- Psycholinguistics
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- First Semester
- Lecture 2

The Biological Bases of Human Communicative Behavior

- **Introduction:**
- In this lecture we explore the anatomical and physiological bases of speech and language behavior. In following lectures we will ask the question of *how* people understand and produce spoken and written language. Today we ask the following questions:

Where such abilities lie within the brain? Can given communicative abilities be attributed to particular areas of the cerebral cortex? How does one determine where in the brain a particular function is encoded? Are particular speech and language abilities represented in a single discrete area, or multiple areas? What happens to communicative ability in the presence of brain damage? These questions will be addressed while surveying historical and current **neurolinguistics** (neurology of language).

- **psycholinguistics** typically attempt to provide explanations of behaviors in terms of information –processing descriptions.
- **neurolinguistics** seeks explanations for the same behaviors in terms of neurological processes.

- **Topics covered in this lecture:**

1. How early researchers first discovered and investigated the relation between brain and language?
2. The anatomy and physiology of the brain and some speech and language consequences of brain damage, which will allow us to see the roles that particular parts of the brain play in language production and understanding.
3. The relative contributions made by each of the two cerebral hemispheres to speech and language function, a concept termed **lateralization of function.**
4. Recently developed experimental techniques to more precisely localize particular speech and language functions to specific areas within each hemisphere using subject responses during actual language tasks.
5. The efforts of linguists, neurologists, and psychologists to integrate findings from both normal and language-impaired individuals to construct a rational model of the neurological bases of speech and language function.

Early Neurolinguistic Observations

1. Edwin Smith (1862) was the first to mention the consequences of brain injury and the first to mention **aphasia** (loss of language abilities due to brain damage). To this day, **trauma** (injury to the brain produced by external force) continues to provide us with insights into brain function.

2. The ancient Greeks offered little insight about brain function. They developed the Ventricle or Cell theory of the brain function, which localized brain activity to its cavities, the ventricles, where cerebral spinal fluid (CSF) production takes place. Leonardo da Vinci (1452-1519) disproved the theory.

3. Hippocratic scholars (460-370 B.C.) noted that speech disturbances commonly accompanied left-side brain injury.

4. By the eighteenth century almost all known language and speech disorders had already been described.

5. In the sixteenth century Johann Von Grafenberg (1530-1598) distinguished between aphasia and dysarthria (the neuromotor speech disorder in which the ability to articulate speech sounds is impaired).

Since then several kinds of language disabilities have been described:

- Pure alexia or alexia without agraphia (can write but can't read).
- Bilingual aphasia (affecting the use of two languages).
- Jargon aphasia and jargon agraphia (speech and writing contain meaningless nonsense words).

