The Organization of the Nervous System

Lecture 2
William James (1842-1910)

“Psychology is the science of mental life”

Principles of Psychology (1890)

The study of mind includes the study of mind in body.

R.W. Wozniak
Levels of Biological Organization

**The Individual Organism**
- Cell
- Tissue
- Organ
- System
- Organism

**Groups of Organisms**
- Species
- Genus
- Family
- Order
- Class
- Phylum (Division)
- Kingdom (Domain)
Systems of the Body

- Nervous System
- Endocrine System
- Integumentary System
- Skeletal System
- Muscular System
- Cardiovascular System
- Lymphatic System
- Respiratory System
- Digestive System
- Urinary System
- Reproductive System
- Immune System
Levels of Neural Organization

**Cell**
- Neuron

**Tissue**
- Nerves, Ganglia, Nuclei

**Organ**
- Brain, Spinal Cord, Brainstem

**System**
- Nervous System
  - Central
    - Brain, Spinal Cord
  - Peripheral
    - Somatic (Skeletal), Autonomic

**Organism**
- Person
Neurons

- Afferent
  - Sensory
- Efferent
  - Motor
- Interneurons
  - “Central”
Glia Cells (Neuroglia)

- **Functions**
  - Build Myelin sheath
  - Guide Migration
  - Packing Tissue
  - Transfer Nutrients
  - Remove Waste

- **Pathology**
  - Alzheimer’s Disease
    - Plaques and Tangles
  - Brain Tumors
The Reflex Arc
Sherrington (1906)

- Afferent Neuron
  - Sensation
- Interneuron
  - Processing
- Efferent Neuron
  - Response
Depolarization
Sherrington (1906)

- Resting Potential
  - Negative
- Ion channels
  - Sodium (Na)
  - Potassium (K)
- Depolarization
- Action Potential
  - Positive
- The Synapse
Synaptic Transmission

- Neurotransmitters
  - Release
  - Uptake
  - Re-Uptake

- Acetylcholine
  - Botulism
  - Curare
  - Nerve Gas
Excitatory and Inhibitory Neurotransmitters

• Amines
  – Acetylcholine (Ach)

• Monoamines
  – Catecholamines
    • Epinephrine (Adrenaline)
    • Norepinephrine (NA)
    • Dopamine (DA)
  – Serotonin (5-HT)

• Amino Acids
  – Glutamate
  – GABA

• Peptides
  – Substance P
  – Beta-Endorphin
  – Corticotropin (ACTH)
  – Oxytocin
Dynamics of the Neural Impulse

• “All-of-None” Law

• Refractory Period
  – Absolute
  – Relative

• Thresholds
  – Superthreshold
  – Subthreshold
Temporal and Spatial Summation
Nerves, Ganglia, Nuclei

- **Nerves**
  - Afferent Neurons
    - Ascending Tract of Spinal Cord
  - Efferent Neurons
    - Descending Tract of Spinal Cord

- **Ganglia**
  - Interneurons Outside Brain, Spinal Cord

- **Nuclei**
  - Interneurons Inside Brain, Spinal Cord
Major Divisions of the Nervous System

CNS
  Brain
    Hindbrain
    Midbrain
    Forebrain
  Spinal cord

PNS
  Somatic
    Afferent
    Efferent
  Autonomic
    Sympathetic
      Afferent
      Efferent
    Parasympathetic
      Afferent
      Efferent
Organization of the Autonomic Nervous System

• Sympathetic: Meet Emergencies
  – Flight or Fight
    • Emotional Arousal (Adrenaline)
    • Release of Sugar (Noradrenaline)
    • Rechannel Blood Flow
  – Tend and Befriend
    • “Choice” Largely Determined by Hormones
      – Testosterone vs. Estrogen

• Parasympathetic: Vegetative Functions
Antagonistic Relationship between Sympathetic and Parasympathetic Nervous Systems

