


CISC 3250 Systems Neuroscience

Neural systems and
neuroanatomy

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JMh 328A



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Levels of organization

Central Nervous System 1m

Systems 10cm


Networks 1mm

Neurons 100µm

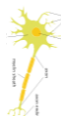
Synapses 1µm

Molecules 1Å

10¹¹ neurons



10⁸ neurons

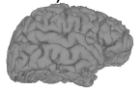


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Elements of the central nervous system

- Cerebral cortex ■
- Thalamus ■
- Hypothalamus ■
- Brainstem ■ ■ ■
- Cerebellum ■
- Spinal cord

Lateral (outside)
view



Medial (inside)
view




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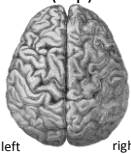
Cerebral cortex broad divisions

- Four lobes
 - Frontal ■
 - Parietal ■
 - Temporal ■
 - Occipital ■
- Two hemispheres: left and right, linked by corpus callosum

Lateral view



Dorsal (top) view

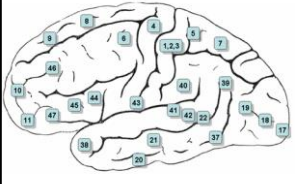


left right

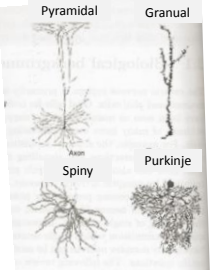
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Brodman areas

- Divide brain based on arrangement of neurons in each region



Lateral view

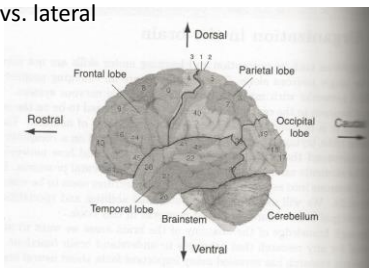


Common neuron types

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Navigating the cerebral cortex

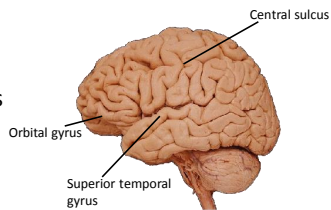
- Dorsal (top) vs. ventral (bottom)
- Anterior/rostral (front) vs. posterior/caudal (back)
- Medial vs. lateral



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Dividing the cerebral cortex surface

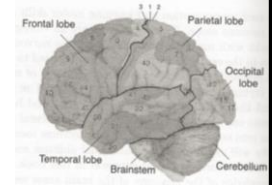
- Sulci – folds
- Gyri – bulges



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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

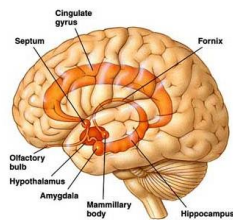


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Limbic system – memory/emotion

Medial area of cerebral cortex

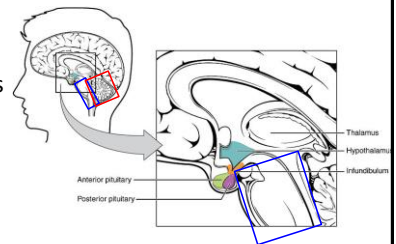
- Hippocampus: memory
- Amygdala: emotion
- Cingulate and parahippocampal gyri



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The brain beyond the neocortex

- Thalamus
- Hypothalamus
- Brain Stem
- Cerebellum



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http://en.wikipedia.org/wiki/File:1806_The_Hypothalamus-Pituitary_Complex.jpg

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The brain beyond the neocortex

- Thalamus
 - All sensory information (except olfaction/smell) passes through
- Hypothalamus
 - Emotions, memory
 - Homeostasis: temperature, sleep/alertness, hunger

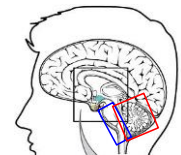


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The brain beyond the neocortex

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



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Two dimensional slices of the brain

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

Anterior
Posterior

Axial Coronal

Sagittal

Grey and white matter

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

Grey matter
White matter

Anterior
Posterior

Axial

Corpus callosum

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<http://en.wikipedia.org/wiki/File:3DSlicer-KubickiPR2007-fig6.jpg>

At the periphery

- Spinal cord
 - Muscles: motor
 - Mechanoreceptors: touch
- Sensory organs
 - Ears: Hearing and balance
 - Eyes: Vision
 - Olfactory bulb: smell

