Neurophysiology

Cerebral cortex

Fatima Ryalat, MD, PhD

Thoughts

- Each thought involves simultaneous signals in many portions of the cerebral cortex, thalamus, limbic system, and reticular formation of the brain stem.

Memory

- Memories are stored in the brain by changing the basic sensitivity of synaptic transmission between neurons as a result of previous neural activity.

- The new or facilitated pathways are called **memory traces**. They are important because once the traces are established, they can be selectively activated by the thinking mind to reproduce the memories.

Memory

- The greater share of our memories is negative, not positive.
- If our minds attempted to remember all the sensory information, the memory capacity of the brain would be rapidly exceeded.
- the brain has the capability to ignore information that is of no consequence.
- This capability results from inhibition of the synaptic pathways for this type of information; the resulting effect is called habituation, which is a type of **negative memory**.

Memory

- Conversely, for incoming information that causes important consequences such as pain or pleasure, the brain has a different automatic capability of enhancing and storing the memory traces, which is **positive memory**.

- It results from facilitation of the synaptic pathways, and the process is called memory sensitization.

Classification of memory

- (1) short-term memory, which includes memories that last for seconds or at most minutes.
- (2) intermediate long-term memories, which last for days to weeks but then fade away.
- (3) long-term memory, which, once stored, can be recalled up to years or even a lifetime later.
- (4) working memory, which includes mainly short-term memory that is used during the course of intellectual reasoning but is terminated as each stage of the problem is resolved.

Classification of memory

- **Declarative memory** basically means memory of the various details of an integrated thought, such as memory of an important experience that includes memory of the following: (1) the surroundings; (2) time relationships, (3) causes of the experience; (4) meaning of the experience; and (5) the deductions that were left in the person's mind.
- **Skill memory** is frequently associated with motor activities of the person's body, such as all the skills developed for hitting a tennis ball

Short term memory

- Such as memorizing 7 to 10 numerals in a telephone number for a few seconds to a few minutes at a time but lasting only as long as the person continues to think about them.

Short term memory

- Theories suggested are:
- it is caused by continual neural activity resulting from nerve signals that travel around and around a temporary memory trace in a circuit of reverberating neurons.
- presynaptic facilitation or inhibition.

Intermediate long term memory

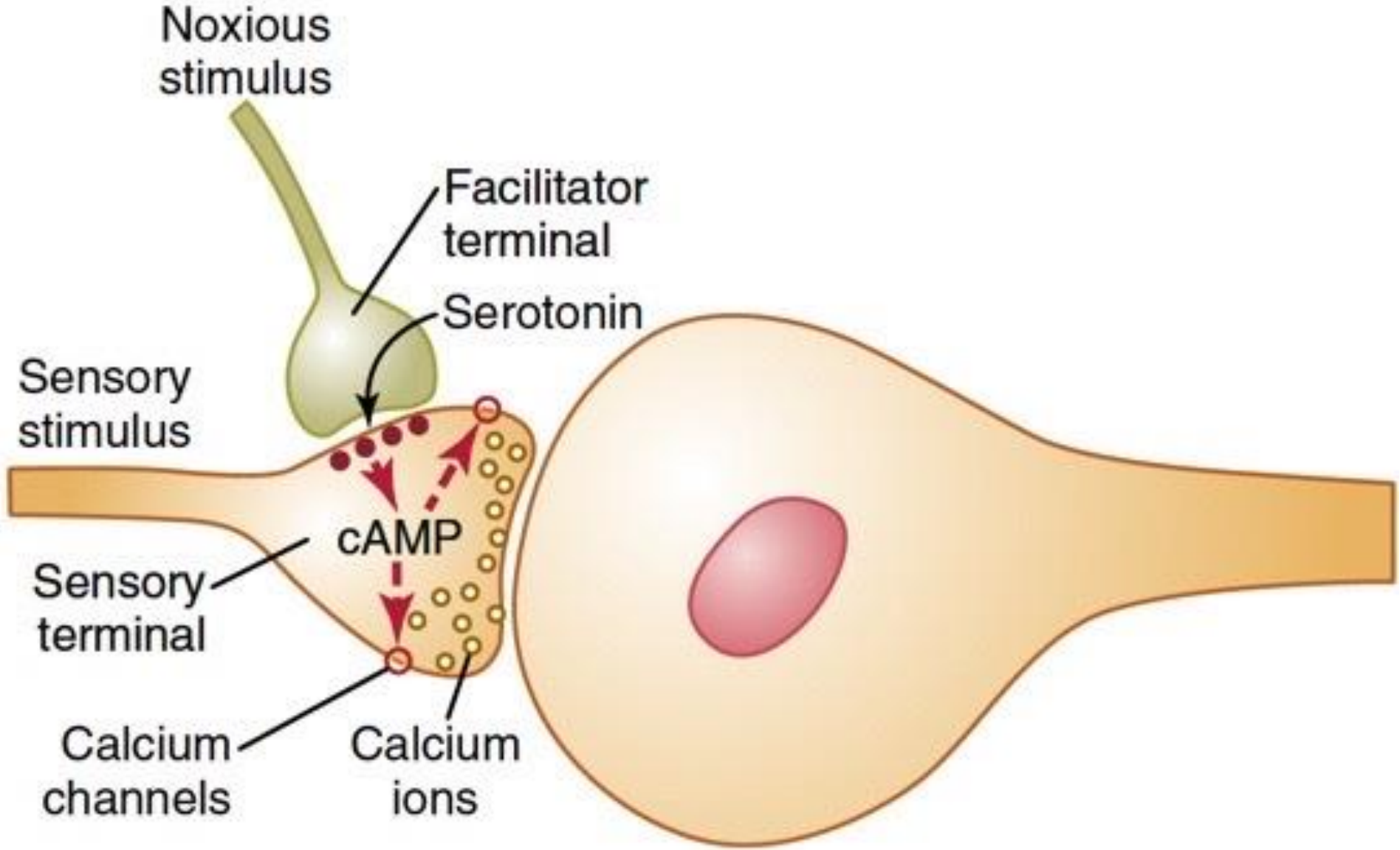
- They will eventually be lost unless the memory traces are activated enough to become more permanent; then they are classified as long-term memories.

- Experiments in animals have demonstrated that these memories can result from temporary chemical changes in either the synapse presynaptic terminals or the synapse postsynaptic membrane, changes that can persist for a few minutes up to several weeks.

Molecular mechanisms of intermediate memory

- Mechanism for Habituation.

- At the molecular level, it results from progressive closure of calcium channels through the terminal membrane, although the cause of this calcium channel closure is not fully known.