**Sympathetic**
- Acts as a Unit
- Rapid Onset, Offset
- Depletes Resources

**Parasympathetic**
- Acts Discretely
- Slow Onset, Offset
- Conserves, Restores Resources
The General Adaptation Syndrome
Selye (1956)

• Gross Emotional Reaction
  – Sympathetic Activation

• Decreased Emotion
  – Parasympathetic Activation

• Exhaustion, Death
  – Depletion of Resources
Organization of the Somatic Nervous System

- 31 Spinal Nerves
  - Spinal Cord
- 12 Cranial Nerves
  - Brain
  - Brainstem
12 Cranial Nerves

- **Afferent**
  - Olfactory (I)
    - smell
  - Optic (II)
    - vision

- **Efferent**
  - Oculomotor (III)
    - eyes
  - Hypoglossal (XII)
    - tongue

- **Mixed**
  - Trigeminal (V)
    - touch, chewing
  - Facial (VII)
    - taste, face
Spinal Nerves: Combine Afferent and Efferent Functions

- Afferent Branch
  - Dorsal Root
- Efferent Branch
  - Ventral Root
Distribution of 31 Spinal Nerves
Spinal Cord
Paraplegia (Quadriplegia)

- Loss of Function
  - Sensation
  - Voluntary Movement
- Vagus Nerve
  - Vital Functions
- Spinal Reflexes
  - Exaggerated
  - Unconscious
  - Involuntary
Brainstem and Subcortical Structures

- Forebrain (Diencephalon)
  - Thalamus
    - Sensory Relay Station
  - Hypothalamus
    - Biological Motives
  - Basal Ganglia
    - Coordinate Movement
  - Limbic System
    - Emotional Experience

- Midbrain (Mesencephalon)
  - Reticular Formation
    - Regulates Cortical Arousal

- Hindbrain (Metencephalon)
  - Cerebellum
    - Coordinates Sensation, Action
  - Medulla (Oblongata)
    - Vegetative Functions
  - Pons
    - Regulates Cortical Arousal
The Human Brain
Topography of Cerebral Cortex
(Telencephalon)

Lateral View

INTRODUCTION TO BRAIN STRUCTURE I.

FOREBRAIN,
LONGITUDINAL FISSURE,
CENTRAL SULCUS,
LATERAL FISSURE,
FRONTAL LOBE,
SPEECH AREA,
MOTOR AREA,
TEMPORAL LOBE.

PARietal LOBE,
PRIMARY SENSORY AREA,
OCCipital LOBE.

Hindbrain,
Pons,
Cerebellum,
Medulla oblongata.

Medial View

INTRODUCTION TO BRAIN STRUCTURE II.

CEREBRAL HEMISPHERE,
FRONTAL LOBE,
TEMPORAL LOBE,
PARietal LOBE,
OCCipital LOBE,
Limbic LOBE,
BASAL GANGLIA.

UPPER BRAIN STEM,
Thalamus,
Hypothalamus,
Pineal Gland.

MIDDLE BRAIN STEM,
Midbrain.

LOWER BRAIN STEM,
Pons,
Medulla,
Cerebellum,
Spinal Cord.
Cerebral Cortex as Neocortex

- “New” Phylogenetically
  - Evolution of Species
    - Emerged Relatively Recently in Evolutionary Time
- “New” Ontogenetically
  - Development of the Individual Organism
    - Emerges Relatively Late in Fetal Development
Phylogenetic Comparisons

Drawings on these two pages, which show a representative selection of vertebrate brains, all drawn to the same scale. In vertebrates lower than mammals the cerebrum is small. In carnivores, and particularly in primates, it increases dramatically in both size and complexity.