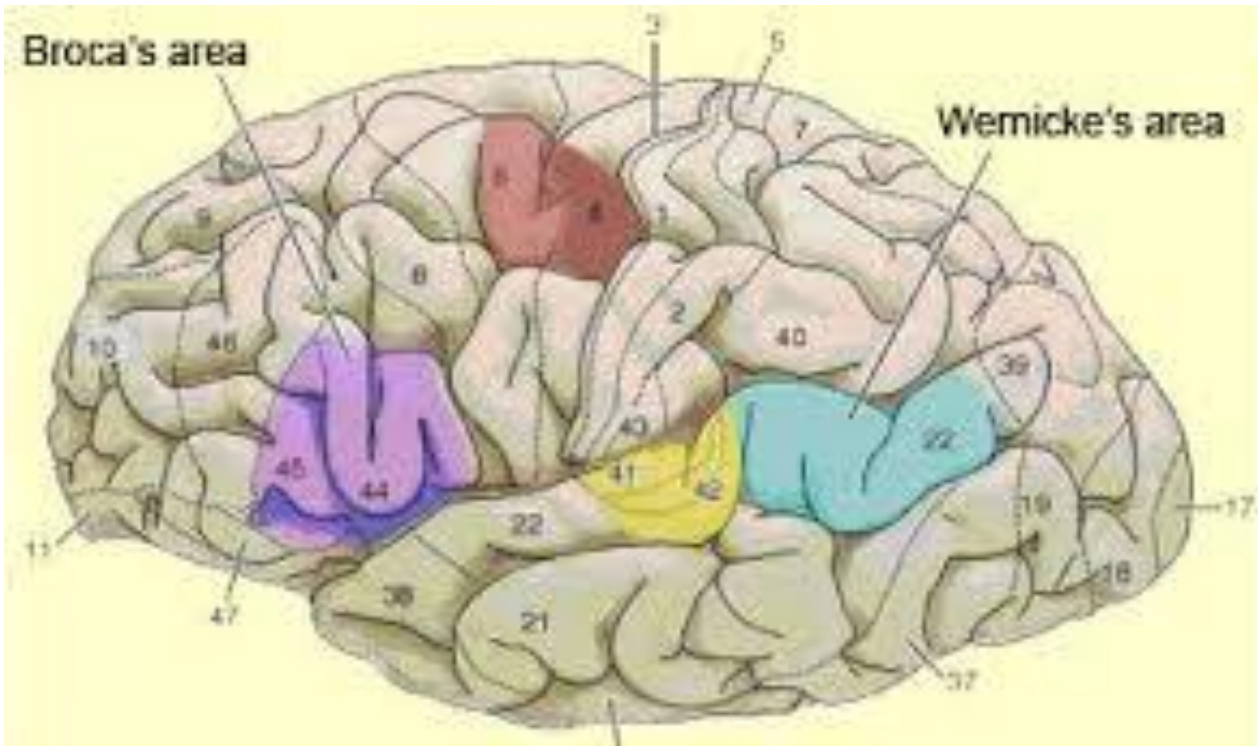
The ability to recite overlearned materials such as prayers in the presence of severe aphasia.

6. In 1819 the view that language might be localized in the frontal lobes was advanced by Franz Josef Gall (1758-1828) who was the first to distinguish between