Noxious stimulus
Facilitator terminal
Serotonin
Sensory stimulus
cAMP
Sensory terminal
Calcium channels
Calcium ions

Molecular mechanisms of intermediate memory

- Mechanism of facilitation:

- The associative effect of stimulating the facilitator terminal at the same time that the sensory terminal is stimulated causes prolonged increase in excitatory sensitivity of the sensory terminal, which establishes the memory trace.

Long term memory

- it is generally believed to result from actual structural changes, instead of only chemical changes, at the synapses, and these changes enhance or suppress signal conduction.

Long term memory

- The following important structural changes occur:
- 1. An increase in vesicle release sites for secretion of transmitter substance
- 2. An increase in the number of transmitter vesicles released
- 3. An increase in the number of presynaptic terminals
- 4. Changes in structures of the dendritic spines that permit transmission of stronger signals

Long term memory

- The number of neuronal connections is determined by specific nerve growth factors released retrogradely from the stimulated cells.
- Furthermore, when insufficient connectivity occurs, the entire neuron that is sending out the axon branches might eventually disappear.
- Therefore, soon after birth, the principle of “use it or lose it” governs the final number of neurons and their connectivities in respective parts of the human nervous system.

Memory consolidation

- Conversion of short-term memory into long-term memory.
- The short-term memory, if activated repeatedly, will initiate chemical, physical, and anatomical changes in the synapses that are responsible for the long-term memory.
- rehearsal of the same information again and again in the mind accelerates and potentiates the degree of transfer of short-term memory into long-term memory and therefore accelerates and enhances consolidation.

Memory consolidation

- One of the most important features of consolidation is that new memories are **codified** into different classes of information.
- during consolidation, the new memories are not stored randomly in the brain but are stored in direct association with other memories of the same type.
- This process is necessary for one to be able to “search” the memory store at a later date to find the required information.

Memory consolidation

- The **hippocampi** especially and to a lesser degree the **dorsal medial nuclei of the thalamus** have proved especially important in making the decision about which of our thoughts are important enough on a basis of reward or punishment to be worthy of memory.

Retrograde amnesia

- When retrograde amnesia occurs, there is a loss of memory access to events and information learned prior to an injury or disease that caused the amnesia.
- In some people who have hippocampal lesions, some degree of retrograde amnesia occurs along with anterograde amnesia, which suggests that these two types of amnesia are at least partially related and that hippocampal lesions can cause both.

Retrograde amnesia

- However, damage in some thalamic areas may lead specifically to retrograde amnesia without causing significant anterograde amnesia.
- A possible explanation of this is that the thalamus may play a role in helping the person “search” the memory storehouses and thus “read out” the memories.
- That is, the memory process not only requires the storing of memories but also an ability to search and find the memory at a later date.

Hippocampus

- People with hippocampal lesions usually do not have difficulty in learning physical skills that do not involve verbalization or symbolic types of intelligence.
- This type of learning is called **skill learning or reflexive learning**; it depends on physically repeating the required tasks over and over again, rather than on symbolic rehearsing in the mind.

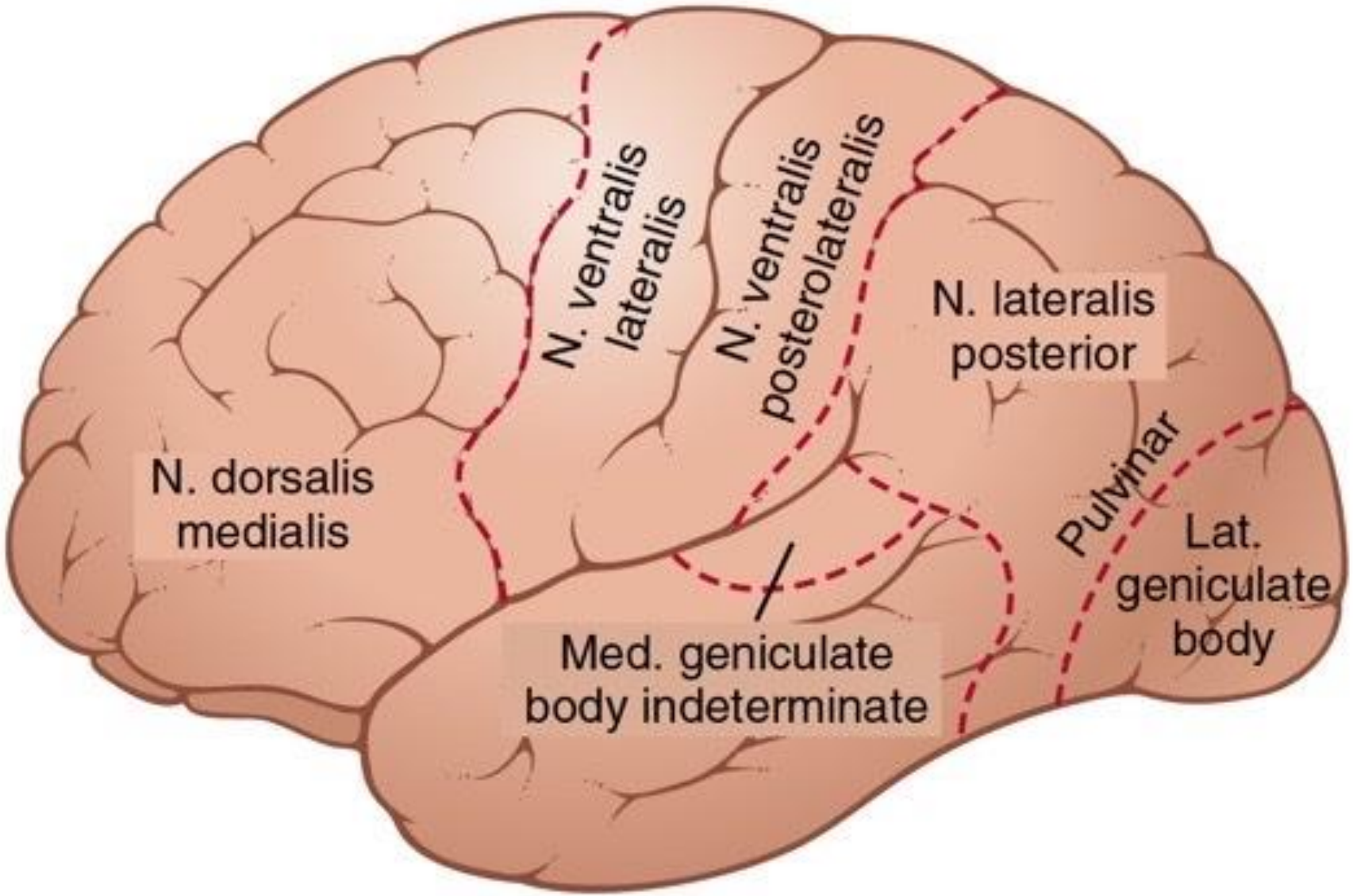
Working memory

- This ability of the prefrontal areas to keep track of many bits of information simultaneously and to cause recall of this information instantaneously as it is needed for subsequent thoughts is called the “brain’s working memory,” which may explain the many functions of the brain that we associate with higher intelligence.

