CNS
Doctor 2021

Physiology

Modified (18)

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Neurophysiology

Cerebral cortex

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Thoughts

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

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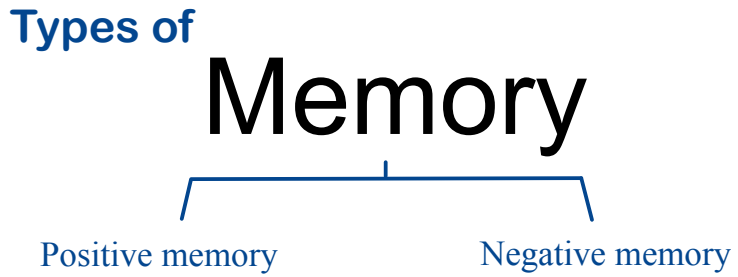
We might formulate a provisional definition of a thought in terms of neural activity as follows: A thought results from a "pattern" of stimulation of many parts of the nervous system at the same time, probably involving most importantly the cerebral cortex, thalamus, limbic system, and upper reticular formation of the brain stem. This theory is called the **holistic theory** of thoughts

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.



- 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. Negative Memory
- 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 means that the transmission of signals between neurons is [enhanced] or [made more efficient]

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

Which refers to increased response with positive stimuli.

Memory

- Incoming information within the CNS can be directed to one of two destinations: it may either be **ignored** through a mechanism called Habituation, typically associated with negative memories, or it can trigger an **increased response** known as Sensitization, often linked with positive memories.

- The presence of **reward** or **punishment** responses determines whether information will undergo sensitization or habituation. If reward or punishment is present, sensitization develops, leading to positive memory. If reward or punishment is not present, the CNS will ignore the information through habituation.

Classification of memory

Based on the **duration** 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.

Short term memory

Reverberatory neuronal circuit

- 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.+ repeat 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.

Which occurs at synapses that lie on terminal nerve fibrils immediately before these fibrils synapse with a subsequent neuron. The neurotransmitter chemicals secreted at such terminals frequently cause facilitation or inhibition lasting for seconds up to several minutes. Circuits of this type could lead to short-term memory.
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- the doctor didn't mention this theory at all.

