



بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

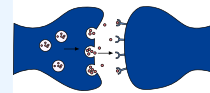


Cerebral Cortex Intellectual Functions (Pt.1)

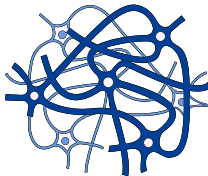
MID | Lecture 7

﴿إِنِّي تَوَكَّلْتُ عَلَى اللَّهِ رَبِّي وَرَبِّكُمْ مَا مِنْ دَابَّةٍ إِلَّا هُوَ آخِذٌ بِنَاصِيَتِهَا إِنَّ رَبِّي عَلَى صِرَاطٍ مُسْتَقِيمٍ﴾

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Cerebral Cortex; Intellectual Functions of the Brain; Learning and Memory

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I included some notes from the first two anatomy lectures on the cerebral cortex as revision, but keep in mind, unlike anatomy, Brodmann numbering isn't important here.

Objectives

- Describe intellectual functions of the cerebral cortical areas
- Explain memory and learning
- Outline the dominant and non-dominant hemispheres
- Delineate language areas of speech

Physiologic Anatomy of Cerebral Cortex

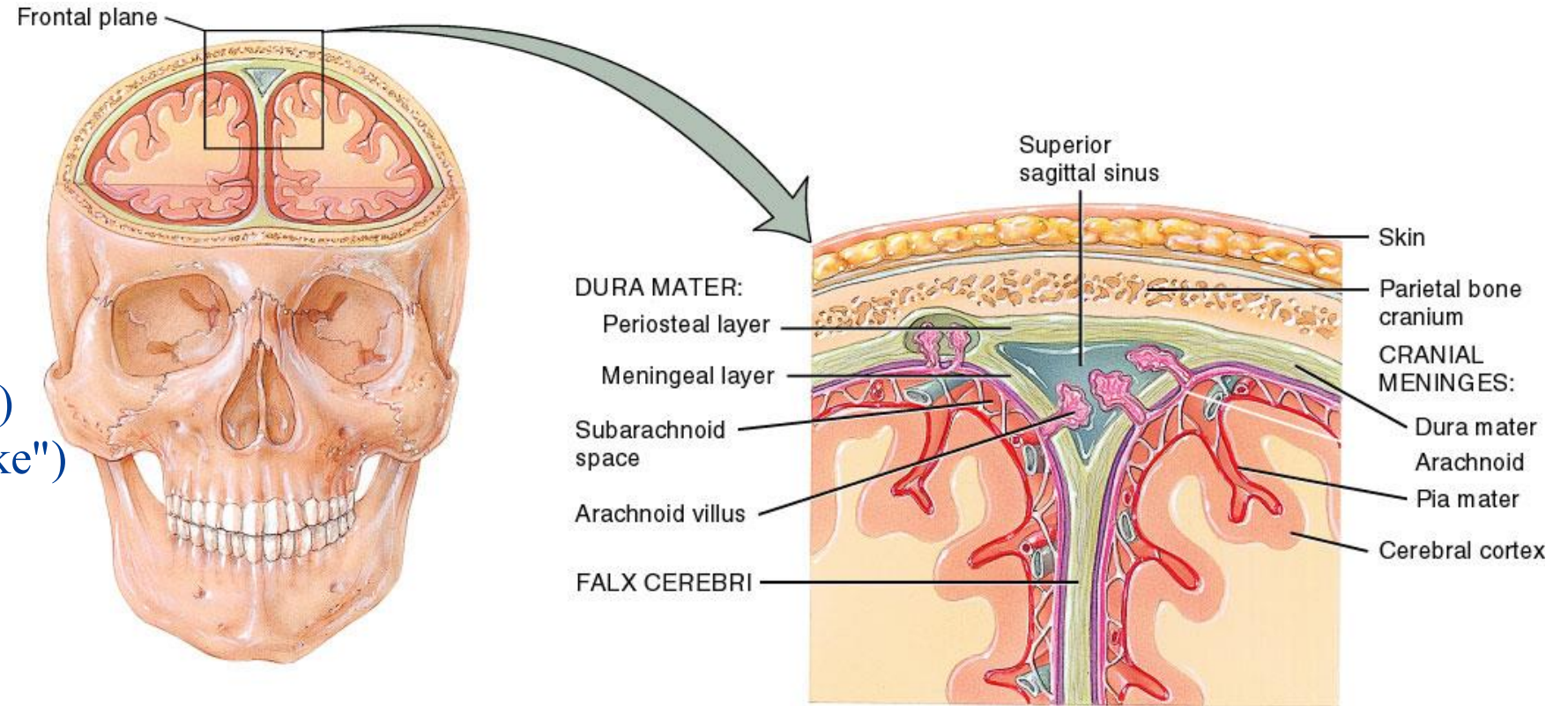
- Each area of the cortex is connected to a specific part of the thalamus, **nothing goes to the cortex without passing the thalamus.**
- When thalamic connection is lost cortical function stops.

Examples: **VPL/VPM** for sensory information, **VA/VL** for motor, **lateral geniculate** for visual and **medial geniculate** for audition.

- All sensory pathways pass through the thalamus with the exception of **some** olfactory signals.

“Some” pass the thalamus before the cortex, through the mediodorsal thalamic nucleus.