Cerebral cortex

- All areas of the cerebral cortex have extensive to-and- fro efferent and afferent connections with deeper structures of the brain.

- When the **thalamus** is damaged along with the cortex, the loss of cerebral function is far greater than when the cortex alone is damaged, because thalamic excitation of the cortex is necessary for almost all cortical activity.

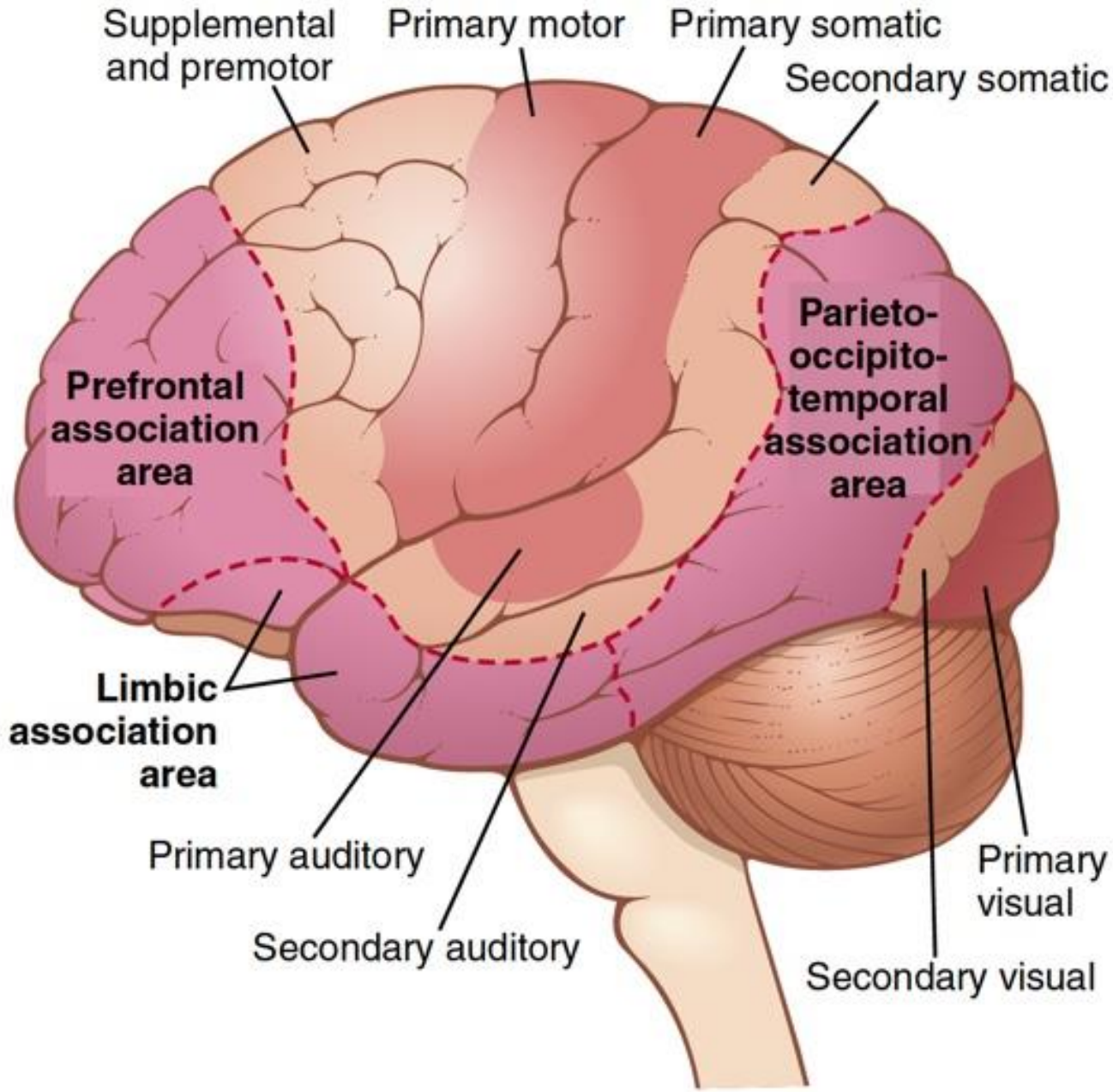

N. ventralis lateralis
N. ventralis posterolateralis
N. lateralis posterior
N. dorsalis medialis
Pulvinar
Lat. geniculate body
Med. geniculate body indeterminate

Thalamocortical system

- cerebral and thalamic connections act in **two directions**, both from the thalamus.
- Furthermore, when the thalamic connections are cut, the functions of the corresponding cortical area become almost entirely lost.
- Therefore, the cortex operates in close association with the thalamus and can almost be considered both anatomically and functionally a unit with the thalamus called the thalamocortical system.