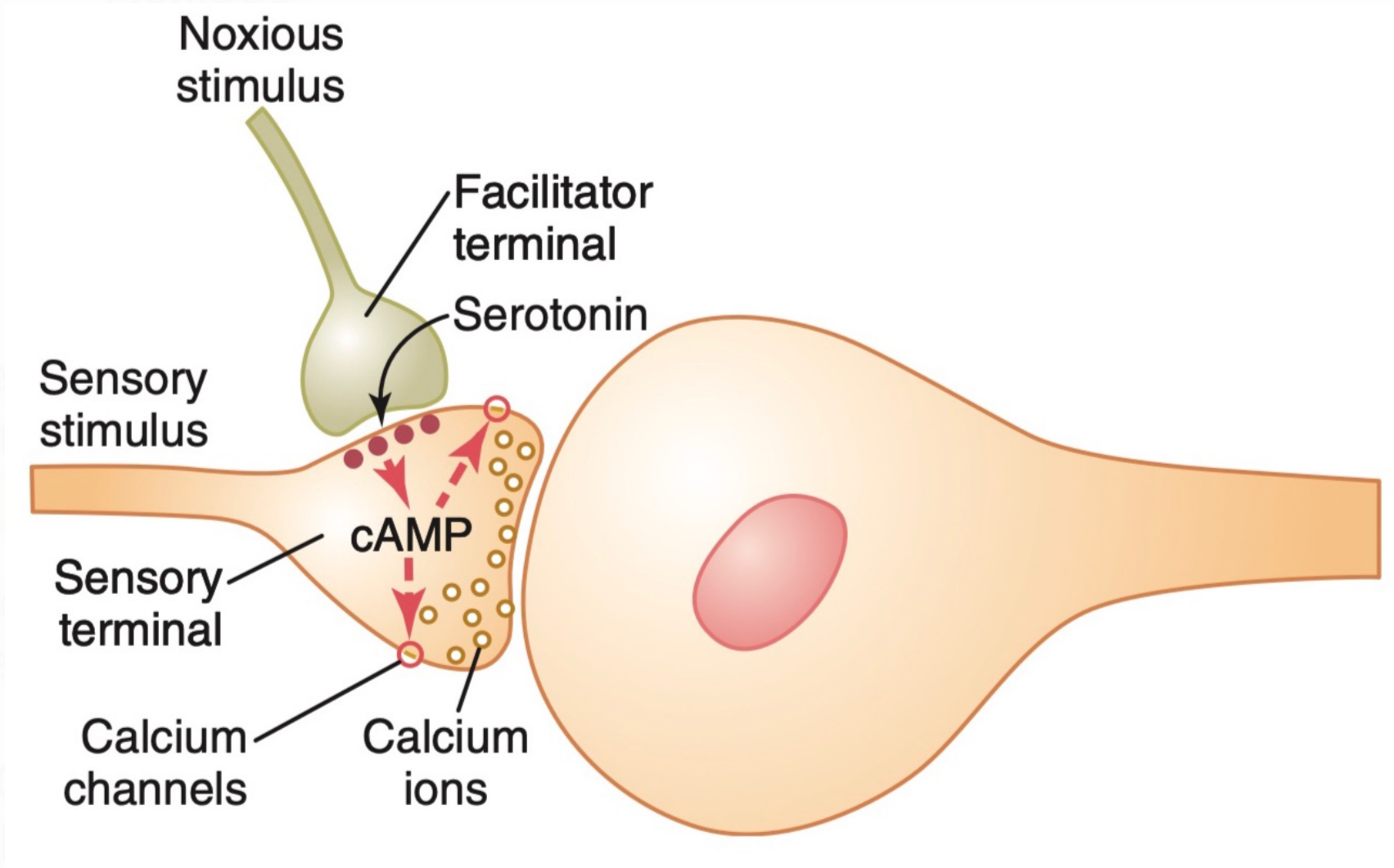
Intermediate long term memory

Chemical changes

- 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.

Memory system that has been discovered in the snail.



Molecular mechanisms of intermediate memory

- Mechanism for Habituation.

  involves the stimulation of the sensory terminal neuron **without** concurrent activation of facilitatory neurons → the sensory terminal neuron's response gradually decreases with each repeated presentation of the stimulus

- 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.

Without the entry of calcium ions, there is NO signal transmission because Ca++ is the primary stimulus for transmitter release.