Scientific American
Ontogenetic Comparisons

DEVELOPING HUMAN BRAIN is viewed from the side in this sequence of drawings, which show a succession of embryonic and fetal stages. The drawings in the main sequence (bottom) are all reproduced at the same scale approximately four-fifths life-size. The first five embryonic stages are also shown enlarged to an arbitrary common size to clarify their structural details (top). The three main parts of the brain (the forebrain, the midbrain and the hindbrain) originate as prominent swellings at the head end of the early neural tube. In human beings the cerebral hemispheres eventually overgrow the midbrain and the hindbrain and also partly obscure the diencephalon. The characteristic convolutions and invaginations of the brain's surface do not begin to appear until about the middle of pregnancy. Assuming that the fully developed human brain contains on the order of 100 billion neurons and that virtually no new neurons are added after birth, it can be calculated that neurons must be generated in the developing brain at an average rate of more than 250,000 per minute.
Prefrontal Cortex: Phylogenetic Comparisons

**Figure 11.2** The areas of the frontal lobe. The prefrontal cortex includes all of the areas in front of the primary and secondary motor regions. The three major subdivisions of prefrontal cortex are the lateral prefrontal, ventromedial prefrontal, and the anterior cingulate cortex.

**Figure 11.3** The shaded areas show the extent of prefrontal cortex in six species. Note how small this region is in the cat, dog, and squirrel monkey. It is greatly enlarged in humans. The brains are not drawn to scale. Adapted from Fuster (1989).
Learn Your Brain with
*The Human Brain Coloring Book*
M.C. Diamond, A.B. Scheibel, & L.M. Elson (1985)

An excellent introduction to neuroanatomy, and basic principles of neuroscience, from which many illustrations in these lectures were taken.
Hindbrain, Midbrain, Forebrain

Lecture 3
Phrenology
An Early View of Functional Specialization

• In Vienna
  – F.J. Gall (1788-1828)
  – J.K. Spurzheim (1776-1832)

• In Scotland
  – G. Combe (1788-1858)

• In the United States
  – O.S. Fowler (1809-1887)
  – L.N. Fowler (1811-1896)
  – N. Sizer (1812-1897)
According to phrenologists of the period, analysis of the shape and lumps of the skull would reveal a person’s personality and intellect. Below, a contemporary map of localized characteristics.
Brain Lesions

• Brain Insult, Injury, or Disease
  – Broca’s Area
  – Patient H.M.

• Nonhuman Animals
  – Surgery
  – Electrical Current

• Temporary Lesions
  – Cooling
  – Spreading Depression
Electrical and Magnetic Stimulation

• Electrical Stimulation
  – Reticular Formation
    • Lesions (Nauta)
    • Stimulation (Moruzzi & Magoun)

• Transcranial Magnetic Stimulation
  – Striate Cortex of Occipital Lobe
Psychophysiology

- **Autonomic Nervous System**
  - Electrocardiogram (EKG)
  - Plethysmograph
  - Electrodermal Response (EDR)
    - Skin Conductance/Resistance
  - Electromyogram (EMG)

- **Central Nervous System**
  - Electroencephalogram (EEG)
  - Event-Related Potentials (ERP)
Brain Imaging

- X-Ray Computed Tomography (CT, CAT)
- Magnetic Resonance Imaging (MRI)
  - Radio Waves
- Positron Emission Tomography (PET)
  - Glucose
- Functional MRI (fMRI)
Identifying Natural Objects From Patterns of fMRI Activity
Kay, Naselaris, Prenger, & Gallant (2008)

Topographical Organization of Visual System
Accuracy of Identification
Kay et al. (2008)

- Chance = 1/120 = 0.8%
- 13 Repeated Trials
  - Subject 1: 92%
    - 1000 Images: 82%
      - Chance = 0.1%
    - Subject 2: 72%
- Single-Trial Performance
  - Subject 1: 51%
  - Subject 2: 32%
Reconstructing Natural Images
Naselaris, Prenger, Kay, Oliver, & Gallant (2009)
The Doctrine of Modularity
Fodor (1983)