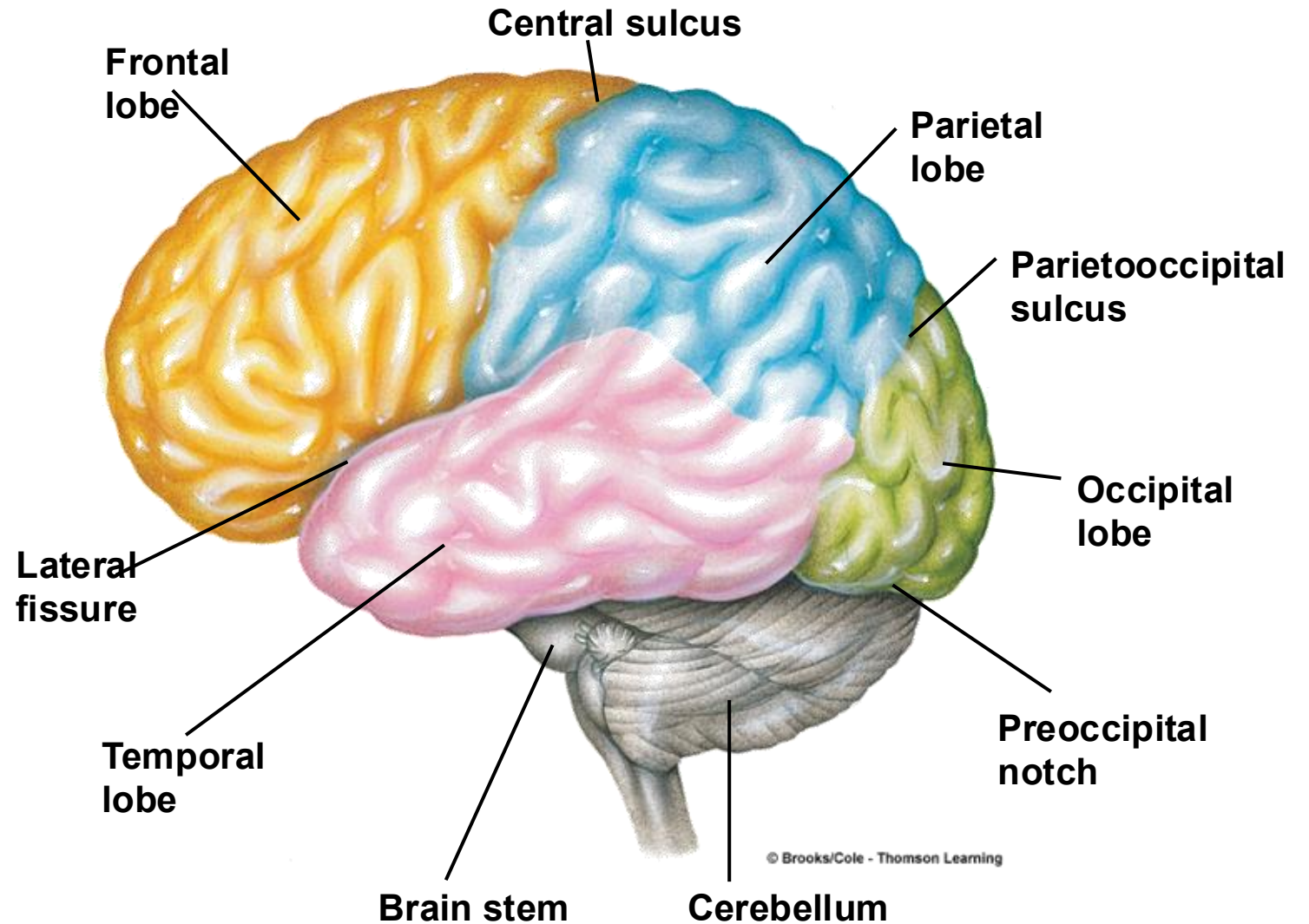
Brain meninges consist of:
Dura mater ("tough mother")
Arachnoid mater ("spider-like")
Pia mater ("tender mother")

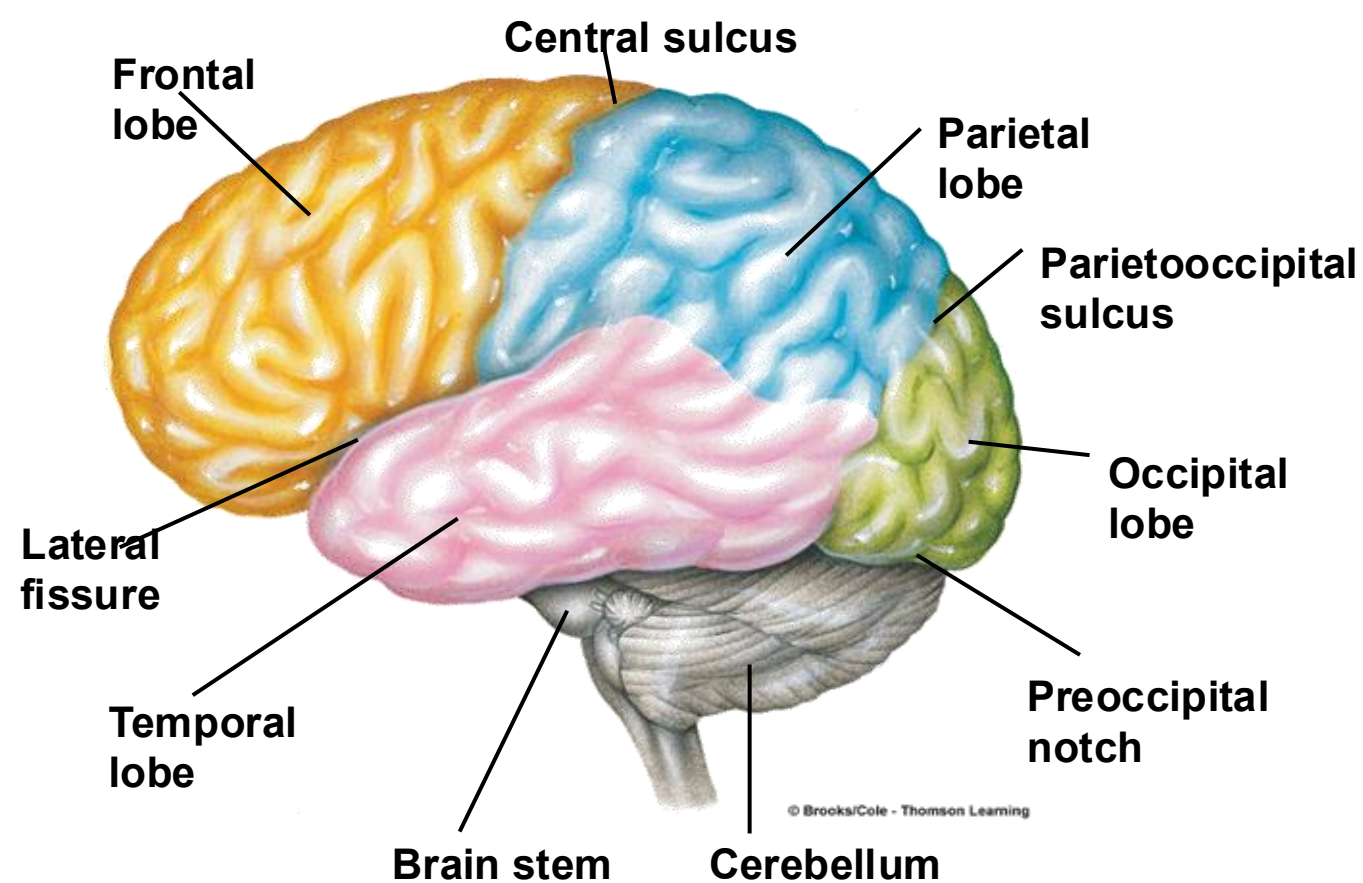


Frontal section through skull showing the cranial meninges

14.02

- The brain is classically divided into **four lobes**: frontal, parietal, temporal, and occipital. Some classifications include a **fifth lobe**, the insula, or even a **sixth “functional” lobe**, the limbic system.
- Each lobe is designed for a certain function.
- Brodmann used cortical cytoarchitecture—the cellular organization of neurons within the cortex—to identify **52 distinct regions**, now known as **Brodmann areas**.



