Week 4:
Basic Neuroanatomy, part II (Ch 3) & Hemispheric Localization (Ch 4)
Odds & Ends

- **Homework #2**
  - Pass up HW2 to front for me to collect
  - Collect HW1 + Solutions (up front); notes on grading, self-correction
  - HW2 solutions passed out at end of class today — don’t let me forget!

- **Exam #1 (Feb 25 – Next Week!!)**
  - Page of notes: 1 side, 8.5 x 11 in; Turn in notes with exam
  - Study guide – Pick up copy from front for review last 30 mins of class today (8:10–8:40)

- **Xtra credit opportunities**
GreeneLab is Recruiting Volunteers for Psychology Studies

- Volunteers MUST BE ages 18--35
- Experiments are performed on a PC with keyboard & mouse; sometimes auditory content via headphones
- Earn Extra Credit
- Studies require 45 to 90 minutes
- Located in basement of Garland Hall Rm B09
- 229-6089
- Greenelab@gmail.com
- EMAIL US OR SIGN UP NOW TO SCHEDULE AN APPOINTMENT
Quick Review (HW1-Q#2)

- On what basis did Brodmann decide to divide cortex into different anatomical regions?
Examples of cytoarchitectonic definition of cortical regions [1/2]

- Primary motor cortex (M1) = BA 4
  - Aka “agranular cortex” (along with BA6) because it contains sparse layer IV (i.e., few granular neurons)
  - Well-defined pyramidal layer (layer V: large & dense pyramidal neurons)
Examples of cytoarchitectonic definition of cortical regions [2/2]

- Primary visual cortex (V1) = BA 17
  - Very richly layered (actually has more than the usual 6 cortical layers; see notes on visual system later today…)
  - Very well-defined layer IV (granular layer)
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• Basic neuroanatomy (part II)
  – Cerebrum [part II]
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    • Cerebral White matter (major categories)
  – Visual system (overview)
  – Auditory system (overview)
  – Somatosensory system (overview)
  – Motor system (overview)

• Hemispheric lateralization (part I)
  – Structural & functional laterality in nonhumans
  – Laterality in humans
    • Structural asymmetries
    • Functional asymmetries (next time)
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Medial Divisions 1: Limbic “Lobe”

• **Key structures**
  – Cingulate gyrus
  – Medial temporal lobe
    • Hippocampus
    • Parahippocampal gyrus
    • Amygdala

• **Functions**
  – Regulation of visceral and endocrine functions
  – Emotion
  – Motivation
  – Memory, learning
Limbic “Lobe”

cingulate cortex

hippocampus

amygdala
hippocampus

Cingulate gyrus
Papez Circuit

FIGURE 23-16
The Papez circuit. The shortcut from the hippocampus directly to the anterior thalamic nucleus, not part of the circuit as originally proposed, is indicated by a dashed line. A, Anterior thalamic nucleus; D, dentate gyrus; H, hippocampus; M, mammillary body.
Medial Divisions 2: Insular Lobe
Medial Divisions 3: Basal Ganglia

• **Key structures**
  – Caudate (nucleus)
  – Putamen
  – Globus pallidus

• **Functions**
  – Control of movement (< “extrapyramidal” motor system)
  – Reward system and reward-based learning
  – Procedural (non-declarative, “skill-based”) memory

• **Terms to be familiar with:**
  – basal ganglia also called *striatum*
  – Globus pallidus also called *pallidum*
  – *Lenticular nuclei* = putamen + globus pallidus
  – *Ventral striatum* = caudate + putamen
Ventral striatum
Lenticular nuclei

caudate nucleus

putamen

globus pallidus
Basal Ganglia

- Putamen
- Globus pallidus (lateral part)
- Globus pallidus (medial part)
- Caudate nucleus
- Thalamus
- Subthalamic nucleus
- Substantia nigra
Basal Ganglia Circuit
Cerebral White matter

• Projection fibers: vertical
  – Corona radiata
  – Internal capsule

• Association fibers: intrahemispheric
  – Short fibers
  – Long fibers
    • Arcuate fasciculus

• Commissural fibers: interhemispheric
  – Corpus callosum
  – Anterior commissure
Recall: White Matter Tracts connecting brain with S.C.