Cortical areas

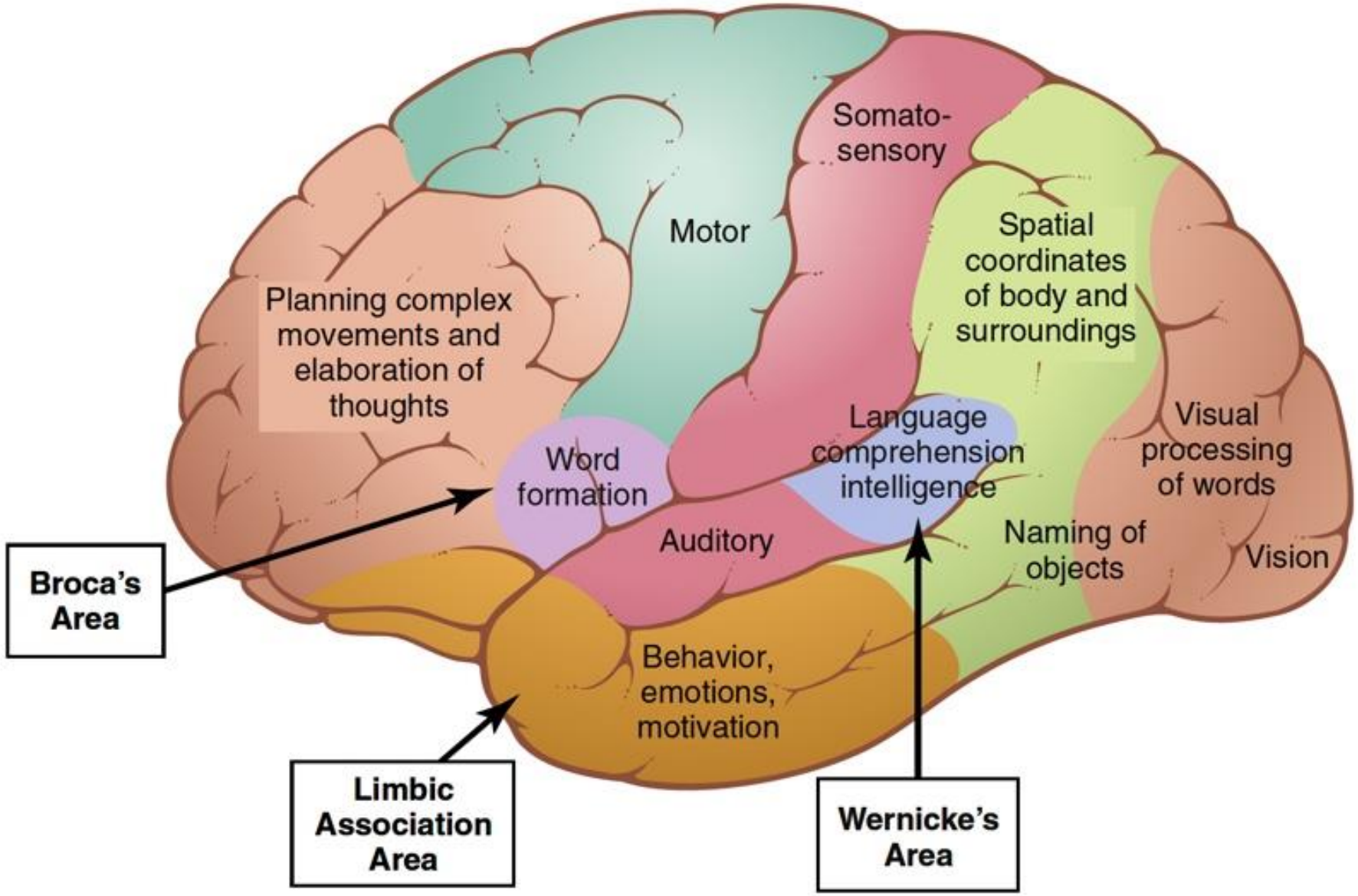
- The **primary** motor areas have direct connections with specific muscles for causing discrete muscle movements. The primary sensory areas detect specific sensations transmitted to the brain from peripheral sensory organs.
- The **secondary** areas make sense out of the signals in the primary areas (pattern of movement, color, texture…etc.).
- The **association** areas receive and analyze signals simultaneously from multiple regions of both the motor and sensory cortices, as well as from subcortical structures.


Supplemental and premotor
Primary motor
Primary somatic
Secondary somatic
Prefrontal association area
Parieto-occipito-temporal association area
Limbic association area
Primary auditory
Secondary auditory
Primary visual
Secondary visual

Parieto-occipito-temporal association area

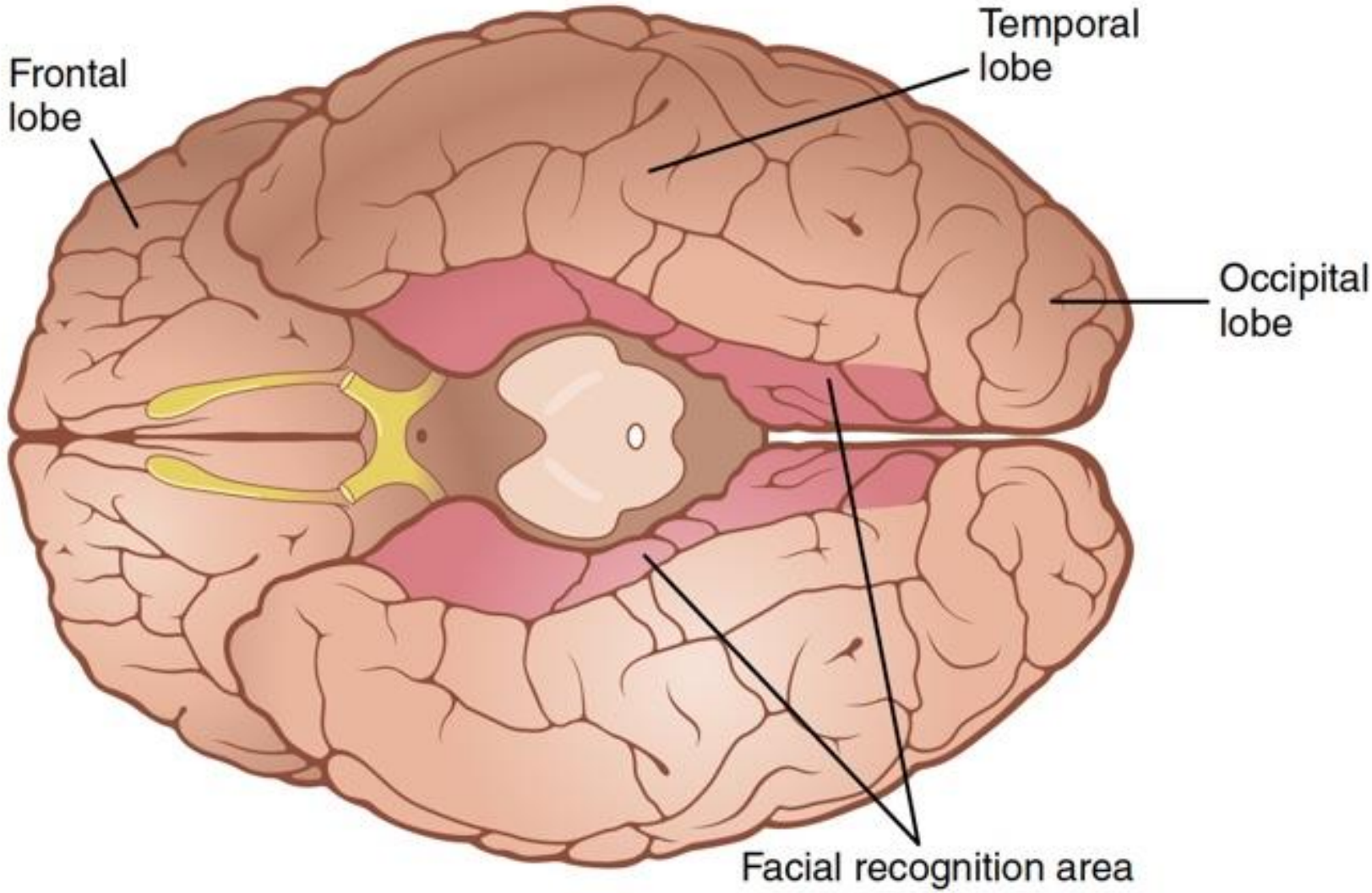
- Functional subareas:

- Area for spatial coordinates:
- provides continuous analysis of the spatial coordinates of all parts of the body, as well as of the surroundings of the body.