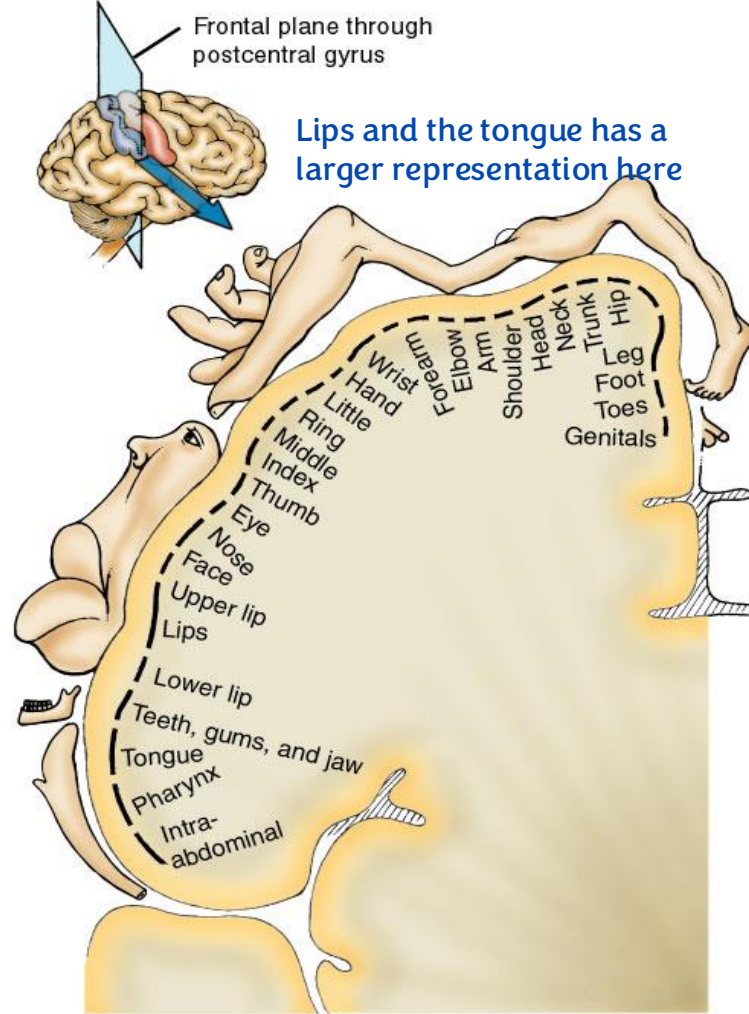


- The central sulcus **extends from the superomedial surface** and separates the frontal and parietal lobes. Anterior to it is the precentral gyrus, which is the **primary motor cortex (Brodmann area 4)**, and posterior to it is the postcentral gyrus, which is the **primary somatosensory cortex (Brodmann areas 3, 1, and 2)**.
- In both gyri, there is a **somatotopic representation of the body**, which is **contralateral and inverted (upside-down)**. Each body region is represented in proportion to the **density of sensory receptors (in areas 3, 1, and 2)** and the **number of motor units required for fine, precise movements (in area 4)**.

Motor Units & Movement Precision

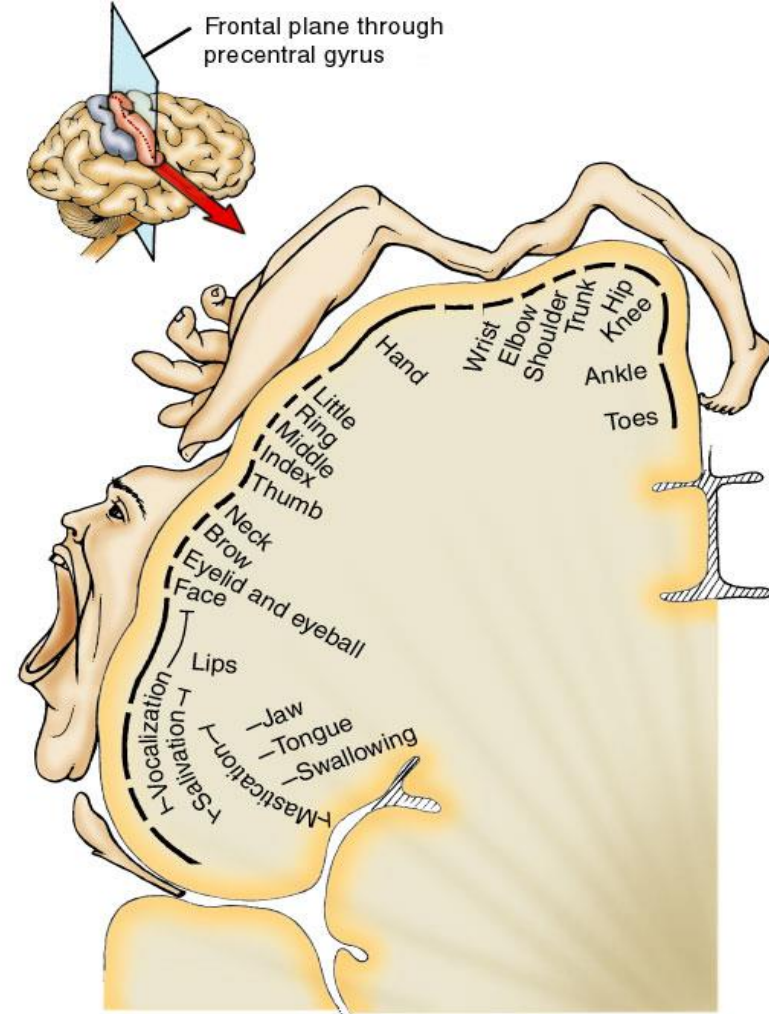
- A motor unit is a **single motor neuron and all the muscle fibers it innervates**. When that neuron fires, **all of its innervated muscle fibers contract simultaneously**. Thus, if it innervates only one muscle fiber, **only that fiber will contract**.
- The number of motor units supplying a muscle is **not proportional to muscle size**, but rather to the **precision of its movements**.
- In other words, the smaller the **innervation ratio (number of muscle fibers per motor neuron)**—for example, **one neuron supplying 1–3 muscle fibers**—the **greater the number of motor units supplying that muscle**. This allows the brain to **activate very small, specific portions of the muscle**, resulting in **fine, precise movements**.
- In contrast, a higher innervation ratio, where one neuron supplies **many muscle fibers**, reduces the ability to control specific regions of the muscle, leading to **less precise movement**. For example, when a motor neuron supplying the **quadriceps muscle** is activated, **a large portion of the muscle contracts simultaneously**.

