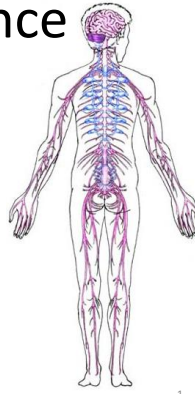


# CISC 3250

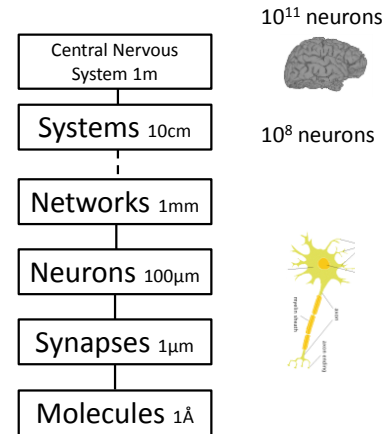
## Systems Neuroscience

Neural systems and  
neuroanatomy

Professor Daniel Leeds  
dleeds@fordham.edu  
JMH 332



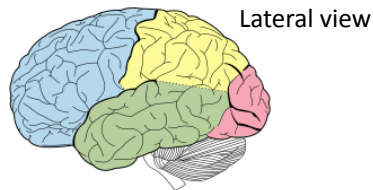
## Levels of organization



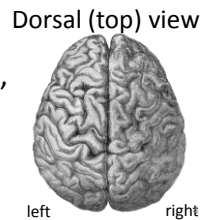
## Cerebral cortex broad divisions

- Four lobes

- Frontal ■
- Parietal ■
- Temporal ■
- Occipital ■

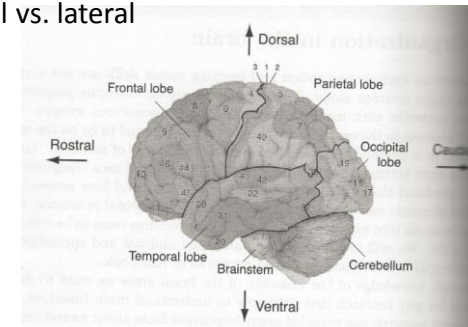


- Two hemispheres: left and right, linked by corpus callosum



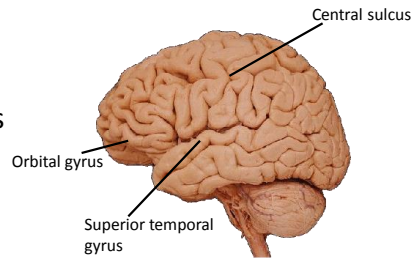
## Navigating the cerebral cortex

- Dorsal/superior (top) vs. ventral/inferior (bottom)
- Anterior/rostral (front) vs. posterior/caudal (back)
- Medial vs. lateral



## Dividing the cerebral cortex surface

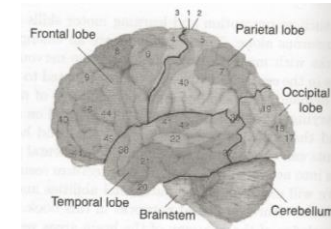
- Sulci – folds
- Gyri – bulges



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## Functional divisions

- Frontal
  - Future planning, personality, judgment, social behavior
  - Motor cortex
- Temporal
  - Auditory cortex
  - High-level vision
- Parietal
  - Spatial vision
  - Primary sensory cortex
  - Visual-auditory-spatial sensory integration
- Occipital
  - Primary visual cortex

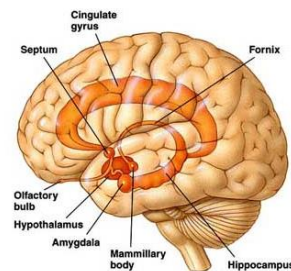


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## Limbic system – memory/emotion

Medial area of cerebral cortex

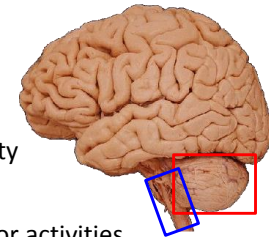
- Hippocampus: memory
- Amygdala: emotion
- Cingulate and parahippocampal gyri



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## The brain beyond the neocortex

- Brain Stem
  - Conduit for spinal cord and cranial nerves
  - Respiratory and cardiac activity
- Cerebellum
  - Plan, coordinate, modify motor activities

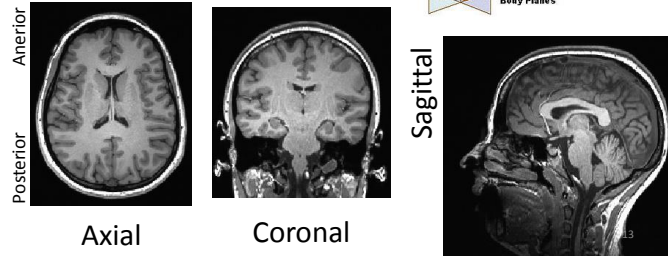
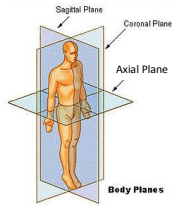