white and gray matter in the brain (hypertrophy-excessive growth), which may be correct in its basic outline, but the type of mental faculties that Gall chose to localize is incorrect.

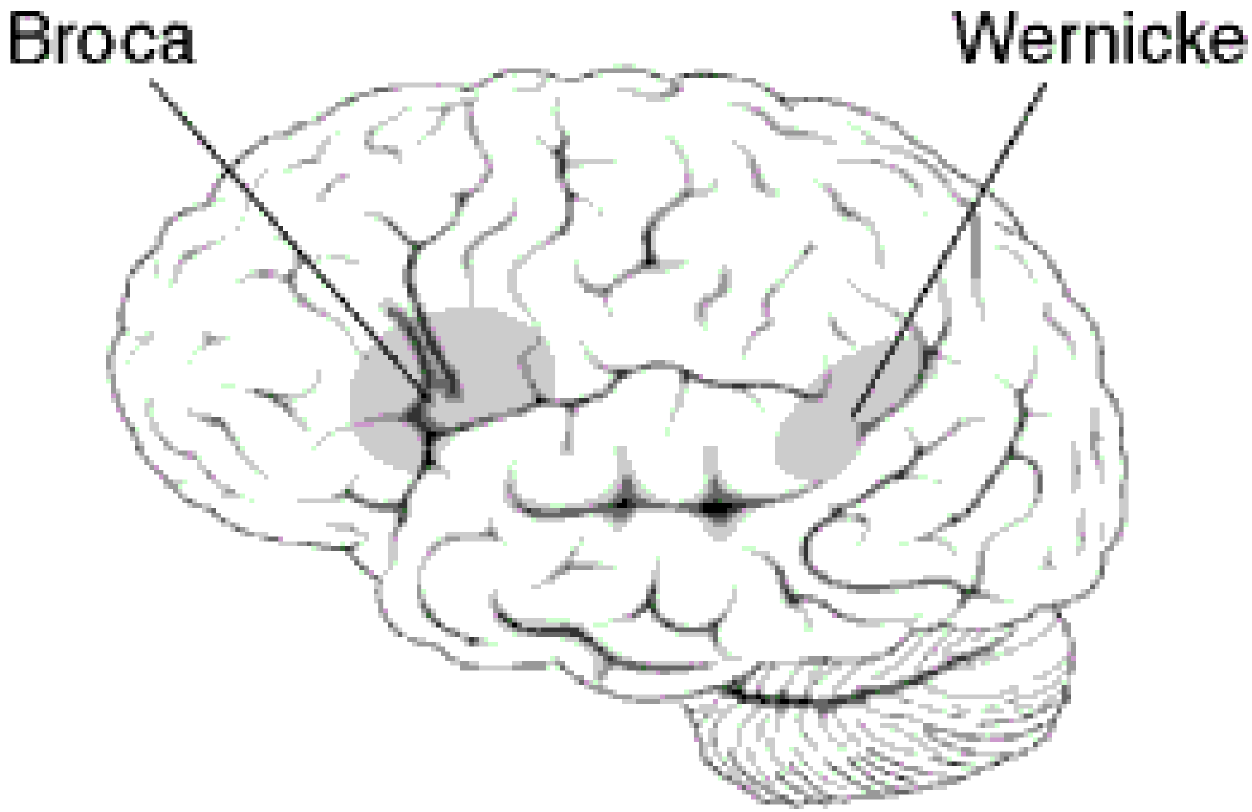
- **Lobes of the brain:** Frontal- temporal- occipital- parital.