- Domain-Specific
- Informational Encapsulation
- Hardwiring
- Innate Specification
- Automaticity
- Characteristic Development
- Characteristic Breakdown
- Fixed Neural Architecture
Functional Specialization
Outside the Brain

- Afferent and Efferent Neurons, Nerves
- Interneurons, Ganglia, Nuclei
- Autonomic Nervous System
  - Sympathetic and Parasympathetic Branches
- Somatic Nervous System
  - Afferent and Efferent Cranial Nerves
  - Afferent and Efferent Tracts in Spinal Nerves
  - Afferent and Efferent Tracts in Spinal Cord
Excitatory and Inhibitory Neurotransmitters

• Amines
  – Acetylcholine (Ach)

• Monoamines
  – Catecholamines
    • Epinephrine (Adrenaline)
    • Norepinephrine (NA)
    • Dopamine (DA)
  – Serotonin (5-HT)

• Amino Acids
  – Glutamate
  – GABA

• Peptides
  – Substance P
  – Beta-Endorphin
  – Corticotropin (ACTH)
  – Oxytocin
Neurotransmitters and Brain Disease

- Myasthenia Gravis (Ach)
- Parkinson’s disease (Dopamine, L-DOPA)
- Chorea (Dopamine; Haloperidol)
- Huntington’s Disease
- Gilles de la Tourette’s Syndrome
- Schizophrenia
  - Dopamine Hypothesis, Chlorpromazine
- Affective Disorder
  - Serotonin Hypothesis, SSRIs
Functional Specialization in the Brainstem

- Hindbrain
  - Medulla Oblongata (Myelencephalon)
  - Pons (Metencephalon)

- Midbrain (Mesencephalon)
  - Reticular Formation

- Cerebellum
Coma

- Loss of Consciousness
  - Eyes Closed
  - Unresponsive to Stimulation
  - No Sleep-Wake Cycle
  - Spared Vegetative Function

- Posterior Brain Stem
  - Reticular Formation
    - Periaqueductal Gray
    - Parabrachial Nucleus
  - Diencephalon (Bilateral)
    - Thalamus, Hypothalamus
Persistent Vegetative State
Jennett & Plum (1972)

- Follows Coma
  - Within 1 month
- Wakefulness Without Consciousness
  - Eyes Open
  - Apparently Vigilant
  - Some reflex functions
  - Normal Sleep Cycle
  - Unresponsive to Stimulation
  - Spared Vegetative Function
- “Minimally Conscious State”
“Locked-In” Syndrome

• Follows Coma
• Largely Immobile
• Limited Responsiveness
  – Vertical Eye Movements
  – Blinking
• Anterior Brain Stem
  – Pons
  – Excludes Reticular Formation
  – Above Trigeminal Nerve (V)
    • Oculomotor Nerve (III)
    • Trochlear Nerve (IV)
Subcortical Structures of the Forebrain

- Limbic System (Lobe)
  - Cingulate Gyrus
  - Parahippocampal Gyrus
  - Hippocampal Formation
    - Amygdala
    - Hippocampus
    - Fornix
    - Mammillary Bodies

- Basal Ganglia
  - Globus Pallidus
  - Caudate Nucleus
  - Putamen

- Diencephalon
  - Thalamus
  - Hypothalamus
Hypothalamus and Eating Behavior
Teitelbaum & Epstein (1962); Teitelbaum (1976)

- **Ventromedial Lesions**
  - Hyperphagia

- **Lateral Lesions**
  - Aphagia

- **Dual-Center Theory**
  - VMH Inhibits Eating
  - LH Disinhibits Eating
Patient H.M.
Bilateral Resection of Hippocampus
Scoville & Milner (1957); Milner, Corkin, & Teuber (1968)

Anterograde Amnesia
The Medial Temporal Lobe Memory System
Squire & Zola-Morgan (1991)
Patient S.
Bilateral Calcification of Amygdala
Adolphs, Tranel, Damasio, & Damasio (1994)
The Triune Brain
MacLean (1970, 1990)