The representation is contralateral and upside down



(a) Frontal section of primary somatosensory area in right cerebral hemisphere

Lips and the tongue has a larger representation here



(b) Frontal section of primary motor area in right cerebral hemisphere

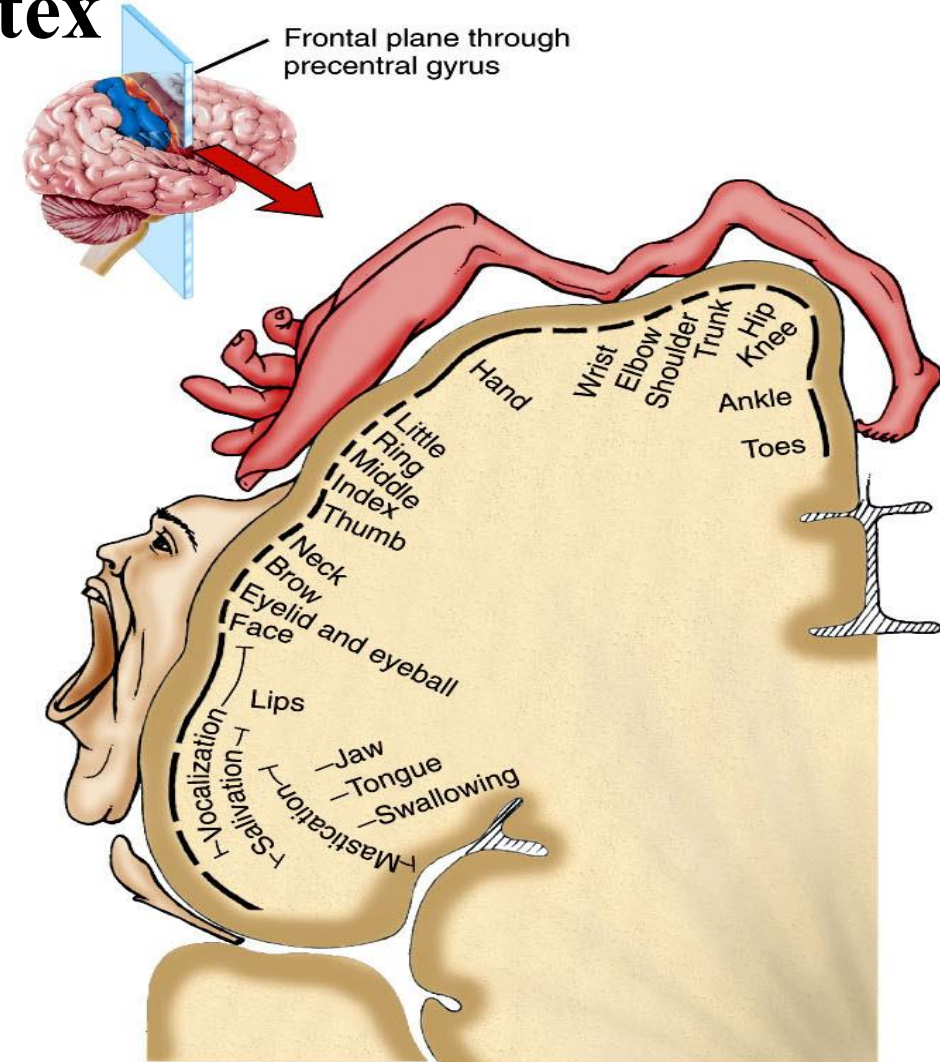
The professor claims that AD&D (NOT LIFE INSURANCE) will compensate someone for about 50% if they lose their thumb, since it's that significant in most hand movements and has a large representation in the motor cortex. However, this seems to be a myth. If you lose a hand, you get compensated for 50%, but losing a thumb and index finger together results in roughly 25%, and losing just the thumb alone is even less. They don't really pay for the "function" lost due to the accident; instead, the body part lost. their policies are more rigid, focusing on

Functional organization of the primary Motor Cortex

- ❖ Located in the precentral gyrus of the frontal lobe.
- ❖ More cortical area is devoted to those muscles involved in skilled, complex or delicate movements, that have more motor units i.e the cortical representation is proportional to the No of motor units

When electrically stimulated it produces isolated movements in the opposite part of the body, and bilateral movements in the muscles of the upper face (such as the forehead) [1].

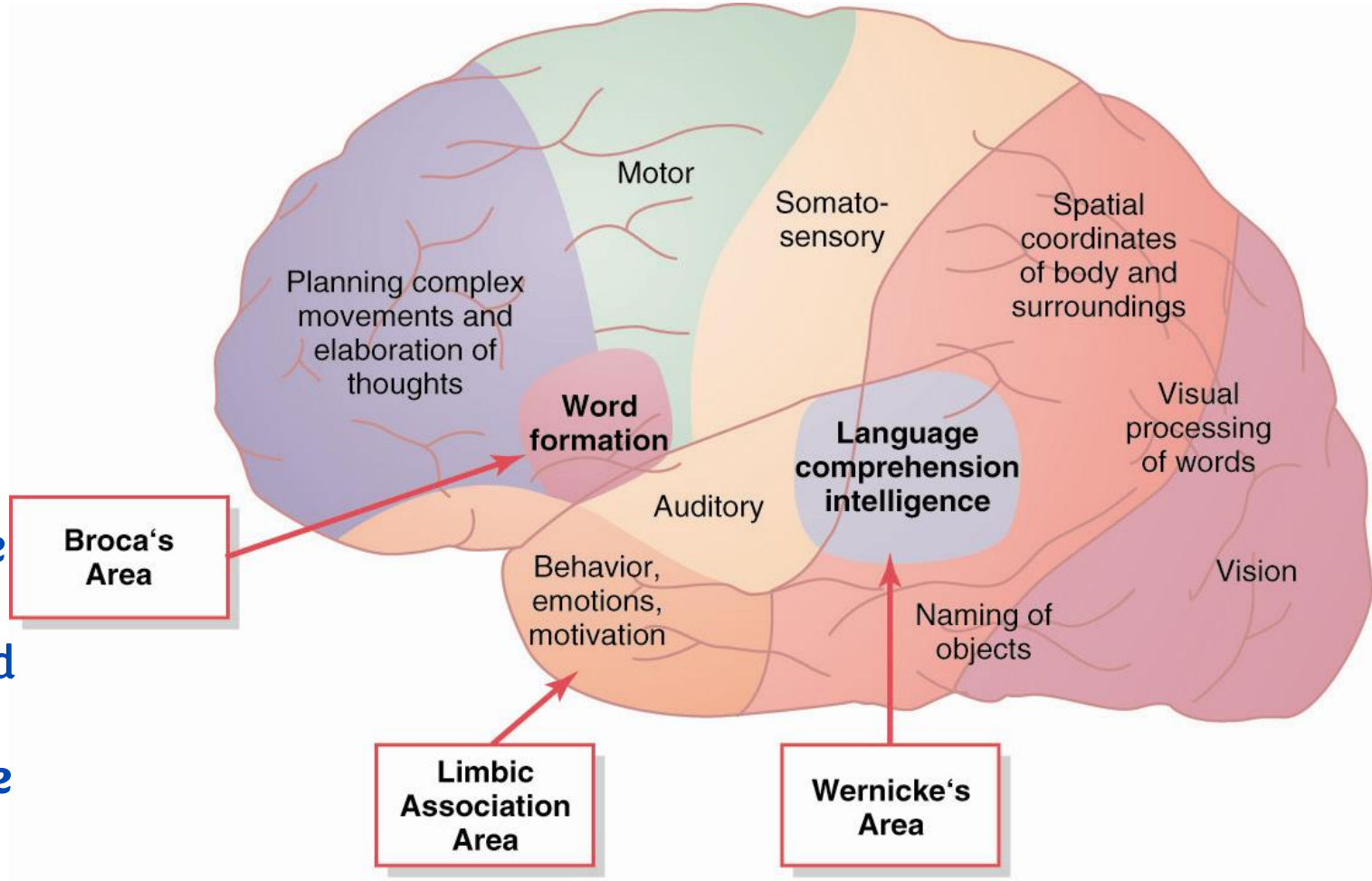
It doesn't function in the higher order "design of the pattern of motor movement" but rather in the final execution and specification of movement parameters[1].