Localization of function
Neurology in the nineteenth and twentieth centuries

- 1. The French surgeon Pierre Paul Broca (1824-1880) is the founder of physical anthropology. He was interested in brain size and its relationship to age, sex, intelligence, race, and environment. After studying 20 cases that had the same language deficit, he found that in 19 of these cases there was a lesion in the posterior part of the left third frontal convolution. The case is called now **Broca's aphasia** in which the speech of the patient is nonfluent and agrammatic.
- Broca came to the conclusion that we speak with the left hemisphere. He made it clear that we are usually left-lateralized for articulate language but not for the motor act of articulation, which he correctly stated depended to an equal degree on both hemispheres.


Broca's area
Wernicke's area

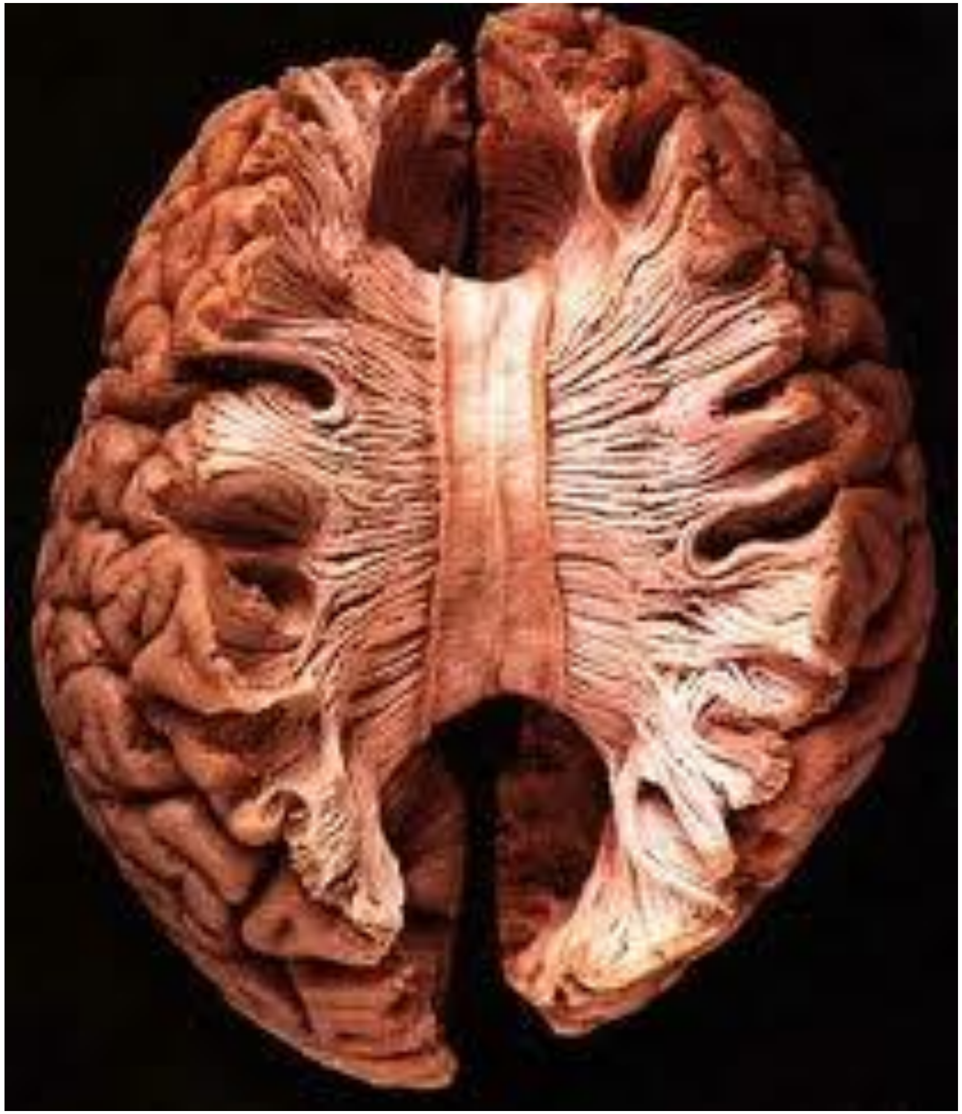
- Further, Broca (1875) demonstrated that the two hemispheres of the brain are not identical by analyzing 37 brains.
- Figure 2.10 shows what has become known as Broca's area on the lateral surface of the cerebral cortex.
- In the following years there were examples of the flexibility of the young brain in responding to brain damage to the extent that Lenneberg (1967) argued that there was a critical period for language acquisition.
- 2. Carl Wernicke (1848-1904) is a German neurologist who showed another area of the brain implicated in language and speech processing and became named after him. He traced the auditory nerve-a complex cranial nerve which reaches from the ear to the cortex. The highest area of hearing is known as Heschl's gyrus and is buried deep within the Sylvian fissure. The area of interest to Wernicke is parallel with this cortical area for hearing. Damage to this area resulted in a complex of symptoms quite unlike those which Broca had observed. This patient's speech has grammatical structure but doesn't make much sense.