- Neocortex
  - “New Brain”
- Limbic System
  - “Old Mammalian Brain”
    - Amygdala
    - Hypothalamus
    - Hippocampus
- R-Complex
  - “Reptilian Brain”
    - Brain Stem
    - Cerebellum
Cerebral Cortex

Lecture 4
Functional Specialization So Far

- Neurons and Nerves
  - Afferent, Efferent, Interneurons
- Peripheral Nervous System
  - Autonomic
    - Sympathetic, Parasympathetic
  - Somatic
    - Afferent, Efferent Pathways

- Brain
  - Hindbrain
    - Pons, Medulla, Cerebellum
  - Midbrain
    - Reticular Formation
  - Forebrain Subcortical Structures
    - Hypothalamus
    - Hippocampus
    - Amygdala
Topography of Cerebral Cortex

Telencephalon

Lateral View

INTRODUCTION TO BRAIN STRUCTURE I.

FOREBRAIN.
LONGITUDINAL FISSURE.
CENTRAL SULCUS.
LATERAL FISSURE.
FRONTAL LOBE.
SPEECH AREA.
MOTOR AREA.
TEMPORAL LOBE.

PARIETAL LOBE.
PRIMARY SENSORY AREA.
OCCIPITAL LOBE.

HINDBRAIN.
PONS.
CEREBELLUM.
MEDULLA OBLONGATA.

Medial View

INTRODUCTION TO BRAIN STRUCTURE II.

CEREBRAL HEMISPHERE.
FRONTAL LOBE.
TEMPORAL LOBE.
PARIETAL LOBE.
OCCIPITAL LOBE.
LIMBIC LOBE.
BASAL GANGLIA.

UPPER BRAIN STEM.
THALAMUS.
HYPOTHALAMUS.
PINEAL GLAND.

MIDDLE BRAIN STEM.
MIDBRAIN.

LOWER BRAIN STEM.
PONS.
MEDULLA.
CEREBELLUM.
SPINAL CORD.
Locating Yourself in the Brain
Folds in Cerebral Cortex

- **Gyrus (Gyri)**
  - Inferior Frontal
  - Superior Temporal

- **Sulcus (Sulci)**
  - Central Sulcus
  - Parieto-Occipital
  - Pre-Occipital Notch
Cytoarchitectonics of the Cerebral Cortex

Brodmann (1909)
Primary Motor and Somatosensory Areas

- Primary Motor Cortex
  - Precentral Gyrus
    - Brodmann Area 4
  - Premotor Cortex
    - Brodmann Area 6
    - Brodmann Area 8
- Postcentral Gyrus
  - Brodmann Areas 1-3
Consequences of Stroke
Insufficient Blood Supply to Brain

• Paralysis
  – voluntary motor function
• Anesthesia
  – tactile sensation
• Aphasia
  – speech, language
Sensory and Motor Homunculus
Penfield & Jasper (1954)

Parietal Lobe

Frontal Lobe

Longitudinal Fissure

Central Fissure

Lateral Fissure

SOMATIC SENSORY AND MOTOR REGIONS of the cerebral cortex are specialized in the sense that every site in these regions can be associated with some part of the body. In other words, most of the body can be mapped onto the cortex, yielding two distorted homunculi. The distortions come about because the area of the cortex dedicated to a part of the body is proportional not to that part's actual size but to the precision with which it must be controlled. In man the motor and somatic sensory regions given over to the face and to the hands are greatly exaggerated. Only half of each cortical region is shown: the left somatic sensory area (which receives sensations primarily from the right side of the body) and the right motor cortex (which exercises control over movement in the left half of the body).
Primary Auditory and Visual Areas

• Primary Auditory Cortex
  • Superior Temporal Gyrus
    • Heschl’s Gyrus (Al)
    • Brodmann Areas 41, 42
    • “Tonotopic” Organization