Somato-
sensory
Motor
Spatial
coordinates
of body and
surroundings
Planning complex
movements and
elaboration of
thoughts
Language
comprehension
intelligence
Visual
processing
of words
Word
formation
Auditory
Naming of
objects
Vision
Broca's
Area
Behavior,
emotions,
motivation
Limbic
Association
Area
Wernicke's
Area

Area for naming objects

- The names are learned mainly through auditory input, whereas the physical natures of the objects are learned mainly through visual input. In turn, the names are essential for both auditory and visual language comprehension.


Frontal lobe
Temporal lobe
Occipital lobe
Facial recognition area

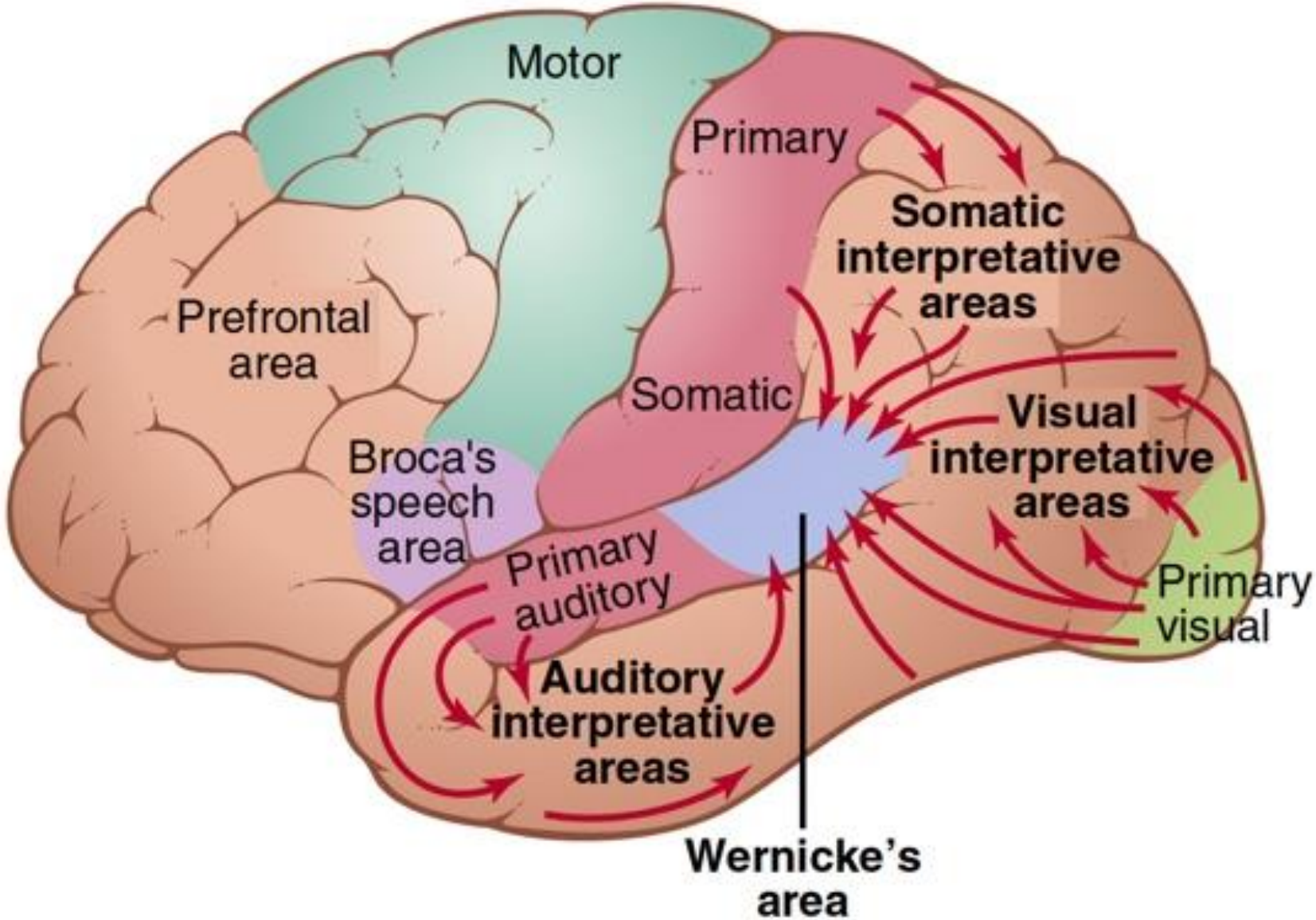
Area for face recognition

- The occipital portion of this facial recognition area is contiguous with the visual cortex, and the temporal portion is closely associated with the limbic system that has to do with emotions, brain activation, and control of one’s behavioral response to the environment

Wernicke's area

- The major area for language comprehension, lies behind the primary auditory cortex.

- it is one of the most important regions of the entire brain for higher intellectual function because most of these intellectual functions are language based.


Motor
Primary
Somatic interpretative areas
Prefrontal area
Somatic
Visual interpretative areas
Broca's speech area
Primary auditory
Primary visual
Auditory interpretative areas
Wernicke's area

Wernicke’s area

- After severe damage in Wernicke’s area, a person might hear perfectly well and even recognize different words but still be unable to arrange these words into a coherent thought.

- Likewise, the person may be able to read words from the printed page but be unable to recognize the thought that is conveyed.

Wernicke’s area

- When Wernicke’s area in the dominant hemisphere of an adult person is destroyed, the person normally **loses almost all intellectual functions associated with language** or verbal symbolism, such as the ability to perform mathematical operations, and the ability to think through logical problems.

Wernicke’s area

- it is believed that **activation of Wernicke’s area can call forth complicated memory patterns** that involve more than one sensory modality even though most of the individual memories may be stored elsewhere.

- The importance of Wernicke’s area in **interpreting the complicated meanings of different patterns of sensory experiences.**

Wernicke's area

- **A major share of our sensory experience is converted into its language equivalent before being stored in the memory areas of the brain and before being processed for other intellectual purposes.**

- this area is closely associated with both the primary and secondary hearing areas of the temporal lobe. This close relation probably results from the fact that the first introduction to language is by way of hearing.