Broca
Wernicke

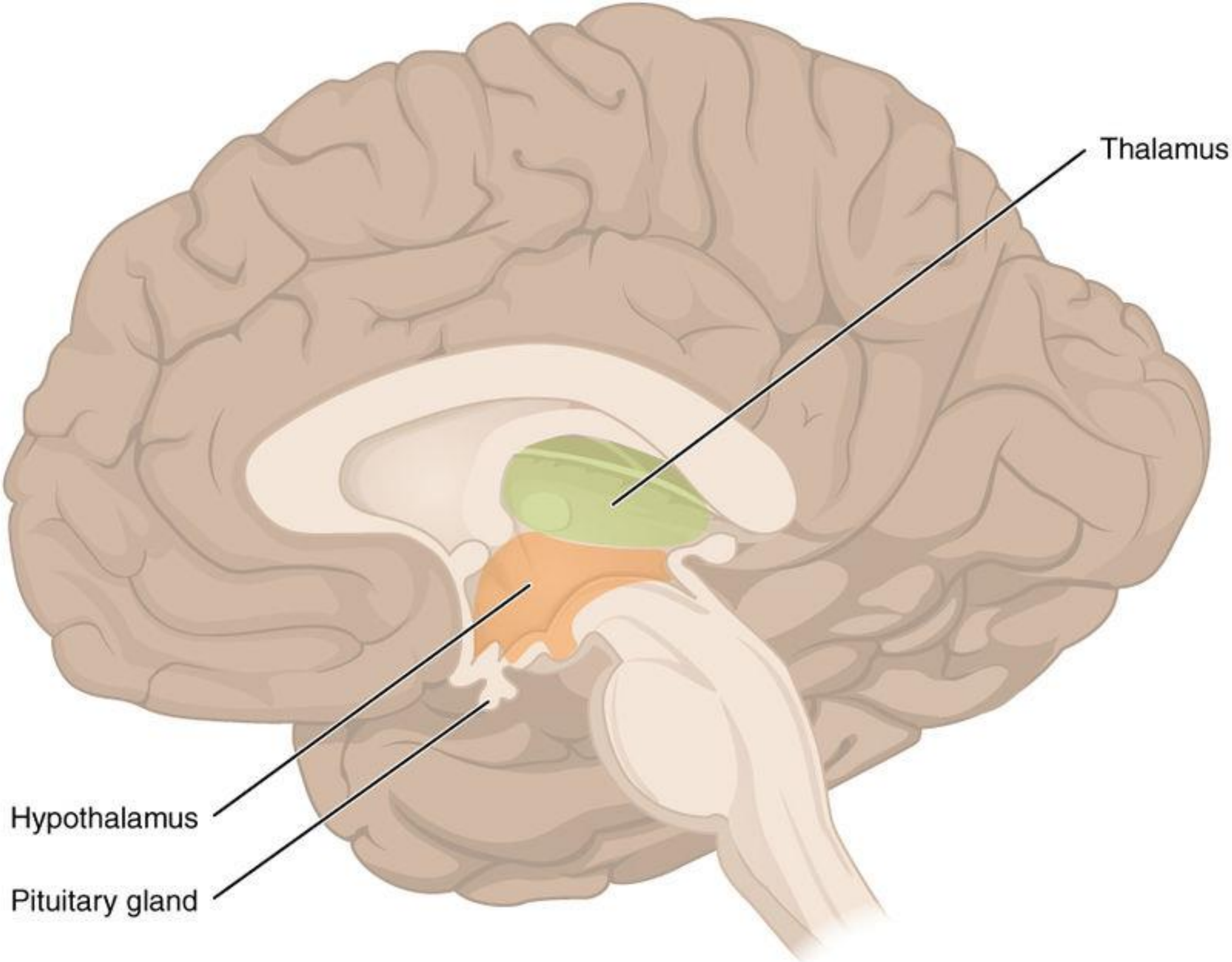
- Whereas Broca's aphasics are aware of their language problems, Wernicke's aphasics often are not and may even deny that they are ill.
- Both Broca's and Wernicke's aphasics have comprehension problems, but they are more severe in Wernicke's aphasia.
- The Broca's aphasic is nonfluent and uses language that seems sparse and agrammatic (missing important grammatical morphemes) although comprehension appears reasonable. The Wernicke's aphasic appears fluent and uses long complicated utterances that unfortunately make little sense. Their speech is full of neologisms (nonsense words). They appear quite disordered in their ability to understand both the speech of others and their own output.