• Primary Visual Cortex
  • Striate Cortex (VI)
    • Brodmann Area 17
    • “Retinotopic” Organization

• Extrastriate Cortex
  • Brodmann’s Areas 18, 19
Specialization in Extra-Striate Cortex

HUMAN VISUAL PATHWAY begins with the eyes and extends through several interior brain structures before ascending to the various regions of the visual cortex (V1, and so on). As the optic chiasm, the optic nerves cross over partially so that each hemisphere of the brain receives input from both eyes. The information is filtered by the lateral geniculate nucleus, which consists of layers of nerve cells that each respond only to stimuli from one eye. The inferior temporal cortex is important for seeing forms. Researchers have found that some cells from each area are active only when a person or monkey becomes conscious of a given stimulus.
“Association Areas”

- **Posterior**
  - Perceptual Integration

- **Frontal**
  - Executive Functions
  - Problem-solving

- **“Prefrontal” Cortex**
  - Frontal Gyri
    - Superior, Middle, Inferior
  - Frontal Sulci
    - Superior, Inferior
Some Common Neurological Symptoms

- Amnesia (Memory)
- Aphasia (Speech)
- Alexia (Reading)
- Agraphia (Writing)
- Acalculia (Math)
- Apraxia (Action)
- Agnosia (Knowledge)
Major Syndromes of Aphasia

• Broca’s Aphasia: “Expressive”
  – Slow, Labored, Inarticulate Speech
    • Possible Problems with Writing, Reading Aloud
  – Speech Comprehensible
  – No Problems Understanding Speech, Reading

• Wernicke’s Aphasia: “Receptive”
  – Fluent (Phonetics, Grammar)
  – Paraphasias
  – Semantic Deviance
  – Problems Understanding Speech, Writing
Language Centers in the Brain

MAP OF THE HUMAN CORTEX shows regions whose functional specializations have been identified. Much of the cortex is given over to comparatively elementary functions: the generation of movement and the primary analysis of sensations. These areas, which include the motor and somatic sensory regions and the primary visual, auditory and olfactory areas, are present in all species that have a well-developed cortex and are called on in the course of many activities. Several other regions (dark color) are more narrowly specialized. Broca's area and Wernicke's area are involved in the production and comprehension of language. The angular gyrus is thought to mediate between visual and auditory forms of information. These functional specializations have been detected only on the left side of the brain; the corresponding areas of the right hemisphere do not have the same linguistic competence. The right hemisphere, which is not shown, has its own specialized abilities, including the analysis of some aspects of music and of complex visual patterns. The anatomical regions associated with these faculties, however, are not as well defined as the language areas. Even in the left hemisphere the assignment of functions to sites in the cortex is only approximate; some areas may have functions in addition to those indicated, and some functions may be carried out in more than one place.
Coordination of Language Functions

Petersen et al. (1988, 1989)
Electrocorticogram of Verb Generation
Edwards et al. (2007, 2010)
Face Recognition in the Fusiform Gyrus

- Prosopagnosia
  - Bodamer (1947)
  - Brodmann Area 37
    - Also Areas 18, 19
- fMRI in Face Recognition
- “Fusiform Face Area” (?)
Self-Regulation in the Anterior Cingulate Gyrus

• Part of Limbic Lobe
  – Anterior Cingulate Cortex
    • “ACC”

• Executive Functions
  – Controlled Processing

• Self-Regulation
  – Error Detection
  – Conflict Monitoring
The Parietal Cortex and Attention

- Hemispatial Neglect
  - Contralateral
- Temporoparietal Junction

Typical performance by a “neglect” patient on the line-bisection task

Fig. 10-5. Lateral view of the right hemisphere. Lesions (as determined by CT scan) of ten patients with the neglect syndrome are superimposed.
Imaging the Stage Model of Attention
Fan et al. (2005), after Posner & Peterson (1990)

- Alerting and Interruption
  - Fronto-Parietal
  - Thalamus
- Orienting and Localizing
  - Superior Parietal
- Executive Control
  - Anterior Cingulate Gyrus
  - Frontal
    - Disengage
    - Move (Shift)
    - (Re-) Engage
    - Inhibit
Old and New Views of Specialization

19TH-CENTURY HEAD EXAMINATION
According to phrenology of the period, analysis of the shape and lumps of the skull would reveal a person's personality and intellect. Below, a contemporary map of localized characteristics.

