Language & the Brain
“Reflecting on Noam Chomsky’s ideas on the innateness of the fundamentals of grammar in the human mind, I saw that any innate features of the language capacity must be a set of biological structures, selected in the course of the evolution of the human brain.”

S. E. LURIA, A Slot Machine, a Broken Test Tube, an Autobiography, 1984
The nervous systems of all animals have a number of basic functions in common, most notably the control of movement and the analysis of sensation. What distinguishes the human brain is the variety of more specialized activities it is capable of learning. The preeminent example is language.
Linguistics shares with other sciences a concern to be objective, systematic, consistent, and explicit in its account of language. Like other sciences, it aims to collect data, test hypotheses, devise models, and construct theories. Its subject matter, however, is unique: at one extreme it overlaps with such “hard” sciences as physics and anatomy; at the other, it involves such traditional “arts” subjects as philosophy and literary criticism. The field of linguistics includes both science and the humanities, and offers a breadth of coverage that, for many aspiring students of the subject, is the primary source of its appeal.

“The functional asymmetry of the human brain is unequivocal, and so is its anatomical asymmetry. The structural differences between the left and the right hemispheres are visible not only under the microscope but to the naked eye. The most striking asymmetries occur in language-related cortices. It is tempting to assume that such anatomical differences are an index of the neurobiological underpinnings of language.”

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“[The brain is] the messenger of the understanding [and the organ whereby] in an especial manner we acquire wisdom and knowledge.”

from the Hippocratic Treatises on the Sacred Disease, written c. 377 B.C.E.
Linguistic Nativism vs Empiricism
• Innate content?
• Independence of experience?
• Our brains hardwired for language?
• Psycholinguistics and Neurolinguistics
• Little input and the final state!
Neurolinguistics

The study of the biological and neural foundations of language is called neurolinguistics. Neurolinguistic research is often based on data from atypical or impaired language and uses such data to understand properties of human language in general.
• 3 lbs

• 2% of the total body weight

• Consumes 25% of the body’s oxygen supply

• Consumes 70% of the body’s glucose supply

• 100 Billion Neurons

• 1 quadrillion connections

• 100% of brain is used
Grey matter, which has a pinkish-grey color in the living brain, contains the cell bodies, dendrites and axon terminals of neurons, so it is where all synapses are.

White matter is made of axons connecting different parts of grey matter to each other.
Contralateral function of the brain
• **The left hemisphere** receives most inputs from and controls mostly the right side of the body. This hemisphere in humans is also specialized for **language, rule-based reasoning, and analytic skills.**

• **The right hemisphere** deals with the left side of the body, and it is better at **visual pattern recognition and more holistic kinds of perception.**

• In most tasks, the two hemispheres use a divide-and-conquer strategy, where the left hemisphere processes the details, and the right takes in the big picture. The two hemispheres are connected by the largest fiber tract in the brain, **the corpus callosum**, which contains 200 million fibers.
Let's Discover the BRAIN!
The Brain’s Four Lobes: an overview

- **Occipital Lobe**
  - processes visual input
- **Parietal Lobe**
  - processes sensory information
- **Frontal Lobe**
  - executing behavior
- **Temporal Lobe**
  - combines auditory and visual information
- **Cerebellum**
  - processes sensory information
Frontal Lobe
- Movement
- Thinking initiation
- Reasoning (judgement)
- Behavior (emotions)
- Memory
- Speaking

Parietal Lobe
- Knowing right from left
- Sensation
- Reading
- Understanding spacial relationships

Temporal Lobe
- Understanding language
- Behavior
- Memory
- Hearing

Occipital Lobe
- Vision
- Color blindness

Cerebellum
- Balance
- Coordination
- Fine muscle control

Brain Stem
- Breathing
- Blood pressure
- Heartbeat
- Swallowing

- Alertness/sleep
- Body temperature
- Digestion
• Within the **brainstem** is a compact unit of neurons called the *reticular formation*.
• The brain stem *acts as an integrator of incoming auditory, visual, tactile, and other sensory inputs and as a filter to inhibit or facilitate sensory transmission*.
• The *thalamus*, atop your brainstem, near the center of the brain, *relays incoming sensory information (with the exception of smell) to the appropriate portion of the brain for analysis and prepares the brain to receive input*.
• To the rear of the brainstem is the *cerebellum*, which controls equilibrium
The Thalamus and Limbic System
- **The Thalamus:** It functions like a command center that controls what information goes between different parts of the neocortex and the rest of the brain.