Angular gyrus area

- angular gyrus area is needed to make meaning out of the **visually** perceived words.

- In its absence, a person can still have excellent language comprehension through hearing but not through reading; injury to the angular gyrus can result in agraphia (inability to write) with alexia (inability to read), a condition in which a person cannot read, write, or spell words.

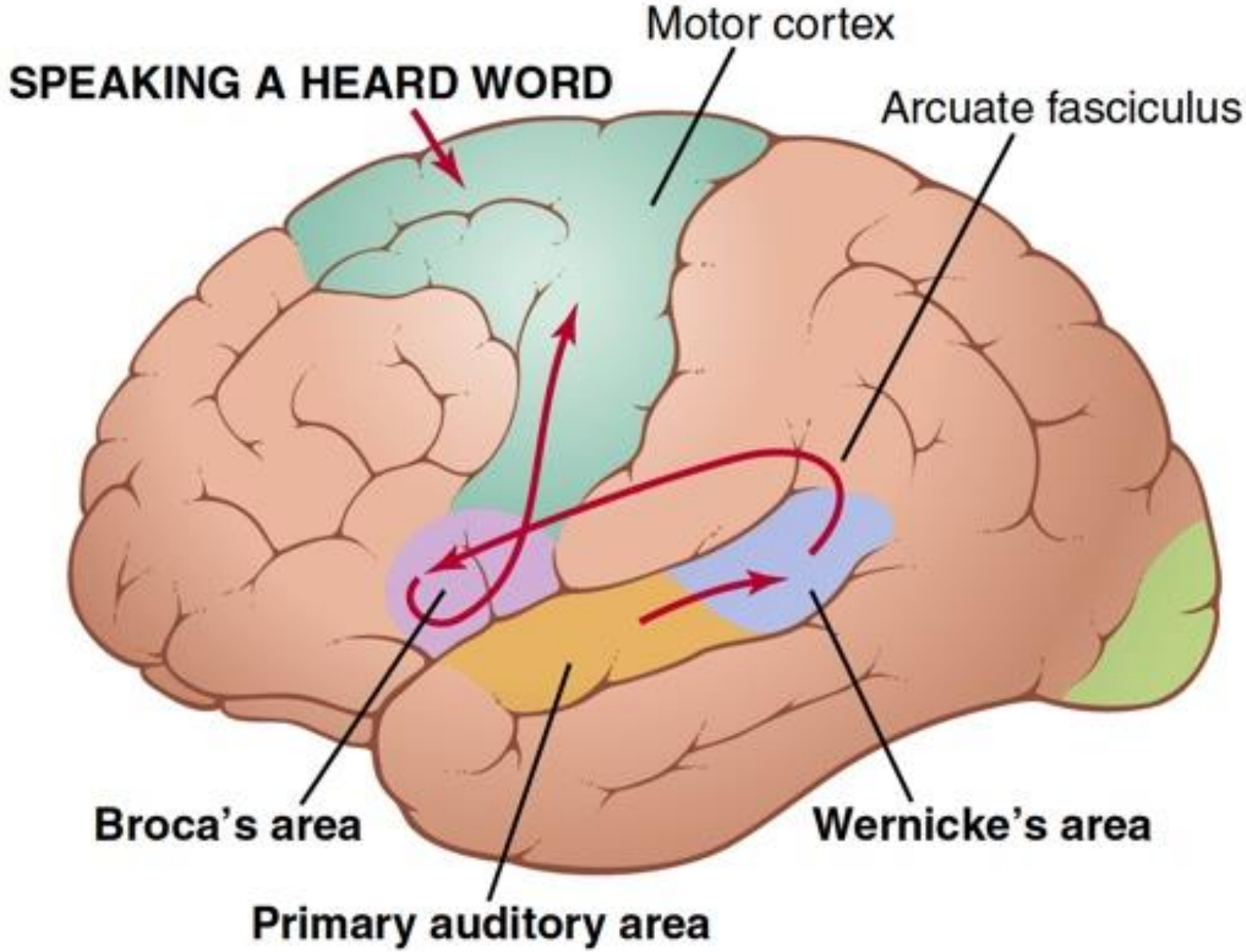
Angular gyrus area

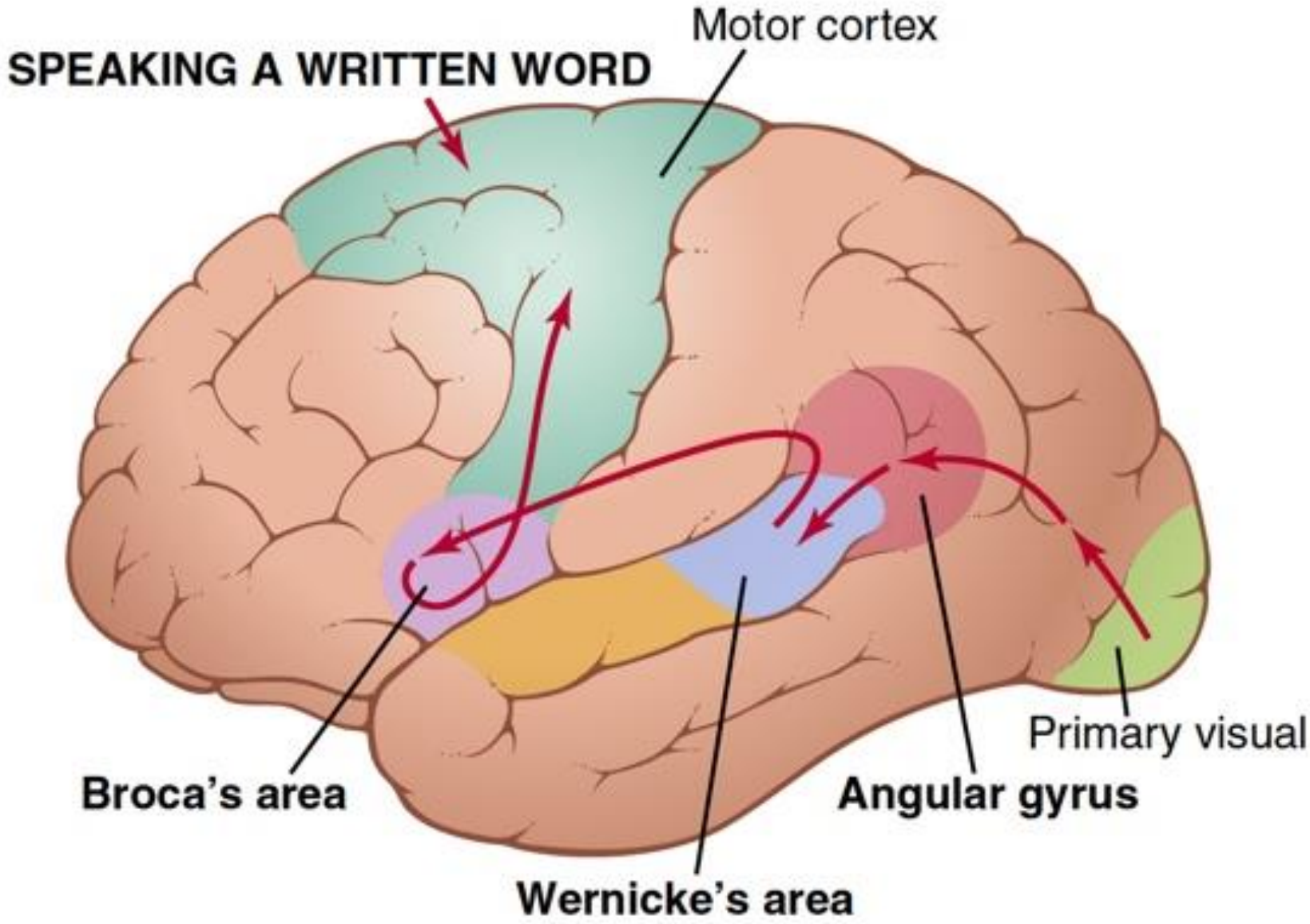
- If this region is destroyed while Wernicke's area in the temporal lobe is still intact, the person can still interpret auditory experiences as usual, but the stream of visual experiences passing into Wernicke's area from the visual cortex is mainly blocked.
- Therefore, the person may be able to see words and even know that they are words but may not be able to interpret their meanings.
- This condition is called alexia, or word blindness. The term "dyslexia" is used to describe difficulty in learning about written language.