(b) Frontal section of primary motor area in right cerebral hemisphere

Physiological Anatomy of the Cerebral Cortex

- In front of the precentral gyrus (primary motor area 4), we have the **premotor area 6**
- For **planned and learned motor movements**, activation of the **premotor cortex**, located lateral and anterior to the precentral gyrus, is required. It helps **select and sequence motor programs based on previous experience**, such as **driving a car**, and also contributes to **postural control**. When activated, it sends signals to the **primary motor cortex (Brodmann area 4)** to initiate activation of **specific muscles**.



Physiological Anatomy of the Cerebral Cortex

Broca's area (Brodmann areas 44 and 45) is located in the inferior part of the premotor cortex within the inferior frontal gyrus, (specifically between the anterior and ascending rami and the ascending and posterior rami of the lateral (Sylvian) fissure.)[1].

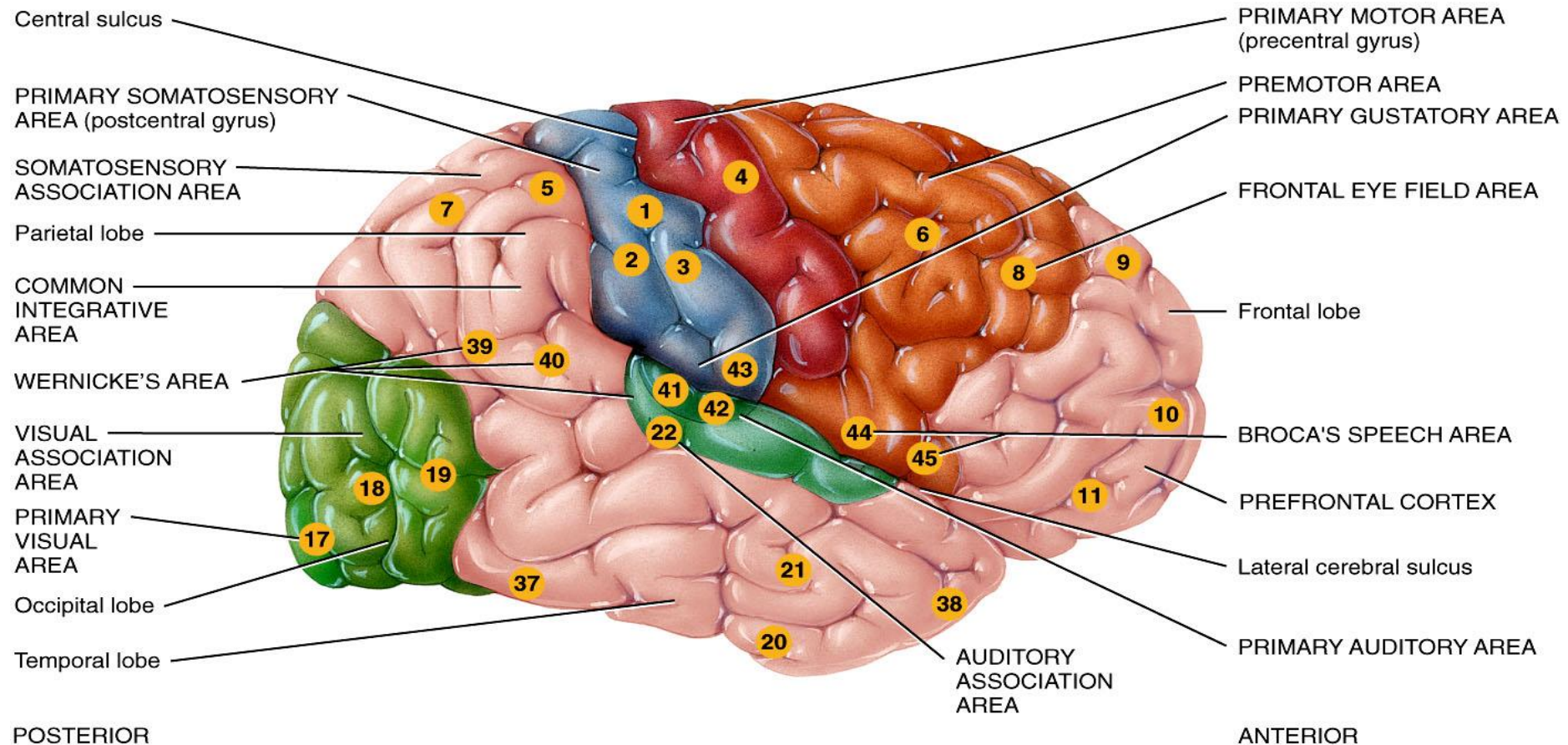
- Broca's area is responsible for the **motor planning of speech production**. It generates the **motor programs for speech**, which are then transmitted to the **primary motor cortex (particularly its inferior region)** to activate the muscles involved in speech, such as the **tongue, larynx, and pharynx**.

- Its proximity to the primary motor cortex reflects **strong functional connectivity**, as both areas are involved in the **motor aspects of speech production**.

Another example is the **frontal eye fields**, which control **voluntary saccadic eye movements** and are located near cortical regions involved in **head movement**, allowing coordinated gaze shifts.

- The **supplementary motor area (SMA)** is located **superior to the premotor cortex and anterior to the primary motor cortex on the medial surface**. Its stimulation often produces **bilateral movements**, and it plays an important role in the **planning and initiation of internally generated movements**, as well as **coordination of posture and movement sequences**.