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[http://en.wikipedia.org/wiki/File:1806\\_The\\_Hypothalamus-Pituitary\\_Complex.jpg](http://en.wikipedia.org/wiki/File:1806_The_Hypothalamus-Pituitary_Complex.jpg)

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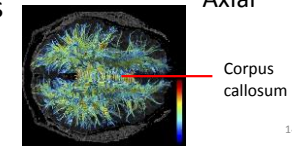
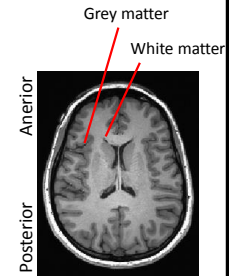
## Two dimensional slices of the brain

- Axial (parallel with ground)
- Coronal (halo)
- Sagittal (in profile)



## Grey and white matter

- Grey matter – soma, performs “computations”
- White matter (60% of brain) – axons, transmits information
- Tractography finds links between brain regions



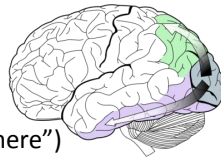
Creative Commons, some rights reserved  
<http://en.wikipedia.org/wiki/File:3DSlicer-KubickiPR2007-fig6.jpg>

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## Cortical processing networks

Perception “hierarchy”

- *Primary sensory areas* capture basic sensory properties, or “features”
- More complex representations in higher sensory areas
- Example: Vision
  - Primary visual cortex in occipital pole
  - Anterior flow of information in ventral (“what”) and dorsal (“where”) pathways



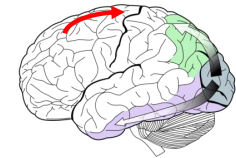
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[http://en.wikipedia.org/wiki/File:Ventral-dorsal\\_streams.svg](http://en.wikipedia.org/wiki/File:Ventral-dorsal_streams.svg)

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## Cortical processing networks

Action

- Motor planning and performance is achieved in stages within the frontal lobe
- Motor correction is supervised by the cerebellum

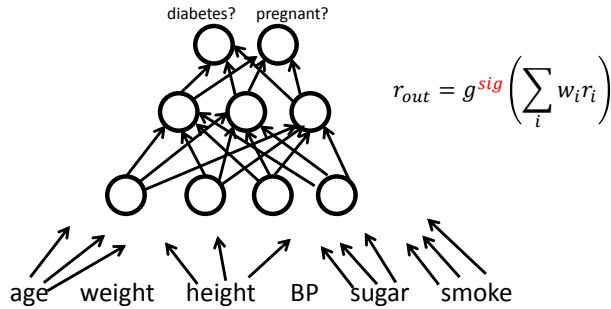


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[http://en.wikipedia.org/wiki/File:Ventral-dorsal\\_streams.svg](http://en.wikipedia.org/wiki/File:Ventral-dorsal_streams.svg)

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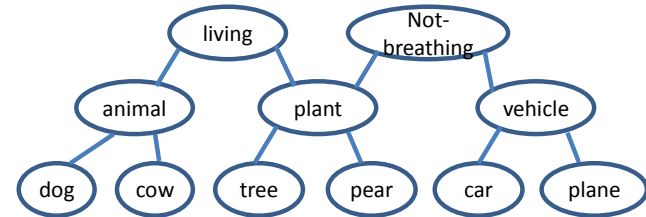
## “Deep” learning

Multiple layers of computation in artificial intelligence



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## Deep factor graphs

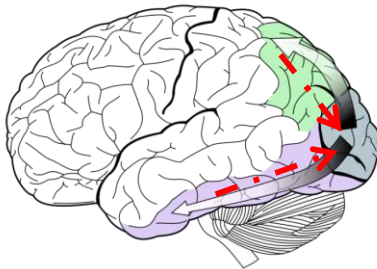


- Hierarchies in reasoning
- WordNet and ImageNet

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## Complexity of cortical networks

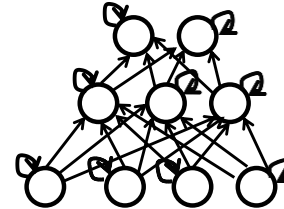
- *Feedback*: connections in both directions along cortical “pathways”



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[http://en.wikipedia.org/wiki/File:Ventral-dorsal\\_streams.svg](http://en.wikipedia.org/wiki/File:Ventral-dorsal_streams.svg)

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## Recurrent neural networks



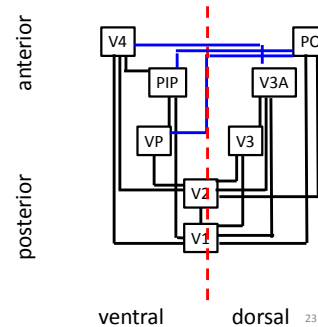
The man walked up the steps into the barn to see

- E.g., Word2Vec: “barn” -> [3, 0, 1, 2, 0, 0, -2]
- Information represented as “neuron” outputs

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## Complexity of cortical networks

- *Lateral connections:* collaboration among cortical regions at similar stage of processing
- *Multi-level connections:* shortcuts between “early” and “late” processing stages