Broca’s area

- This area also works in close association with the Wernicke.

- This speech area is responsible for **formation of words** by exciting simultaneously the laryngeal muscles, respiratory muscles, and muscles of the mouth.


SPEAKING A HEARD WORD
Motor cortex
Arcuate fasciculus
Broca's area
Primary auditory area
Wernicke's area


SPEAKING A WRITTEN WORD
Motor cortex
Broca's area
Wernicke's area
Angular gyrus
Primary visual

Sensory aspect of communication

- destruction of portions of the auditory or visual association areas of the cortex can result in the inability to understand the spoken or written word.

- These effects are called, respectively, auditory receptive aphasia and visual **receptive aphasia** or, more commonly, word deafness and word blindness (also called alexia).

Global aphasia

- When the lesion in Wernicke's area is widespread and extends (1) backward into the angular gyrus region, (2) inferiorly into the lower areas of the temporal lobe, and (3) superiorly into the superior border of the sylvian fissure, the person is likely to be almost totally demented for language understanding or communication and therefore is said to have global aphasia.

Motor aphasia

- Sometimes a person is capable of deciding what he or she wants to say but cannot make the vocal system emit words instead of noises.
- This effect, called motor aphasia, results from damage to **Broca's** speech area, which lies in the prefrontal and premotor facial regions of the cerebral cortex—about 95% of the time in the left hemisphere.

Articulation

- the muscular movements of the mouth, tongue, larynx, vocal cords.
- The facial and laryngeal regions of the motor cortex activate these muscles, and the cerebellum, basal ganglia, and sensory cortex all help to control the sequences and intensities of muscle contractions.
- Destruction of any of these regions can cause either total or partial inability to speak distinctly.

The dominant hemisphere

- The general interpretative functions of Wernicke's area and the angular gyrus, as well as the functions of the speech and motor control areas (rt vs lt handedness), are usually much **more highly developed in one cerebral hemisphere** than in the other. Therefore, this hemisphere is called the dominant hemisphere.
- In about 95% of all people, the left hemisphere is the dominant one, and in the remaining 5%, either both sides develop simultaneously to have dual function or, more rarely, the right side alone becomes highly developed, with full dominance.

The dominant hemisphere

- Although **the interpretative areas** of the temporal lobe and angular gyrus, as well as many of the motor areas, are usually highly developed in only the left hemisphere, these areas **receive sensory information from both hemispheres and are also capable of controlling motor activities in both** hemispheres. For this purpose, they use mainly fiber pathways in the corpus callosum for communication between the two hemispheres.

The nondominant hemisphere

- studies in patients with damage to the nondominant hemisphere have suggested that this hemisphere may be especially important for understanding and interpreting music, nonverbal visual experiences (especially visual patterns), spatial relations between the person and their surroundings, the significance of “body language” and intonations of people’s voices, and probably many somatic experiences related to use of the limbs and hands.

Prefrontal association area

- it receives strong input through a massive subcortical bundle of nerve fibers connecting the parieto-occipitotemporal association area with the prefrontal association area.
- Through this bundle, the prefrontal cortex receives much preanalyzed sensory information, especially information on the spatial coordinates of the body that is necessary for planning effective movements.

Prefrontal association area

- Much of the output from the prefrontal area into the motor control system passes through the caudate portion of the basal ganglia–thalamic feedback circuit for motor planning, which provides many of the sequential and parallel components of movement stimulation.

- It is important for **elaboration of thoughts**, and it is said to store on a short-term basis “working memories” that are used to combine new thoughts while they are entering the brain.

Prefrontal association area

- studies in patients who had prefrontal lobotomy showed the following mental changes:
- 1. The patients lost their ability to solve complex problems.
- 2. They became unable to string together sequential tasks to reach complex goals.
- 3. They became unable to learn to do several parallel tasks at the same time.
- 4. Their level of aggressiveness decreased, sometimes markedly, and they often lost ambition.

Prefrontal association area

- 5. Their social responses were often inappropriate for the occasion, often including loss of morals and little reticence in relation to sexual activity and excretion.
- 6. The patients could still talk and comprehend language, but they were unable to carry through any long trains of thought, and their moods changed rapidly from sweetness to rage to exhilaration to madness.
- 7. The patients could also still perform most of the usual patterns of motor function that they had performed throughout life, but often without purpose.