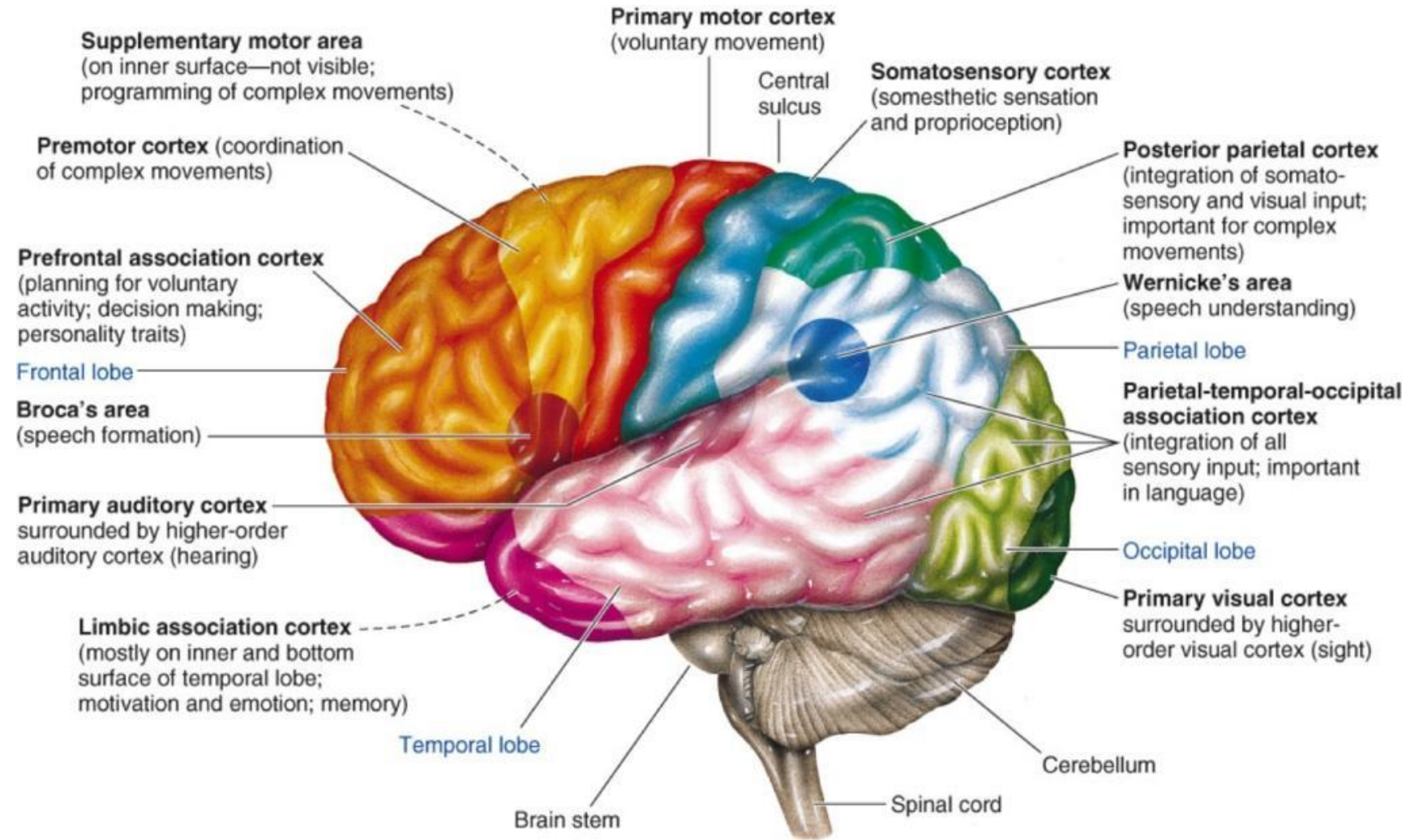
Functional Organization of the Cerebral Cortex: Sensory Areas



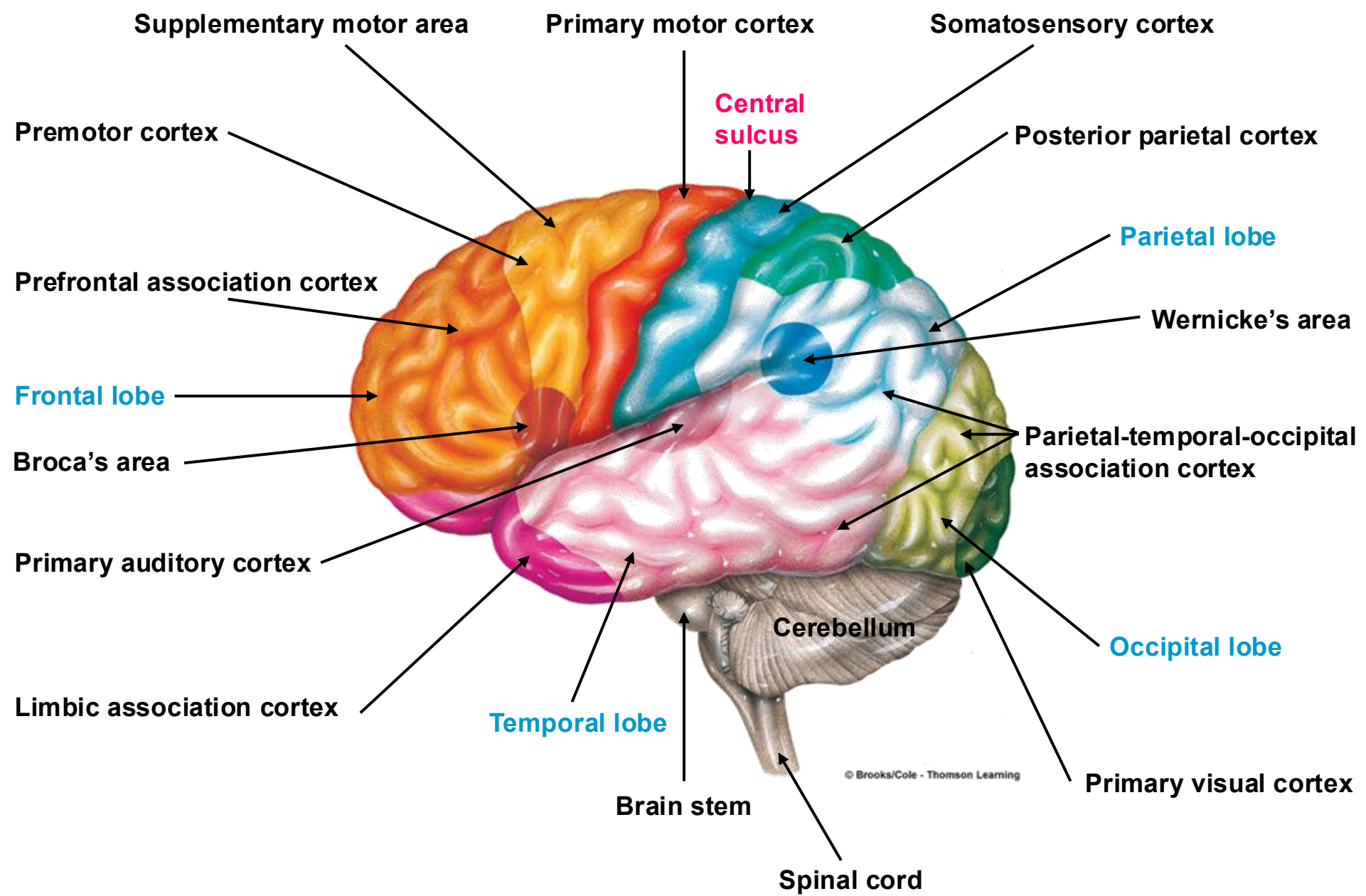
Lateral view of right cerebral hemisphere

Important!

