Understanding the Brain Through Imaging:

Intro to the CNS

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To serve three courses according to the glass [i.e. allot a definite time to each part of the body].

In the first day's lectures the abdomen, nasty yet recompensed by its infinite variety.

In the second the parlour, [i.e., the thorax].

In the third day's lecture the divine banquet of the brain.

William Harvey, 1587-1657
Overview of the Nervous System

- Central Nervous System
  - Brain
  - Spinal Cord
  - Cranial Nerves I-XII

- Peripheral Nervous System
  - Peripheral nerves
Overview of the Nervous System

- **Central Nervous System**
  - Brain
  - Spinal Cord
  - Cranial Nerves I-XII

- **Peripheral Nervous System**
  - Peripheral nerves

- **Supporting structures**
  - Bones
  - Coverings (pia, dura)
  - Cerebrospinal fluid
  - Vasculature
    - Arteries, capillaries, veins
Nerve Basics

Neurons
- Cell Bodies
- Axons (only 1!)
- Dendrites
- Synapses

Santiago Ramón y Cajal (1852-1934)
Nerve Basics

Neurons
Cell Bodies
Axons (only 1!)
Dendrites
Synapses
Neuroglial Cells

- **Astrocytes**
  - Supporting structure for neurons
  - Invest blood vessels

- **Oligodendrocytes**
  - Make **myelin**, which wraps around many CNS axons
    - Myelin is wrapped membrane bi-layers around axons, which increases the transmission speed.

- **Microglia**
  - Defense cells
  - Inflammatory response

- **Ependymal Cells**
  - Around ventricles, CSF

- There are 5-10 x more neuroglia than neurons
Gray & White Matter

• **Gray matter**
  - Consists primarily of cell bodies, neurons
  - Also axons, etc.
  - Gray matter clumps in the middle of white matter is sometimes called “nuclei”

• **White matter**
  - Consists primarily of axons
    - Myelin
Gray & White Matter

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Brain Tissue Contrast with MRI

- **Gray Matter**
  - T1 = 1820 ms, T2 = 100 ms*
  - Brighter than WM on T2-weighted images
  - Darker than WM on T1-weighted images

- **White Matter**
  - T1 = 1100 ms, T2 = 70 ms
  - Darker than GM on T2-weighted images
  - Brighter than GM on T1-weighted images

- **CSF**
  - T1 = 4000 ms, T2 = 2500 ms
  - Very bright on T2-weighted images
  - Very dark on T1-weighted images

* 3T, Stanisz et al., *Magn Reson Med* 2005
Blood-Brain Barrier (BBB)

- Brain is a privileged environment
- Blood-brain barrier restricts movement of small polar molecules
  - Like CT and MR contrast agents
- Essential feature is presence endothelial cell tight-junctions
- Brain parenchyma does not enhance following contrast
  - Very different from almost every other organ
  - Enhancement usually signifies breakdown of the BBB due to pathology
BBB Example

Pre-contrast  Post-contrast
Cerebrospinal Fluid and the Ventricular System

- CSF
  - Watery fluid that surrounds the brain
  - Produced primarily by the choroid plexus
    - Lateral ventricles, third, & fourth ventricles
  - Surface of the brain
  - Resorbed into arachnoid granulations into the dural veins
- Complex 3D structure
- Total volume 140 - 250 ml
- Produce about 700 ml / day
- Sterile
  - Infection here produces meningitis
Cerebral Ventricular System - Axial View

Superior to inferior

Paired lateral ventricles
Foramen of Monro
3rd vent
Cerebral aqueduct
4th vent
Pneumoventriculography

Lateral view

AP view
Arachnoid Cysts

- Focal collections of CSF surrounded by membrane
- Developmental, possibly related to trauma
- Usually no symptoms
- Not uncommon (1-2%, 2:1 M:F)
- Challenge for neuroimaging segmentation and template matching

https://case.edu/med/neurology/NR/Cystmnn2.htm
Brain Parenchyma - an Overview

- Supratentorial brain
  - Cerebral hemispheres
- Infratentorial brain
  - Cerebellum
- Mid-brain
- Pons
- Medulla
- Spinal Cord
**Gyri and Sulci**

- **Gyri**
  - Bumps on the outer portion of the cortex
  - Generally refers to gray matter
  - Often named
  - Often associated with a particular function

- **Sulci**
  - Grooves in between the gyri
  - Filled with CSF, vessels, etc.
  - Major sulci are sometimes called fissures
    - Sylvian fissure
    - Intrahemispheric fissure
  - Still gray matter at the bottom of the sulci!
“Of or pertaining to the forehead”

- Pre-central gyrus (motor)
- Inferior, Middle, Superior frontal gyrus
- Orbital gyri

- Superior and inferior frontal sulci
- Central sulcus

- Motor
- Executive function
- Frontal eye fields

Frontal lobe
Lobes of the Brain

Frontal lobe

Parietal lobe

“Walls of a house” (?)