CURRENT MAPPING THROUGH FUNCTIONAL MAGNETIC RESONANCE IMAGING (FMRI)
Now scientists can capture the brain in action by measuring changes in cerebral blood flow. Critics say the technique isn't being used to answer more complicated questions about the brain's processes.

Just What's Going On Inside That Head of Yours?
Hemispheric Specialization, Recovery of Function, and Plasticity

Lecture 5
Two Cerebral Hemispheres
The Cerebral Commissures
Corpus Callosum; Anterior Commissure

CORONAL SECTION THROUGH
FRONTAL LOBES: LEVEL OF
THE ANTERIOR COMMISSURE.

MEDIAN SECTION.

GYRUS CINGULATE
SUP. FRONTAL
MID. FRONTAL
INF. FRONTAL
INSULAR
SULCUS/FISSURE
LONG. CEREB. F.
LATERAL F.
CINGULATE &
NUCLEUS
CAUDATE NUC.
PUTAMEN
GLOB. PALLIDUS
CLASTRUM
SEPTAL NUC.
AMYGDALOID NUC.
TRACT/NERVE
C. CALLOSUM: BODY
C. RADIATA
INT. CAPSULE: ANT. LIME
SUP. LONG. FASC.UNC.
FASC
EXT. CAPSULE
OPTIC CHIASM
ANT. COMMISSURE
VENTRICLE
LAT. VENTRICLE: BODY
LANDMARK
SEPTUM PELLUCIDUM

GYRUS CINGULATE
NUCLEUS
HYPOTHALAMUS
INFUNDIBULUM
HYPOTHALAMIC BODY
MED. NUC. THAL.
SUP. COLICULUS
INF. COLICULUS
MIDBRAIN TEMENUS
RETIC. FORM.
TRACT/NERVE
OPTIC TR.
STRIA MEDULLARIS
VENTRICLE
FOURTH VENTRICLE
INTERVENTRIC. FOR.
CEREB. AQUEDUCT
LANDMARK
PONS
PALL. GLAND
CEREBELLAR CORTEX
MEDULL. OBLONG.
SUP. MEDULLARY VELUM
Contralateral Projection

Atkinson & Hilgard

Yuja Wang

Wynton Marsalis

Dennis Brain
ANATOMICAL ASYMMETRY of the cortex has been detected in the human brain and may be related to the distinctive functional specializations of the two hemispheres. One asymmetry is readily observed in the intact brain: the sylvian fissure, which defines the upper margin of the temporal lobe, rises more steeply on the right side of the brain. A more striking asymmetry is found on the planum temporale, which forms the upper surface of the temporal lobe, and which can be seen only when the sylvian fissure is opened. The posterior part of the planum temporale is usually much larger on the left side. The enlarged region is part of Wernicke’s area, suggesting that the asymmetry may be related to the linguistic dominance of the left hemisphere. The distribution of the asymmetries varies with handedness.
Cerebral Commissurotomy: “Split-Brain” Patients
Sperry, Gazzaniga, & Bogen (1969)

- Intractable Epilepsy
- Sever Transcortical Connections
  – Corpus Callosum
Cerebral Commissurotomy: “Split-Brain” Patients
Sperry, Gazzaniga, & Bogen (1969)

- Intractable Epilepsy
- Sever Transcortical Connections
  – Corpus Callosum
Hemispheric Specialization
(Especially in Right-Handed Males)