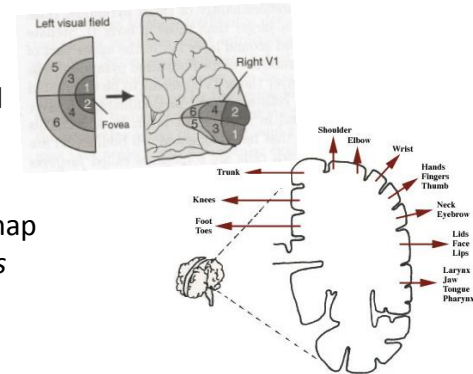


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## Cortical modules

Groups/“columns” of neurons encoding same property  
Subdivisions within cortical region

- Retinotopy
- Body part map  
*Homunculus*

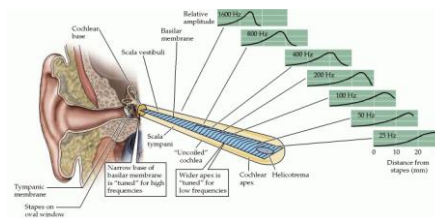
Walter Crane, <http://www.csuchico.edu/~qmcaffrey/syllabi/CMSDN20120362unit4.html>

## Cortical modules

Groups/“columns” of neurons encoding same property

Subdivisions within cortical region

- Retinotopy
- Body part map  
*Homunculus*
- Tonotopy

<http://www.ncbi.nlm.nih.gov/books/NBK10946/>


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## Recording activity in the brain

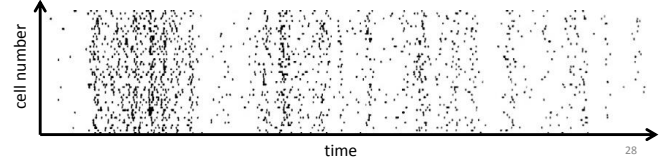
- Electrode recordings
  - Invasive
  - Single neurons close together
- Neuroimaging
  - Non-invasive
  - Hundreds-millions of neurons broadly distributed
- Behavior
  - Non-invasive
  - Overall cognition

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## Electrode recordings



- Membrane potentials
- Spike times
- High temporal resolution (ms)
- High spatial resolution (individual neurons)
- Low field of view (small recording area)

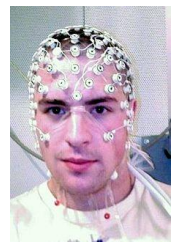


cell number


time

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## Electroencephalography (EEG)




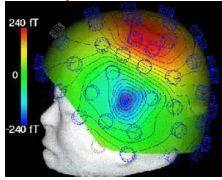
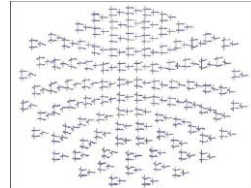
- Records electric fields at skull surface
- ~100 sensors across the head
- low spatial resolution
- high (ms) time resolution
- cheap



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## Magnetoencephalography (MEG)

- Records magnetic “dipoles” from deep in brain
- 300 sources found inside the head
- low spatial resolution
- ms time resolution
- expensive

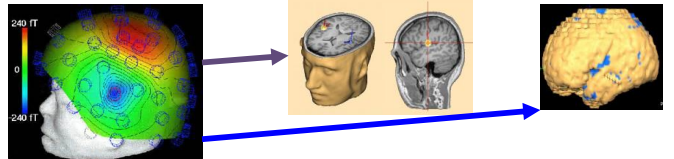




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## Source localization – EEG and MEG

From recordings at surface:

- extrapolate limited localized “dipoles” of activity within the brain
- extrapolate broad regions of activity



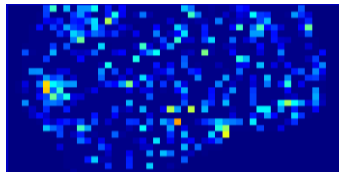
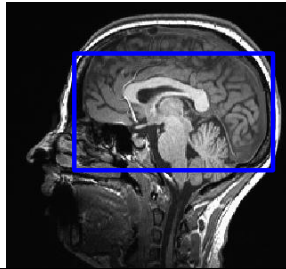
<https://www.cogsci.mq.edu.au/facilities/erp/documents/presentations/an%20introduction%20to%20spatial%20analyses.pdf>

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## functional Magnetic Resonance Imaging (fMRI)



- Records concentration of blood oxygen
- 10,000+ cortical cubes ( $2 \times 2 \times 2 \text{ mm}^3$ )  
relatively high spatial resolution
- Low (0.5-4 seconds) time resolution
- expensive



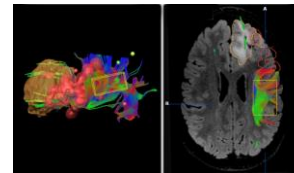
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## Tractography: Diffusion Tensor Imaging (DTI)

Uses MRI

Track flow of water along axon tracts

- Pick source location, see where water flows to



Each color is a different white matter pathway

[https://www.mayfieldclinic.com/PE-fMRI\\_DTI.HTM](https://www.mayfieldclinic.com/PE-fMRI_DTI.HTM)

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