Post-central gyrus (primary sensory)
Superior parietal lobule
Pre-cuneus
Angular gyrus
Supramarginal gyrus

Post-central sulcus
Intraparietal sulcus
Central sulcus

Primary sensory
Language processing
Lobes of the Brain

- Frontal lobe
- Parietal lobe
- Temporal lobe

“time” or “part of the head next to the eye”
Inferior, middle, superior temporal gyri
Fusiform gyrus
Parahippocampal gyrus
Superior and inferior temporal sulci
Collateral sulcus
Primary auditory (Heschl)
Faces
Memory
Lobes of the Brain

- Frontal lobe
- Parietal lobe
- Temporal lobe
- Occipital lobe

- "back of head"
- Lateral occipital gyri
- Lingual gyrus
- Calcarine sulcus
- Parieto-occipital sulcus
- Primary visual cortex
- Secondary visual cortex
Frontal Lobe

- Anterior to the central sulcus, medial to the Sylvian fissure
- Executive function
- Emotional response
Frontal Lobe

- Anterior to the central sulcus, medial to the Sylvian fissure
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Phineas Gage 1823-1860
Frontal Lobe

- Superior frontal gyrus
- Pre-central gyrus
- Central sulcus
Frontal Lobe

- Superior frontal gyrus
- Pre-central gyrus
- Central sulcus
Frontal Lobe

- Superior frontal gyrus
- Pre-central gyrus
- Central sulcus
How to Find the Central Sulcus?

- Deepest to the midline
- Posterior to it is the marginal sulcus which often looks like a mustache
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- Look for the motor “hand knob” - looks like an upside-down omega
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- Deepest to the midline
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- Look for the motor “hand knob” - looks like an upside-down omega
- Motor cortex (pre-central) usually much thicker than sensory cortex (post-central)
Motor & Sensory Homunculus

Motor

Sensory
Coronal T2 with Homonculus
Parietal Lobe

- Posterior to the central sulcus, superior to the parieto-occipital sulcus
- Integration of sensory experience
- Language, spatial relationships
Parietal Lobe

- Post-central gyrus
- Central sulcus
- Post-central sulcus/ intraparietal sulcus
Parietal Lobe

- Parieto-occipital sulcus
Temporal Lobe

- Lateral to the Sylvian fissure, anterior to occipital lobe, inferior to parietal lobe
- Hearing
- Meaning of speech and vision (e.g., faces)
Temporal Lobe

- Sylvian fissure

http://www.med.harvard.edu/AANLIB/cases/caseNA/pb9.htm
Temporal Lobe

- Sylvian fissure
- Superior temporal gyrus (of Heschl)
- Middle and inferior temporal gyrus
- Fusiform gyrus
- Parahippocampal gyrus
Parvizi face

https://www.youtube.com/watch?v=R2AMgLhaxHk
Occipital Lobe

- Inferior to parieto-occipital sulcus, superior to tentorium
- Primarily vision related
- Smallest
Occipital Lobe

- Parieto-occipital sulcus
- Calcarine sulcus
- V1 Region
Occipital Lobe

- Pareito-occipital sulcus
- Calcarine sulcus
- V1 Region
Occipital Lobe - Visual Cortex

“Banks of the calcarine sulcus”

fMRI
“Limbic” Lobe

- Cingulate sulcus
- Cingulate gyrus
- Hippocampus
- Fornix
- Amygdala
- Insula

Medial sagittal view of the hemisphere
Hippocampus

- Cingulate sulcus
- Cingulate gyrus
- **Hippocampus**
- Fornix
- Amygdala
- Insula

www.psycheducation.org
Hippocampus - Sagittal View

- Cingulate sulcus
- Cingulate gyrus
- Hippocampus
- Fornix
- Amygdala
- Insula
Hippocampus - Coronal View

- Cingulate sulcus
- Cingulate gyrus
- **Hippocampus**
- Fornix
- Amygdala
- Insula

7T, Henry et al., Radiology 2011
Hippocampus - Coronal View

- Cingulate sulcus
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7T hippocampus, courtesy of Michael Zeineh
Insula

- Infolded region of cortex surrounded by:
  - Frontal
  - Temporal
  - Parietal
  - “Opercula” - lids
- Region that undergoes relatively little growth with development
- Gets surrounded by the more rapidly growing lobes
- Function: Salience; wide range, self-awareness, disgust, addiction, etc.
Major White Matter Tracts

- Three main types (some overlap)
- Structures that cross midline and connect similar regions (e.g., corpus callosum)
- Structures that connect different regions within the same hemisphere (optic radiations)
- Structures that connect structures in the brain with the spinal cord & rest of the body (corticospinal tracts)
Corpus Callosum

- Splenium
- Body
- Genu
- Rostrum
Corpus Callosum

- Splenium
- Body
- Genu
- Rostrum
- Connects the occipital, parietal, and frontal lobes on each side
• Major pathway connecting 2 cerebral hemispheres

LR=red, AP=green, SI=blue
Major White Matter Tracts - Unilateral

- Optic Pathway
- Retina
- Optic Nerve (CN 2)
- Optic Chiasm
- Optic tracts
- Lateral geniculate
- **Optic radiations**
- Occipital cortex
Optic Radiations

- Optic nerves->chiasm->optic tracts->LGN->Visual cortex
Major White Matter Tracts - Superior Inferior

- Corticospinal system
- Primary motor

Major White Matter Tracts - Superior Inferior

- Corticospinal system
- Primary motor
- **Centrum semiovale**
- **Corona radiata**
- **Internal capsule**
- Cerebral peduncles
- Pons - medulla
- Decussation