Functional Organization of the Cerebral Cortex



(a) Regions of the cerebral cortex responsible for various functions



Functional Organization of Association Areas

- In the brain, primary areas are associated with **nearby and distributed association areas** (they are often adjacent but not necessarily in very close proximity).

The function of the association areas is to **interpret and integrate sensory input from primary areas**, allowing you to understand what you feel, hear, and see, and to coordinate these sensations.

For example, **they help you localize sensations accurately and construct a three-dimensional body image.**

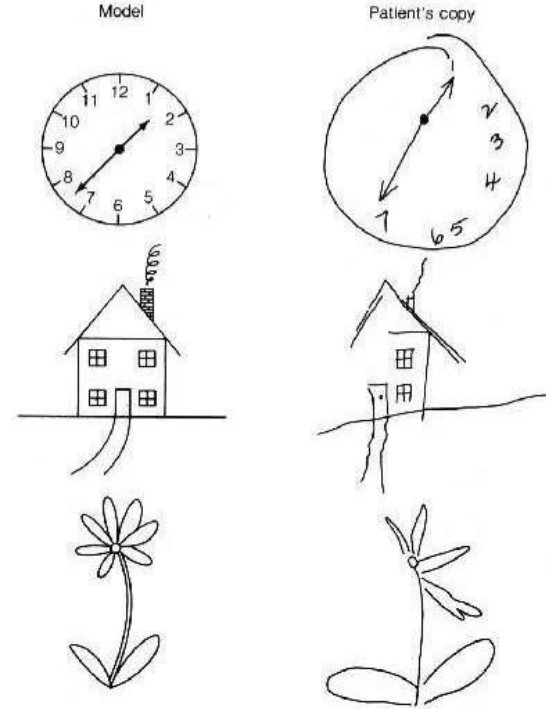
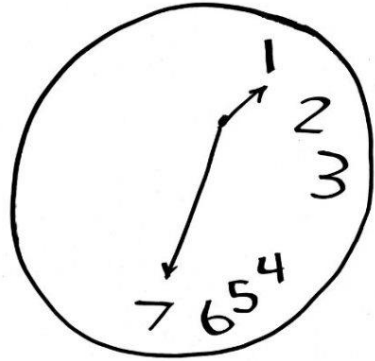
- If there is a lesion in the right inferior parietal lobe (to be discussed in cortical lateralization), the patient may develop **contralateral neglect**. In this condition, the person becomes **unaware of the left side of their body and the left side of space**. It is as if they ignore or fail to attend to the left half of the world. When asked to draw an object, only the right side is drawn, while the left side is omitted.

The doctor referred to this presentation as “**amorphosynthesis**,” which is an older term that is no longer commonly used. It was described by neurologists such as **Denny-Brown** as a failure to integrate sensory information from both sides of the body and space into a coherent whole. In this concept, neglect of one side of the world was considered the main feature.[2].

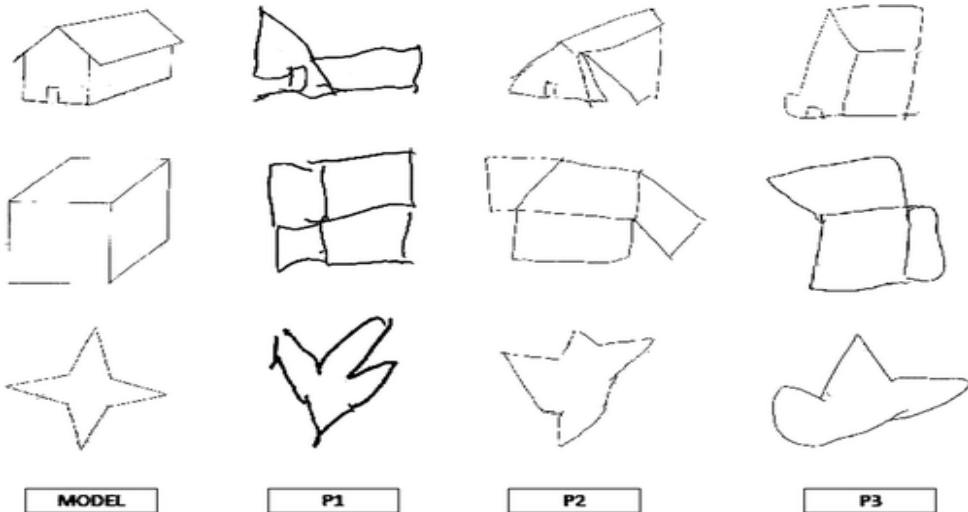
Today, these symptoms are classified into more specific conditions:

- **Contralateral neglect** = an attentional deficit characterized by **ignoring one side of space or the body**
- **Constructional apraxia** = the **inability to organize parts into a correct spatial arrangement** (e.g., drawing all elements of a clock but placing the numbers incorrectly)

How someone with contralateral neglect would draw a clock, daisy and a house:



Drawings by patients with constructional apraxia:



Visual and Auditory Cortical Functions and Disorders

- The **primary visual area (area 17)** is located along the banks of the calcarine sulcus in both **hemispheres**, while the visual association areas (**areas 18 and 19**) are distributed throughout the surrounding occipital cortex.

If a lesion occurs in the primary visual cortex, for example in the right hemisphere, it results in loss of the left visual field in both eyes, a condition known as left homonymous hemianopia. Similarly, a lesion in the left hemisphere causes loss of the right visual field in both eyes (right homonymous hemianopia).

“word blindness” or Pure alexia (alexia without agraphia) is the **loss of the ability to read despite preserved vision and writing ability**. It’s a disconnection syndrome, in which visual information fails to reach language-processing areas, so the patient can see the words but cannot read them.

- Now for **audition**, damage to the primary auditory area (**41 and 42**) won't cause deafness since there is continuous crossing in the central part. **Damage to the auditory association areas can cause auditory agnosia**, in which a person **can hear sounds but cannot recognize or interpret them**. The doctor also mentioned **“word deafness” (pure word deafness or auditory verbal agnosia)**, which is a specific form of auditory agnosia selectively affecting speech comprehension. In this condition, the person **can hear sounds and understand nonverbal sounds, but cannot understand spoken words**, despite having intact hearing.

Limbic Association Areas and Their Functions

- **The orbitofrontal cortex** (the most anterior and inferior part of the frontal lobe) and the anterior temporal lobe (including the amygdala and hippocampus) are **functionally interconnected with limbic association areas**. These areas also connect to the hypothalamus and other key limbic structures, such as the nucleus accumbens.
- The limbic association areas are primarily concerned with **behavior, emotions, motivation, reward, and punishment**. They also play a role in **memory**, working in conjunction with the hippocampus, which is a major limbic structure located in the temporal lobe.