• Left Hemisphere
  – Language
    • Broca’s, Wernicke’s Areas
  – Sequential Analyses
  – Mathematical Computation
  – Fine Motor Control

• Right Hemisphere
  – Simple “Left-Hemisphere” Functions
  – Spatial Analysis
  – Pattern Recognition
Origins of Lateralization

• Phylogeny (Across Species)
  – Nonprimates
  – Monkeys and Other Lesser Apes
  – Chimpanzees and Other Great Apes

• Ontogeny (Across Life Span)
  – Premature Infants
The Advantage of Lateralization

• Contralateral vs. Ipsilateral Projection
• Motor Control
  – Speech
  – Fine Motor Control
  – Gesture
• Why on the Left?
Beware the Adaptationist Fallacy!

Gould & Lewontin (1979)
Summary on Specialization

• Neurons and Nerves
  – Synapses and Neurotransmitters

• Somatic and Autonomic Nervous System
  – Sympathetic and Parasympathetic
  – Central and Peripheral

• Hindbrain, Midbrain, Forebrain

• Cerebral Cortex
  – Hemispheric Specialization
  – Doctrine of Modularity
Limitations on Modularity

• Holism
  – Integration, Coordination of Modules

• Equipotentiality
  – Plasticity Early in Development

• Recovery of Function
  – Redundancy (if not Optimality)

• Regeneration (?)

• Function vs. Content
  – Functions may be localized
  – Contents distributed widely across cortex
Localization of Content?

• Localist View of Knowledge Representation
  – Activity of Single Neurons
    • Or Small Clusters of Neurons
  – Centered on Specific Cortical Location

• Distributed View (Lashley; Hebb)
  – Reverberating Pattern of Neural Activity
  – Distributed Widely over Cerebral Cortex
Localization of Content

• Penfield (1954)
  – Electrical Stimulation
  – “Sensory” Memories?
  – “Grandmother Neurons”?

• Lashley (1950), “Search for the Engram”
  – Rats Learn Maze
  – Ablate Portions of Cerebral Cortex
Extent of Cortical Damage and Errors in Maze Learning
Lashley & Wiley (1933)
The Law of Mass Action
Lashley (1950)

• Degree of memory impairment is correlated with the extent of cortical damage
  – Exact site of cortical damage does not matter

• Specific items of knowledge are distributed widely within cerebral cortex
  – Involve large ensembles of neurons

• Knowledge preserved so long as critical mass of neural substrate is preserved
Recovery of Function

• In Aphagia
  – Lesions in Lateral Hypothalamus

• In Aphasia
  – Lesions in Broca’s and Wernicke’s Areas

• In Paraplegia
  – Severing of Spinal Cord
Mechanisms of Recovery of Function

- Incomplete Damage
- Redundancy in Neural Organization
- Neurogenesis
- Plasticity
Neurogenesis
Rakic (1985); Nottebohm (1989); E. Gould (1999); Rakic (2001)

• Pasko Rakic’s Dictum: No Neurogenesis
  – Organism Born with All Its Neurons
  – Neural Loss is Permanent
  – Peripheral vs. Central

• Songbirds (Nottebohm)

• Mammalian Hippocampus (Gould)

• Mammalian Neocortex
  – Enriched Environment
  – Learning
Evidence of Plasticity
Merzenich et al. (1988); Kass (1995)

• Somatotopic Cortical Mapping
• Mapping Changes with Experience
  – Sever the Nerves to a Digit
  – Amputate Digit
  – Sew Adjacent Digits Together
  – Exercise
"The Knowledge" and Plasticity in the Hippocampus
Maguire et al. (2000)
The Biological Bases of Mind and Behavior

• Nervous System
  – Brain
  – Autonomic Nervous System

• Endocrine and Immune Systems
  – Psychoneuroendocrinology
  – Psychoneuroimmunology

• Ethology and Evolutionary Psychology

• (Behavior) Genetics