Neuroanatomical structures involved in speech and language

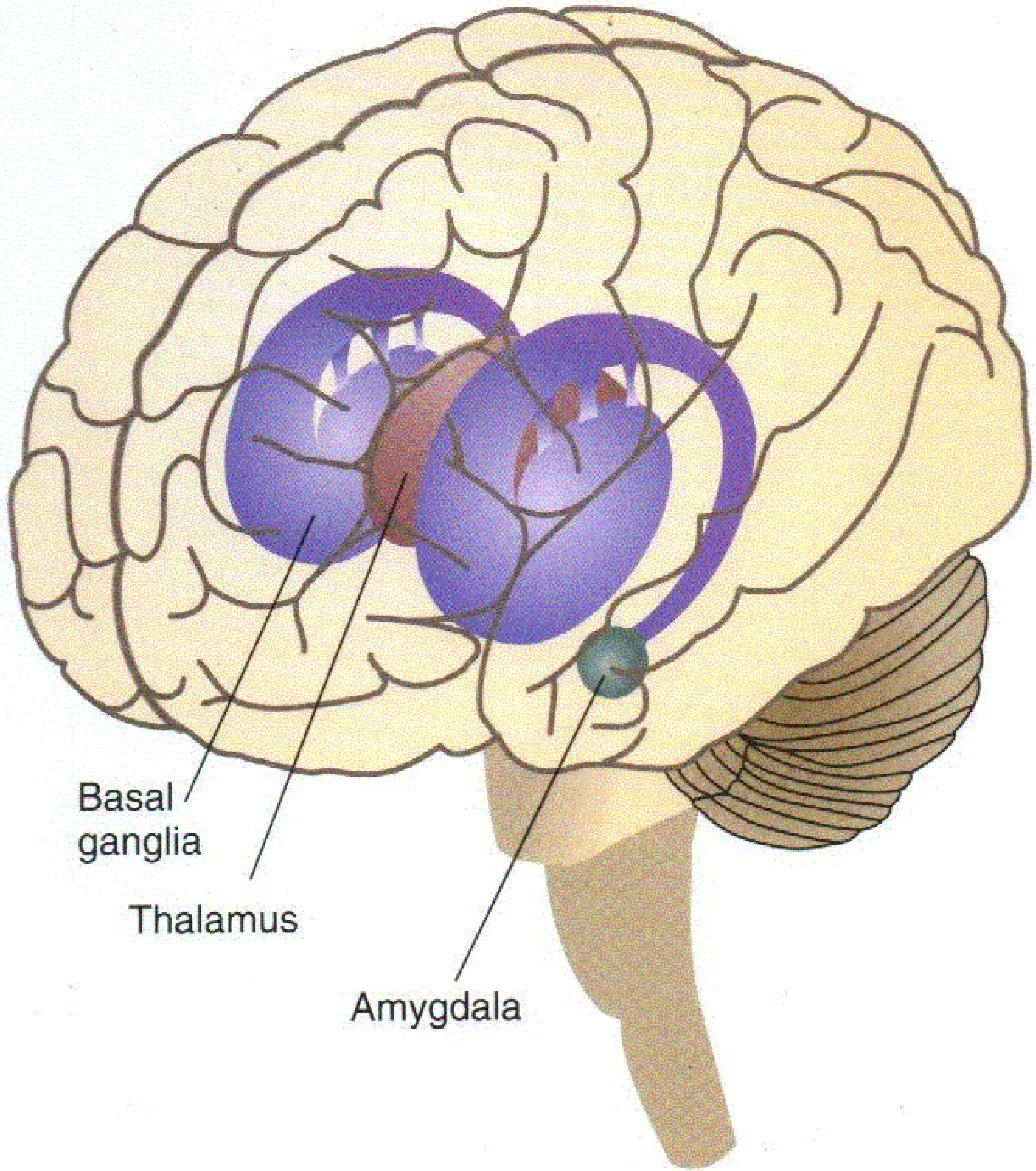
- Figure 2.4, page 61, depicts the central nervous system, which is housed within the bony structures of the skull (cranium) and vertebral column that protects it. It is also wrapped in three layers of membranes (**meninges)**, and floats in **cerebral spinal fluid** produced in the four ventricles (cavities) of the brain. The brain utilizes one-fifth of the body's blood supply.
- The general appearance of the cerebral cortex ("cortex" is Latin for "bark" as in bark of a tree) is characterized by (gyri) and (sulci or fissures). The reason for this bark like appearance of the cortex, which is roughly 2.5 square feet in area, is dictated by folding a sheet of this size into the confines of the cranium.
- The cortex, like almost every structure in the brain (and in the body), is paired-it has left and right part. These are the cerebral hemispheres connected by fiber tracts (commissures), the most massive is the corpus callosum.



- The two hemispheres are not identical. Language, in the vast majority of individuals, is lateralized to the left hemisphere while articulation is subserved by both hemispheres.
- The brain resembles a layer cake with alternating layers of gray and white matters. At the very center of the brain is a mass of neurons, the **diencephalon,** which may be regarded as the first layer of gray matter. It serves as a way station for all incoming sensations–with the exception of smell, before they travel on to the cortex.
- The **dorsal thalamus,** one of the components of the diencephalon, is lateralized like the overlying cortex. Damage to the left side can produce both aphasia and the articulation disorder dysarthria.
- The next layer of gray matter is the **basal ganglia**. This complex structure plays a major role in the control of movement and it is involved in cognitive functioning.