Prefrontal Cortex and Its Role in Behavior

- The prefrontal cortex is a large region at the front of the brain. In the past, it was incorrectly believed to have no essential function and was called a “silent area” because electrical stimulation produced no obvious responses. This misconception led to the use of lobotomies, which involved severing connections between the prefrontal cortex and other brain regions, particularly the thalamus, especially in patients with schizophrenia or severe aggressive behavior.

- One way to understand brain function is to study the effects of damage. A classic example is Phineas Gage, a railroad worker who survived an iron rod passing through his frontal lobe in 1848. After the injury, his behavior changed dramatically—he became careless, unable to plan or organize his thoughts, and showed poor judgment, although his intelligence and memory remained largely intact.

Gage also became socially disinhibited, meaning he showed reduced restraint in social situations, with little regard for social norms and boundaries. He had difficulty making decisions and was easily distracted.

This case provided early evidence for the role of the prefrontal cortex in personality and executive functions.

Language Areas (Wernicke's and Broca's) and Aphasia

- **Wernicke's area** is responsible for **language comprehension (the sensory/receptive aspect of speech)**. It is primarily located in area **22** (superior temporal gyrus), with contributions from areas **39** (angular gyrus) and **40** (supramarginal gyrus).

It receives input from **multiple association areas (auditory, visual, and somatosensory)** and **integrates this information to form meaningful language**. The processed information is then transmitted via the arcuate fasciculus to **Broca's area for speech production**, or to motor regions involved in writing (e.g., Exner's area), depending on the required output.

Lesion to Wernicke's → impaired comprehension and inability to produce meaningful language → speech is fluent but nonsensical → poor understanding of spoken language → **sensory (receptive) aphasia**.

Lesion to Broca's → intact comprehension with impaired speech production → patient knows what they want to say but cannot express it fluently → commonly due to a middle cerebral artery (MCA) stroke → speech is non-fluent and effortful, and writing is usually also impaired → **motor (expressive) aphasia**.

Dominant and Non-Dominant Hemisphere

- Wernicke's area more developed in one hemisphere, responsible for verbal symbolism and related intelligence. *Dominance is related to Language*
- 95% of population has a left dominant hemisphere.
- Wernicke's area can be as much as 50% larger in the dominant hemisphere.

Dominant and Non-Dominant Hemisphere

- The dominant hemisphere is responsible for **language functions**, and in about **95%** of **right-handed** individuals, it is the left hemisphere. **Handedness is associated with hemispheric specialization**. Most right-handed individuals have left hemisphere dominance for language. Among left-handed individuals, approximately 70% have left hemisphere dominance, 15% have right hemisphere dominance, and 15% have bilateral (no clear) dominance.
- Handedness itself does not truly convert, but motor skills can adapt due to neuroplasticity, especially at a young age. For example, if a child loses function of the right hand, they can train the left hand to become more skilled, although this does not necessarily change language dominance.
- Neuroplasticity is greater in younger individuals, which is why learning new skills (such as driving or sports coordination) is easier and faster at a younger age, while it becomes more difficult with aging.
For example, in sports training, young individuals can learn to use both legs with similar proficiency, but this **does not** necessarily affect their handedness or hemispheric dominance, as these are separate functions.

Dominant and Non-Dominant Hemisphere (Cont'd)

- Damage to dominant Wernicke's area leads to dementia.
- Non-dominant side related to other forms of sensory intelligence (music, sensory feelings).

Hemispheric Lateralization

TABLE 14.3

Functional Differences Between the Two Cerebral Hemispheres

LEFT HEMISPHERE FUNCTIONS

Receives somatic sensory signals from and controls muscles on right side of body.

Reasoning.

Numerical and scientific skills.

Ability to use and understand sign language.

Spoken and written language.

RIGHT HEMISPHERE FUNCTIONS

Receives somatic sensory signals from and controls muscles on left side of body.

Musical and artistic awareness.

Space and pattern perception.

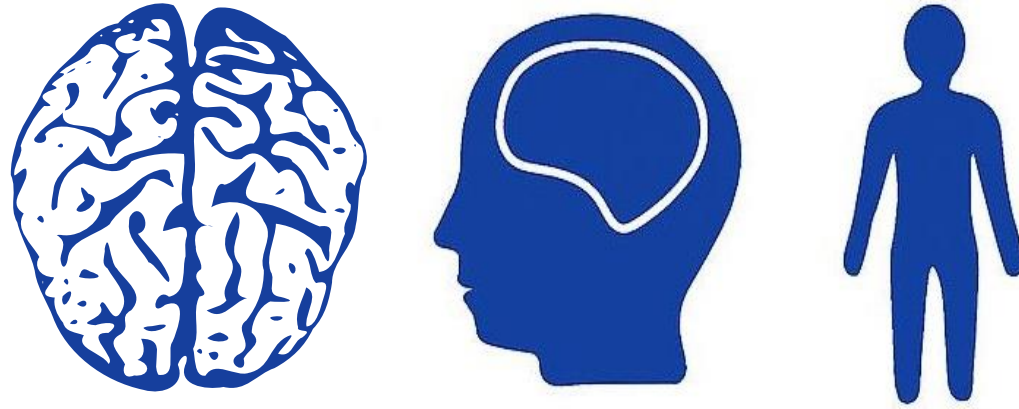
Recognition of faces and emotional content of facial expressions.

Generating emotional content of language.

Generating mental images to compare spatial relationships.

Identifying and discriminating among odors.

Table 14.03 Tortora - PAP 12/e
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PHYSIOLOGY
QUIZ
LECTURE 7

اللهم إن عمر عطية في ذمتك وحبل جوارك، فقه من فتنة القبر وعذاب النار،
أنت أهل الوفاء والحق، فاغفر له وارحمه إنك أنت الغفور الرحيم.

References as cited:

1. Snell Clinical Neuroanatomy 9th edition chapter 14
2. DENNY-BROWN D, BANKER BQ.
Amorphosynthesis from left parietal lesion. AMA Arch Neurol Psychiatry. 1954 Mar;71(3):302-13. doi: 10.1001/archneurpsyc.1954.02320390032003. PMID: 13123592.

Additional sources:

1. Broca's aphasia: <https://youtu.be/RMa9BVpJkYQ?si=IcYM5lv0jgBUXoLJ>
2. wernicke's aphasia: <https://youtu.be/3oef68YabD0?si=-5XSSLvgDVjMP26P>
3. contralateral neglect: <https://youtu.be/d4FhZs-m7hA?si=86X8KwqCtWWDdQ9O>
4. <https://youtu.be/UyjRK9HQtoI?si=bcbkEfKecnus3XQe>

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Corrections from previous versions:

Versions	Slide # and Place of Error	Before Correction	After Correction
V0 → V1			
V1 → V2			