Prefrontal association area

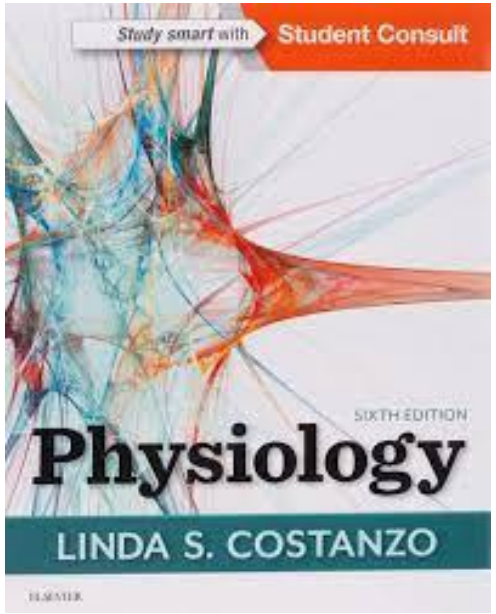
- By combining all these temporary bits of working memory, we have the abilities to do the following:
- (1) prognosticate; (2) plan for the future; (3) delay action in response to incoming sensory signals so that the sensory information can be weighed until the best course of response is decided; (4) consider the consequences of motor actions before they are performed; (5) solve complicated mathematical, legal, or philosophical problems; (6) correlate all avenues of information in diagnosing rare diseases; and (7) control our activities in accord with moral laws.

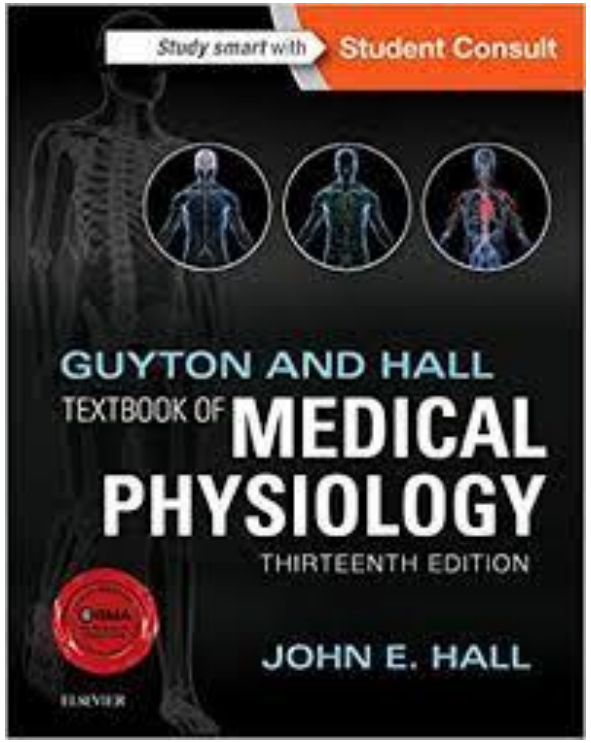
Corpus callosum

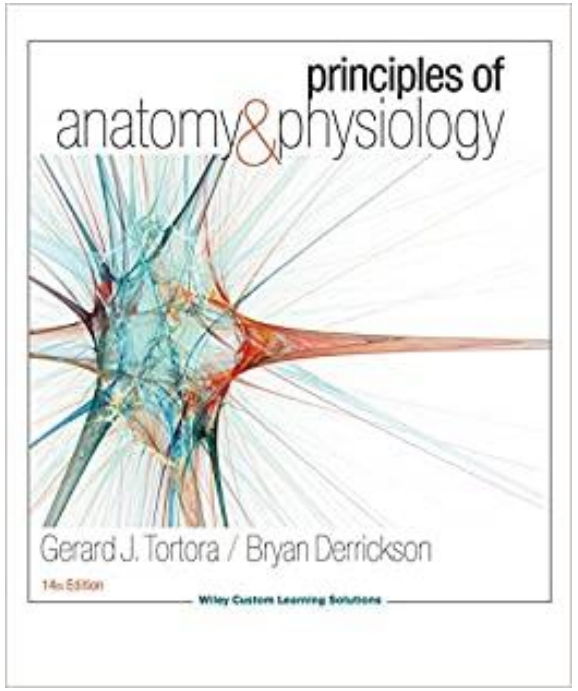
- Fibers in the corpus callosum provide abundant bidirectional neural connections between most of the cortical areas of the two cerebral hemispheres, except for the anterior portions of the temporal lobes; these temporal areas, including especially the amygdala, are interconnected by fibers that pass through the anterior commissure.
- One of the functions of the corpus callosum and the anterior commissure is to make information stored in the cortex of one hemisphere available to corresponding cortical areas of the opposite hemisphere.

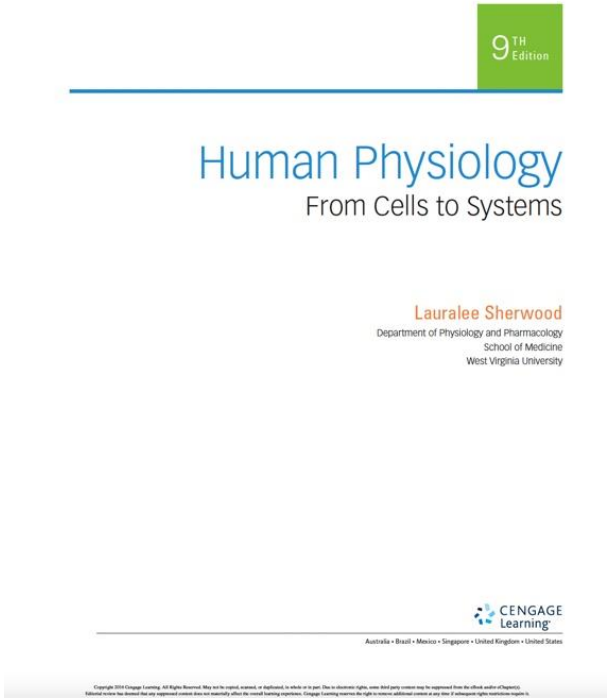
- the two halves of the brain have independent capabilities for consciousness, memory storage, communication, and control of motor activities.
- The corpus callosum is **required for the two sides to operate cooperatively** at the superficial subconscious level, and the anterior commissure plays an important additional role in **unifying the emotional responses** of the two sides of the brain.

References


Study smart with
Student Consult
SIXTH EDITION
Physiology
LINDA S. COSTANZO
ELSEVIER


Study smart with
Student Consult
GUYTON AND HALL
TEXTBOOK OF MEDICAL
PHYSIOLOGY
THIRTEENTH EDITION
JOHN E. HALL
ELSEVIER


principles of
anatomy & physiology
Gerard J. Tortora / Bryan Derrickson
14th Edition
Wiley Custom Learning Solutions


9TH Edition
Human Physiology
From Cells to Systems
Lauralee Sherwood
Department of Physiology and Pharmacology
School of Medicine
West Virginia University
CENGAGE Learning
Australia • Brazil • Mexico • Singapore • United Kingdom • United States

Thank you