- Corona radiata
- Internal capsule
- Pes pedunculi
- Corticospinal tract
- Pyramid of medulla
- Corticospinal tract
Corona Radiata
Internal Capsule
Arcuate Fasciculus
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Visual Processing: Overview

• Parallel processing of different visual inputs, dimensions of input stimuli
  – Movement
  – Color
  – Size

• Two different visual pathways
  – Conscious: retina → LGN → V1
    • Aka Retino-geniculo-cortical pathway
  – Nonconscious: retina → SC → FEF
Important Features of Visual System

- Photoreceptors
- Conversion to nerve impulses in retina
- Visual pathway: from retina to V1 primary visual cortex
- Visual fields & visual field deficits
- Cytoarchitecture
  - LGN of thalamus
  - V1 striate cortex
- Perception in visual association cortex
  - Dorsal & Ventral pathways
  - Conscious: retina $\rightarrow$ LGN $\rightarrow$ V1
  - Nonconscious: retina $\rightarrow$ SC $\rightarrow$ FEF
Visual Pathway from Retina to V1

- **Optic nerve** fibers converge at optic chiasm
- **Partial decussation** of fibers in *optic chiasm*
  - Fibers from temporal half of retina (= *nasal* visual field) ⇒ projects *ipsilateral*
  - Fibers from nasal half of retina (= *temporal* visual field) ⇒ projects *contralateral*
- **Optic tract** [note *contralateral projections]*
  - Right optic tract ⇒ transmits left visual field
  - Left optic tract ⇒ transmits right visual field
- Some tracts project to *Superior Colliculus* in midbrain
- Most project to *Lateral geniculate nucleus* (*LGN*) in thalamus
- Optic radiations project to *V1* primary visual cortex
Visual pathway(s)

- Visual cortex (V1)
- LGN (thalamus) or Superior colliculi (midbrain)
- Optic Tract
- Optic Nerve (CN II)
- Retina
Again, note partial decussation of optic nerve fibers when they reach optic chiasm.
Photoreceptors

• Photoreceptors
  – Rods & Cones
    • Rods -- night vision
    • Cones -- visual acuity & color discrimination
  – Photoreceptive cells *hyperpolarize* to light!!

• Bipolar cells
  – Convey signals from rods and cones to ganglion cells

• Ganglion cells**
  – Transmit impulse to brain (*depolarize* like other civilized cells)
  – M & P cells
    • M-Cells project to *magnocellular* layers of LGN (thalamus)
    • P-Cells project to *parvo cellular* layers of LGN (thalamus)
  – Axons of ganglion cells make up *optic nerve*
Conversion of Light to Neural Signals in Retina
Laminar structure of retina

- Pigment epithelium
- Rod and cone segments
- Outer limiting membrane
- Outer nuclear layer
- Rod and cone terminals
- Outer synaptic layer
- Inner nuclear layer
- Inner synaptic layer
- Ganglion cell layer
- Optic nerve fibers
visual radiation
occipital cortex
optic tract
optic chiasm
 optic nerve (CN II)
LGN
Optic Chiasm (crossing)
Dorsal Lateral Geniculate Nucleus

- Located in posterior thalamus
- Terminus for most retinal inputs
- Laminar structure of LGN
- 6-layered
  - Layers 1-2 are Magnocellular ⇒ Project to *Dorsal* pathway of visual cortex
  - Layers 3-6 are Parvocellular ⇒ Project to *Ventral* pathway of visual cortex
Laminar Structure & Retinotopic Mapping of LGN

A

B

Contralateral retina

Ipsilateral retina

Optic tracts

3-6 = Parvocellular layers

1-2 = Magnocellular layers
Superior colliculus

- Terminus for some retinal inputs
- Located in midbrain tectum
- Control eye movement, & head-and-eye coordination, saccades
Primary Visual Cortex (BA 17)

Note expanded *layer IV*, which is where axons from the LGN terminate. This layer is rich in *granular cells*.
Primary Visual Cortex (V1)

Note that upper half of VF is mapped to lower half of V1 (below calcarine fissure), and conversely.
Visual Fields