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Non-functional anatomy

- Vessels of the brain
- Ventricles with cerebrospinal fluid
- Casing around the brain – pia matter, dura matter

ventricle

Coronal

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Cortical division review

- 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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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

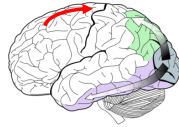
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Cortical processing networks

Action

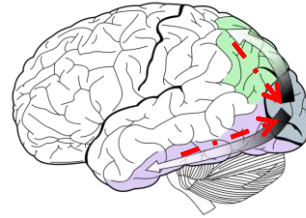
- Motor planning and performance is achieved in stages within the frontal lobe
- Motor correction is supervised by the cerebellum



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Complexity of cortical networks

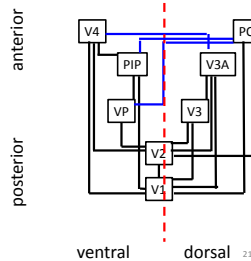
- **Feedback:** connections in both directions along cortical “pathways”



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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

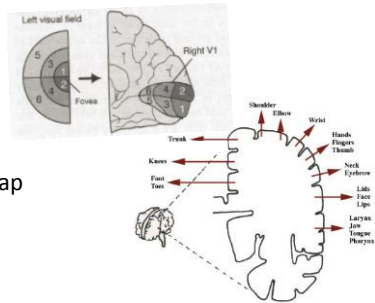


Cortical modules

Groups/“columns” of neurons encoding same property

Subdivisions within cortical region

- Retinotopy
- Body part map *Homunculus*



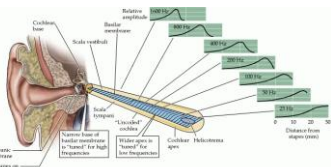
Walter Crane, <http://www.csuchico.edu/~pmcraffrey/lab/CMSDS20130/362unit4.html>

Cortical modules

Groups/“columns” of neurons encoding same property

Subdivisions within cortical region

- Retinotopy
- Body part map *Homunculus*
- Tonotopy

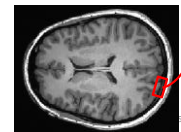
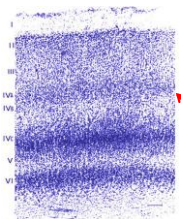


<http://www.ncbi.nlm.nih.gov/books/NBK10946/>

Local cortical structure

Six cortical layers

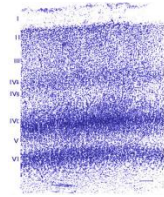
- Layers contain different neuron types
- Nissl staining shows concentration of somas (here, primary visual cortex)



Local cortical structure

Six cortical layers

- Layer IV for input
- Layer V for output
- Layers II & III for lateral connections
- Layer I – largely axons/dendrites



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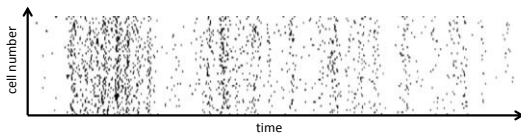
Recording activity in the brain

- 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

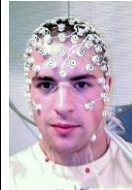
- Membrane potentials
- Spike times



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Electroencephalography (EEG)

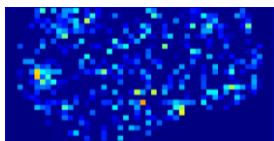
- Records electric fields at skull surface
- ~100 sensors across the head
- ms time resolution



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functional Magnetic Resonance Imaging (fMRI)

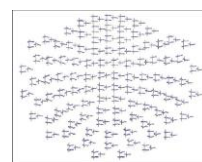
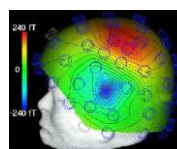
- Records concentration of blood oxygen
- 10,000+ cortical cubes (2x2x 2 mm³)
- 0.5-4 seconds time resolution



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Magnetoencephalography (MEG)

- Records magnetic "dipoles" from deep in brain
- 300 sources found inside the head
- ms time resolution



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Behavior

Typical arrangement:

- Provide stimulus on each trial
- Record response

Data for analysis:

- Button press, eye movement, body movement
- Reaction time
- Accuracy

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