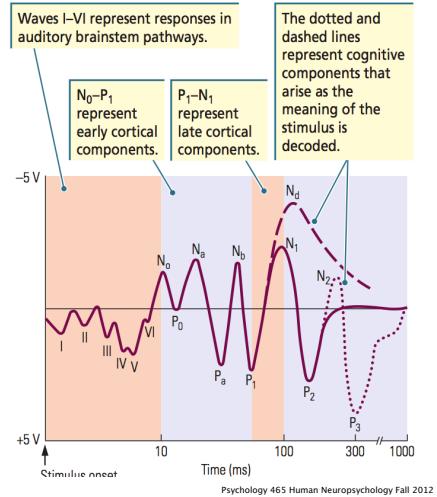


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11

## Common ERP patterns

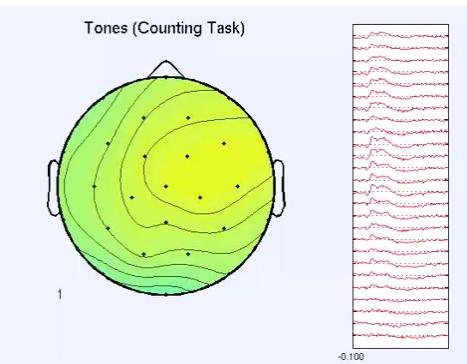
- (P)positive and (N)negative waves
- Early waves in brainstem (I, II, III, IV, V, VI)
- Later waves in cortex (N0, P0...N3, P3)
- Image: ERP in Parietal Cortex in response to spoken word



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



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15

## 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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16

## 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

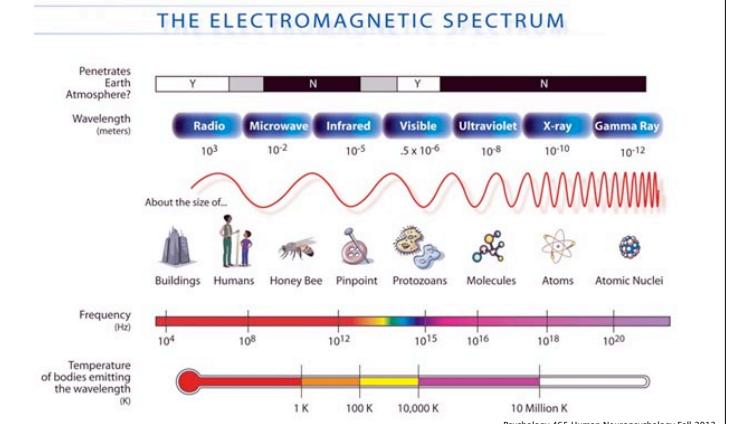


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17

## X-Ray techniques

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

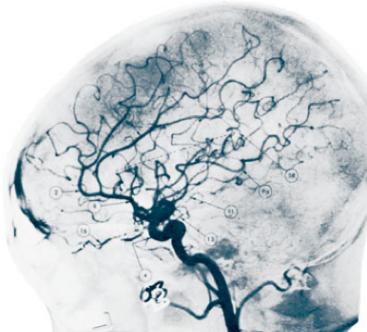


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18

## X-Ray Procedures

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

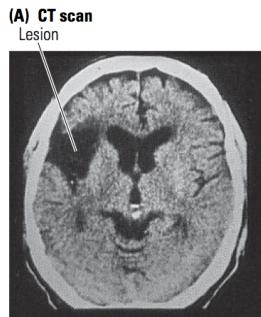


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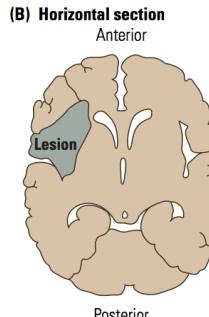
19

## 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



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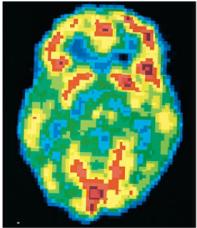
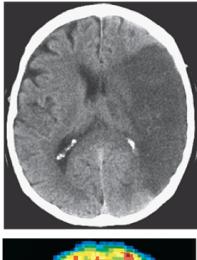


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20

## 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

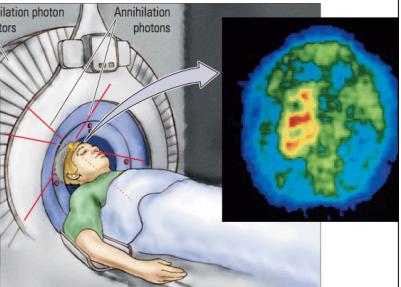


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21

## 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.



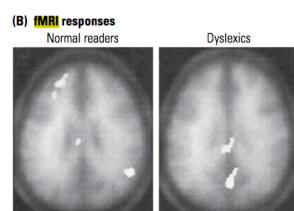
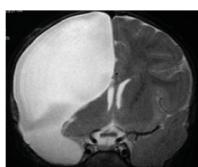
Positrons from the radioactivity are released; they collide with electrons in the brain, and photons (a form of energy) are produced, exit the head, and are detected.

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22

## MRI

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



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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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24



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## MR - DTI - Diffusion Tensor Imaging

- measures directional movements of H<sub>2</sub>O molecules
- in ventricles & cell bodies: water molecules are random
- in nerve fibers, water moves along axis of fiber

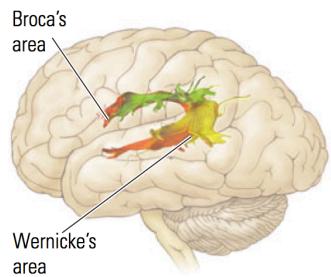
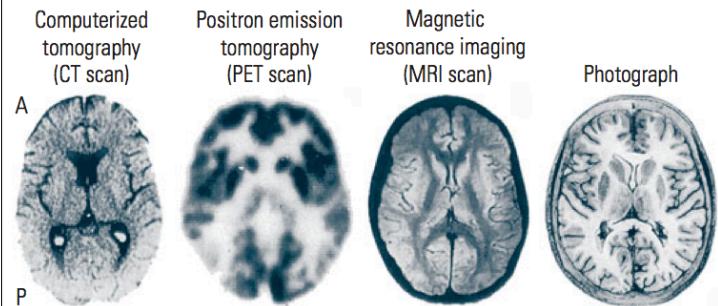


Figure 6.24

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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26

## 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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27

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