• Visual fields divided into
  – Left / right visual fields
  – Central / peripheral visual fields
  – Inner (nasal) / outer (temporal) halves
  – Upper (superior) / lower (inferior) halves

• Visual field projections to retina
  – Nasal visual fields project upon temporal retina
  – Temporal visual fields project upon nasal retina
  – Inverted picture projected upon retina

• Projection upon visual cortex
  – Left visual hemifield "seen" only by right visual cortex
  – Right visual hemifield "seen" only by left visual cortex
Visual Field (VF) Deficits

(a) HEMIANOPIA

(b) SCOTOMA

(c) QUADRANTANOPIA

Medial view
Left Hemisphere

Zeki (1990)
Higher levels of visual cortex: Overview

- Two routes from primary visual cortex
  - Dorsal stream ("where" or possibly "how" pathway)
  - Ventral stream ("what" pathway)
Magno & Parvo projections to Layer IV of Area 17 (V1)

Note well-developed Layer IV (is even subdivided)
Dorsal & Ventral Streams

• Ventral Stream
  – “What” or “object” stream
  – visual properties of an object
    • form
    • color
    • high spatial-frequency information

• Dorsal Stream
  – “Where” or “How” stream
  – Spatial location of visual information
  – Motion perception
  – Low spatial-frequency information
Dorsal & Ventral Streams
Dorsal & ventral pathways

Week 4 (2/18/2009) Psych 433 (Frishkoff)
Lesions to V1 & visual association cortex

• Lesions of V1 (primary visual cortex)
  – Cortical blindness
  – *Blindsight* (aka Anton-Babinski syndrome)

• Lesions to Temporal Lobe/Ventral Stream
  – Achromotopsia
  – Alexia
  – Prosopagnosia

• Lesions to Parietal Lobe/Dorsal Stream
  – Akinetopsia
  – Simultagnosia
Classical Studies (PET)

From Zeki (1990)
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Auditory pathway

- Auditory cortex (A1)
- MGN (thalamus)
- Inferior colliculi (midbrain)
- Olivary nuclei (medulla & pons)
- Cochlear-auditory nerve (CN VIII)
- Cochlea
Auditory system

Words > FM Tones

Binder et al., *Cerebral Cortex*, 2000
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Somatosensory System

- Different receptors for different functions
  - Mechanical (touch), Thermal (heat), Chemical (pain)

- Somatosensory pathways have 3 synapses
  - Spinal Cord $\rightarrow$ VPLN of Thalamus $\rightarrow$ S1
  - Ascending fibers cross to contra-lateral side in CNS (spinocerebellar tracts are exception)

- Somatopic “maps” at multiple levels
  - Spinal cord
  - Thalamus
  - S1 (primary somatosensory cortex)
Somatosensory Pathway(s)

- Somatosensory cortex (postcentral gyrus – contra text!!)
- VPLN (thalamus)
- Medial lemniscus
- Decussation in medulla
- Spinal trigeminal nucleus (medulla)
- Dorsal root ganglion (spinal cord)
Spino-thalamico-cortical tract

- Somatosensory cortex
- Dorsal section spinal cord
- Ventral nuclei of thalamus
Somatotopic mapping in SC

Note the orderly medial-to-lateral mapping of the dermatome in anterior, lateral, and posterior regions of S.C.
Somatotopic mapping in Thalamus
Cortical Representation: Somatosensory Homunculus
Cortical remapping in S1

Also recall TMS study from Week 1
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Motor System

- Movement involves all levels of CNS
  - frontal cortex (UMN)
  - basal ganglia
  - cerebellum
  - spinal cord
  - neuromuscular junction (LMN)

- Cortical motor systems
  - Pyramidal (“direct”) – voluntary movements
  - Extrapyramidal (“indirect”) — reflexes, posture

- Basal Ganglia Circuits

- Cerebellar Circuits
Desire to move (Medial frontal/ (para)limbic) → Association cortex → Basal ganglia control circuit and Cerebellar control circuit → Thalamus → Primary motor cortex (M1) → Indirect motor system (Extrapyramidal system) and Direct motor system (Pyramidal system) → Cranial & spinal nerves → Neuromuscular junction

Adapted from Freed, 2000
Motor Pathway(s)