- While the neocortex can do very fine-grained analysis of the patterns you’re looking at, the thalamus controls where you look. When your neocortex is damaged, you lose particular skills. If your thalamus is damaged sufficiently, you lose consciousness.
- **The hypothalamus:** controls homeostatic body functions such as temperature and circadian rhythms.
1. **The hippocampus:** The hippocampus has a crucial function in the creation of **memory**. The hippocampus receives inputs from virtually the entire neocortex.
2. **The amygdala:** The amygdala is primarily involved with **emotional processing**. The amygdala interacts with the prefrontal cortex to generate and process the major emotions of anger, happiness, disgust, surprise, sadness, and, particularly, fear. People who have sustained damage to their amygdalas have reduced abilities to react to and avoid situations that induce fear.
3. **Orbitofrontal cortex:** The orbitofrontal cortex is where the amygdala and other structures of the limbic system interact with the part of the prefrontal cortex. Suppose that, on some particular Friday evening while driving home, you’re almost hit by another car at a particular intersection. It is very likely that, for a long time after that, when approaching that intersection, particularly on Fridays, you’ll get a little twinge of fear or uneasiness. Your orbitofrontal cortex has stored the circumstances, and the amygdala has stored the fear.
4. **The anterior cingulate cortex**: The anterior cingulate cortex seems to monitor the progress toward whatever goal you're pursuing and generates an "uh-oh" signal when things aren't working out to indicate a change in strategy may be in order.
5. **The basal ganglia:**
The basal ganglia consist of five major nuclei: 1) the caudate, 2) putamen, 3) globus pallidus, 4) substantia nigra, and 5) subthalamic nucleus. These nuclei comprise a highly interconnected system that interacts with the thalamus and neocortex to control behavior.
Central Nervous System (CNS)
Central Nervous System (CNS)

- Contains: **Brain, spinal cord, and all associated nerves and sense organs.**

- **Nerves that conduct messages toward the brain** are called **afferent nerves**

- **Those that conduct information away** are called **efferent nerves.**
Any neural tissue that exists outside the CNS is part of the **peripheral nervous system** (PNS), which conducts impulses either toward or away from the CNS.

Your **nervous system** is responsible for monitoring your body’s state by conducting messages from the senses and organs and responding to this information by conducting messages to the organs and muscles. These messages are transmitted through nerves.
Central Nervous System (CNS)

- The **neuron** or **nerve cell** is the basic unit of your nervous system. A nerve is a collection of neurons.

- **100 billion neurons in your nervous system!**
Neurons

Neurons

Glia
1891 – Hienrich Waldeyer – coined the word “Neuron”
Each neuron consists of three parts: 1) a **cell body**, 2) a single long **axon** that **transmits impulses away from the cell body**, and 3) several branchy **dendrites** that **receive impulses from other cells and transmit them to the cell body**.

Axons vary greatly in length from 1 millimeter to 1 meter, a ratio of 1:1000. Neurons **do not actually touch each other** but are close enough to enable **chemical-electrical impulses to “jump” the minuscule space, or synapse, between the axon of one neuron and the dendrites of the next.**
A whole vs. Individual

Are they connected?

Camilio Golgi

Ramon y Cajal
Frontiers 1: Connectomics - modern brain anatomy

Electron microscope (EM) reconstruction of a whole piece of brain (nanometers resolution). All neurons (and other cell types) and all connections (synapses)

Courtesy of Mitya Chklovskii (Janelia Farm)
Based on hippocampus data from Kristen Harris (U. Texas, Austin)
Connectomics – complete 3D reconstruction - a small volume of mammalian cortex

Courtesy of Sebastian Seung (MIT)
Brainbow technology: Adding a DNA, and making the jungle in Florissant colors!
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• **Brain Machine Interface:**

Action potentials from single neurons signal the information processing activity of the brain.

Each "pop" and waveshape corresponds to the firing of a single neuron (shown next).
Brain-activated robot arm

Courtesy of Miguel Nicolelis (Duke University)
Language Disorders
Language Disorders

1. Aphasia

Aphasia is a disorder of language and speech that is caused by a brain lesion which may be due to an accident or a stroke, after language has been acquired in the normal way.

2. Specific Language Impairment (SLI)

SLI is a term covering disorders in the normal acquisition of language without there being any clear primary deficit. Despite their linguistic problems, SLI children and adults have normal non-verbal IQs, no hearing deficits and no obvious emotional or behavioral disturbances; unlike aphasics, SLI subjects have never acquired language in the normal way.