Thalamus
Hypothalamus
Pituitary gland

The Location of the Basal Ganglia in the Human Brain



- Damage to the basal ganglia can result in poverty of movement (**hypokinesia /--ainisia/**), as in Parkinson's disease, or too much movement (**hyperkinesia**), as in Huntington's chorea (dance), as well as tremor at rest.
- It is also known now that damage here can result in dysarthria and aphasia.
- Bellow the cerebral hemispheres lies the cerebellum. This structure is known to play a major role in motor control(balance) in conjunction with the basal ganglia, diencephalon, and the cortex itself. Damage to the cerebellum results in a breakdown in movement coordination as well as tremor in voluntary movements. Dysarthria can result from damage to the cerebellum. No language deficits have been reported from damage to this area.
- The remainder of the central nervous system consists of the **spinal cord** housed within the vertebral column. It directly controls motor and sensory functions of the entire body except the face area. All functions of the body are controlled from the brain via the spinal cord.

- The **peripheral nervous system** encompasses these components of the nervous system that lie outside of the bony coverings of the central nervous system. This includes the **cranial nerves (12 pairs)** that issue directly from the cranium. They are important in controlling such functions as vision, smell, hearing and facial sensation. Specific cranial nerves play crucial roles in **phonation** (laryngeal or voice activity) and tongue movement necessary for articulation.

Examining the consequences of cortical damage

- 1. Broca's aphasia: results from a lesion of the third frontal convolution, which lies directly in front of the face area of the motor strip. A lesion to the motor strip itself can produce the neuromotor disorder of speech called **dysarthria (**laborious and inaccurate articulation, yet intact ability to formulate language**).**
- 2. Wernicke's aphasia: The area that produced this aphasia is located in the posterior third of the first temporal gyrus.
- 3. Anomia: Slightly behind Wernicke's area lies the **angular gyrus,** which plays a large role in the process of lexical access, or word retrieval. Damage to this area makes the patient experiences difficulty in naming items, even though he can comprehend vocabulary well.
- 4. Subcortical sensory aphasia: results from the disconnection between Wernicke's area and Heschl's gyrus. The patient is able to hear but would not be able to understand what was said because signals are prevented from arriving at Wernicke's area by the lesion. Such patient can speak, write and read normally.

- 5. Subcortical motor aphasia: results from a disconnection between Broca's area and the face area of the motor strip. Patients preserve comprehension of what is said to them, as Wernicke's area is intact; however, they are incapable of volitional speech or repetition, because Broca's area can not control the motor output to the vocal tract.
- 6. Conduction aphasia: results from a disconnction between Wernicke's area and Broca's area. The output of such patients is well formed and they understand most of what they hear because the speech production and comprehension areas are intact. However, because messages cannot travel between auditory and speech production areas, they are unable to repeat what they hear, though they understand the message.
- 7. Global aphasia: results from damage to the vast majority of the region below the dashed line in figure 2.10, page 71. It contains most of the cortex exclusively devoted to language. This aphasia provides insight into the separability of thought and language processes, e.g. Brother John, a Catholic monk.

- 8. Dementia or agnosia: results from damage or lesion above the dashed line. The patient has the ability to produce language but lacks the process of thought and ideation. What is lacking is conceptual rather than linguistic, e.g. the patient HCEM, who can repeat with her own American accent. She was echolalic. She repeats applying the rules of her dialect of English. Although she has not lost the complex rule system of her native language, appears to be unable to use this linguistic "competence" to communicate. This case is termed **mixed transcortical aphasia.** It involves a combination of both transcortical motor aphasia and transcortical sensory aphasia. What distinguishes it from other types of aphasia is the preservation of the ability to repeat.