- Primary motor cortex (precentral gyrus)
- Cerebral peduncle (midbrain)
- Decussation in medulla
- Ventral root ganglion (spinal cord)
Corticospinal Pathway

- Fibers arise from
  - Primary motor cortex (both hemispheres) - 30%
  - Premotor cortex & supplementary motor area
  - Postcentral gyrus

- Corona radiata

- Posterior limb of internal capsule

- Cerebral peduncle of midbrain

- Pons

- Lower medulla \(\rightarrow\) pyramids
  - Lateral corticospinal tract
  - Anterior corticospinal tract

- Ventral gray horn
Direct Motor System

- Aka “pyramidal system”
- Divided into
  - corticospinal tracts (spinal nerves)
  - corticobulbar tracts (cranial nerves)
- Direct connection to LMN
- Direct activation of LMN
- Responsible for discrete skilled aspects of an act (voluntary acts)
Indirect Motor System

- Originates in reticular formation in brainstem

- Reticular formation
  - Diffuse network of neurons in brainstem
  - Many connections with other regions of the brain
  - Descending and ascending fibers

- Pathways - originate in brainstem
  - Reticulospinal tract
  - Vestibulospinal tract
  - Rubrospinal tract
  - Tectospinal tract
Motor Homunculus
Premotor Activations (fMRI)

A. Left hemisphere
   - Simple movements

B. Right hemisphere
   - Complex movements

C. Mental rehearsal of complex movements
   - Large increases in blood flow (25%-35%)
   - Moderate increases in blood flow (10%-25%)
Taste and Olfaction

• Taste: Figure 3.25 in book
• Taste information enters primarily through three cranial nerves (7, 9, and 10) enervating the taste buds
• Olfactory information enters through the first cranial nerve which enervates the olfactory epithelium in the nose (book figure 3.26)
• Primary olfactory cortex is referred to as piriform cortex; extreme anterior/inferior insula is also primary olfactory cortex
• Insula also serves as primary taste (gustatory) cortex
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Laterality in non-humans

• What would laterality in non-humans prove?
• Examples of laterality in non-humans
  – Songbirds: left-hemisphere control of song
  – Tail-wagging in dogs
  – Primate studies
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Laterality in humans: Physical Asymmetries

Figure 4.1 Asymmetry of the face revealed by constructing composite faces in which the face is made up of the same two sides
### Laterality in humans: Structural asymmetries in the brain

<table>
<thead>
<tr>
<th>Structure/region</th>
<th>Characteristics</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heschl’s gyri</td>
<td>Two in RH; one in LH</td>
<td>Heschl (1878)</td>
</tr>
<tr>
<td></td>
<td>More oblique in LH</td>
<td>Galaburda (1995)</td>
</tr>
<tr>
<td>Right hemisphere</td>
<td>Larger/heavier than LH</td>
<td>Heschl (1878); Schwartz et al. (1985)</td>
</tr>
<tr>
<td>Left occipital lobe</td>
<td>Larger than right</td>
<td>Cunningham (1892)</td>
</tr>
<tr>
<td>Right frontal lobe</td>
<td>Larger than left</td>
<td>Weinberger et al. (1982)</td>
</tr>
<tr>
<td>Planum temporale</td>
<td>Larger in LH</td>
<td>Pfeifer (1936); Geschwind and Levitsky (1968); Wada et al. (1975)</td>
</tr>
<tr>
<td>Tpt</td>
<td>Larger in LH</td>
<td>Galaburda et al. (1978)</td>
</tr>
<tr>
<td>Sylvian fissure</td>
<td>Larger in LH</td>
<td>Eberstaller (1890); Cunningham (1892); Yeni-Komishian and Benson (1976)</td>
</tr>
<tr>
<td>Pallidum</td>
<td>Larger in LH</td>
<td>Kooistra and Heilman (1988)</td>
</tr>
<tr>
<td>Area 44</td>
<td>Larger in LH</td>
<td>Eberstaller (1890); Galaburda (1980)</td>
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</tbody>
</table>

RH = right hemisphere; LH = left hemisphere

**Table 4.1** Summary of neuroanatomical asymmetries in the human brain