Lateralization of function

- Broca introduced the idea that the two cerebral hemispheres, despite their apparent symmetry, might differ in function. Broca provided evidence for an anatomical asymmetry.
- Researchers have more closely examined the specific functions of the two hemispheres and found that some communicative functions do appear to reside in the nondominant (usually right) hemisphere. The difference between the two hemispheres is then not dichotomous but ranges a long a continuum.
- Next we survey some of the experimental findings that lead to these conclusions.

What functions reside in the nondominant hemisphere?

- Metabolic neuroimaging techniques strongly support the view that both hemispheres are active during linguistic processing. Thus, laterality appears to be continuous rather than dichotomous.
- Although aphasia is extremely rare from right-hemisphere lesions in right-handed individuals, such lesions do affect communication. Many of these problems relate to less "structural" aspects of linguistic functioning. Patients do not have problems with phonology, lexicon, or syntax but often seem to:
  - confuse the order of events in a story,
  - are unable to formulate a moral for a story,
  - and are impaired in their ability to draw inferences from a story

- They also experience problems with ambiguous, metaphorical, and figurative terms, and tend to interpret them narrowly and literally, e.g. a "broken heart" may be understood as a cardiac condition.
- They experience difficulty in using and interpreting prosodic cues in conversation (stress and intonation), which, for example, might lead the patient to misinterpret sarcasm.

Many of the variables mentioned so far may aid us in understanding "brainedness". One variable currently of some interest is gender.

Do men and women differ in their lateralization patterns?

Aphasia is more common after left-hemisphere damage in males than it is in females, suggesting that language functions may be more diffusely organized in women. The corpus callosum is larger in females. In general, recovery from aphasia is better for women than for men. These and other observations about brain and language functioning in men and women continue to spur further research into gender differences. See page 91.

Measuring electrical activity in the brain

- **Electroencephalogram (EEG)** is a method of monitoring electrical activity of the brain from electrodes placed on the scalp. It demonstrates differences between the hemispheres on language-related tasks.
- More recently, researchers monitor the electrical activity of the brain in specific, time-referenced response to a stimulus. **Event-related potentials (ERPs)** cast some light on the brain's behavior during language comprehension tasks. Using data on both the timing (latency) and strength (amplitude) of ERPs, researchers have found physical evidence that the brain responds differently to tasks involving syntactic and semantic processing, e.g. ERPs differ when subjects are asked to read sentences that are syntactically or semantically ill-formed.

Measuring blood flow in the brain

- The blood flow of the brain is controlled by the mtabolic activity of neuronal tissue. Several techniques are currently available for measuring regional cerebral blood flow to study functional changes within discrete areas of the brain during various behaviors.
- **Some findings of this method of study**:
- Listening to simple words produces involvement of the auditory cortex in both hemispheres.
- Speaking aloud adds three more areas: the face area of the sensorimotor strips, the supplementary motor areas, and Broca's area in both hemispheres.
- Reading aloud adds the visual association cortex, as well as the frontal eye fields bilaterally.

- In another task subjects were to either look at nouns, hear nouns, repeat nouns, supply a matching verb to each noun they hear. (for the results see page 87, paragraph 3).
- In a third task subjects were asked to provide the past tense of a set of regular verbs, a set of irregular verbs, and nonsense verbs. (for the results see page 88, paragraph 3)
- Some other interesting findings emerge from such studies. One is the effect of practice on brain activity. The rehearsal or practice of a linguistic task reduces brain activity while often increasing efficiency or accuracy of response. **This may be counter-intuitive**. We tend to think of "brain power" when imagining a person who is quick or knowledgeable. In fact, **increased efficiency corresponds with less brain activity**, perhaps because the brain develops patterns or habits that allow more automatic performance.

Linguistic Aphasiology

- A blend of **cognitive psychology** and **neuropsychology** is a new subdiscipline termed **cognitive neuropsychology.** The study of language within this approach is termed **linguistic aphasiology.**
- Linguistic aphasiologists critique the terminology of traditional aphasic syndromes on several grounds. See page 93.