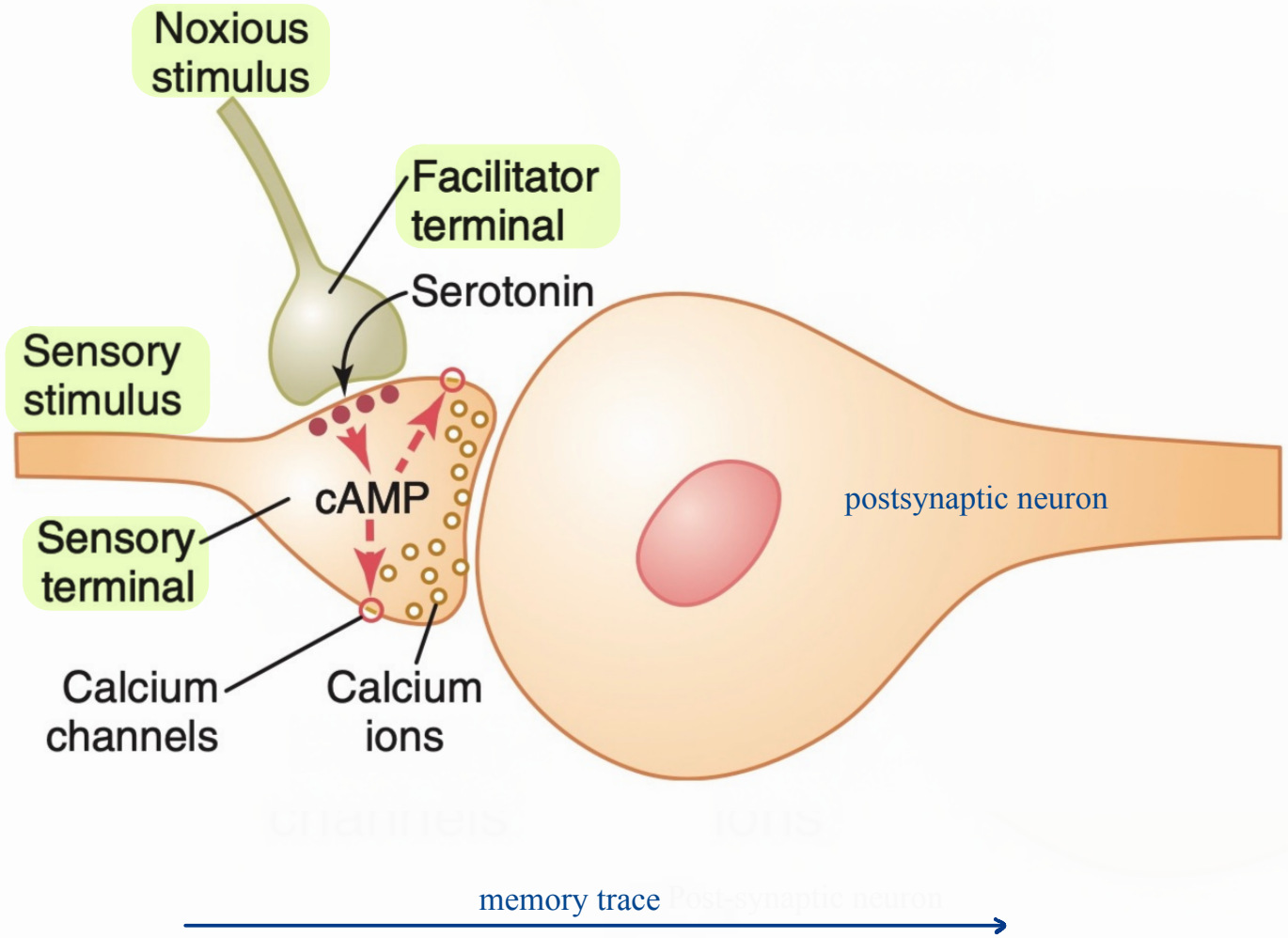
Molecular mechanisms of intermediate memory

- 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.

- The facilitatory terminal is activated by the stimulus of **noxious stimuli (pain)** because, in order to convert the memory from short-term to intermediate long-term memory, we need to link it to either punishment or reward. In this case, it's the noxious stimulus that causes the facilitation.

How to convert short term memory into intermediate long term memory ?



We have two synaptic terminals:

1. Sensory terminal → sensory stimulus
2. Facilitator terminal → noxious stimulus

- When the sensory terminal is stimulated repeatedly but without stimulation of the facilitator terminal, signal transmission at first is great, but it becomes less and less intense with repeated stimulation until transmission almost ceases. This phenomenon is **habituation**, It is a type of negative memory, thus resulting in **short term memory.**

- If a noxious (pain) stimulus excites the **facilitator terminal** at the same time that the sensory terminal is stimulated, instead of the transmitted signal into the postsynaptic neuron becoming progressively weaker, the ease of transmission becomes stronger and stronger, and it will remain strong for minutes, hours, days, or, with more intense training, up to about 3 weeks even without further stimulation of the facilitator terminal - **intermediate long term memory.**

Molecular mechanisms of intermediate memory

- In the case of facilitation, the molecular mechanism is believed to be the following:

① Stimulation of the facilitator presynaptic terminal, along with the sensory terminal, leads to the release of **serotonin**.

② Serotonin then binds to receptors on the sensory terminal membrane, activating adenyl cyclase & increasing **cAMP** production.

③ Elevated cAMP levels activate a **protein kinase**, resulting in the inhibition of **potassium channels** in the sensory synaptic terminal membrane. This inhibition **prolongs the action potential in the terminal**.

④ Prolonged action potential leads to increased activation of calcium channels, allowing a significant influx of calcium ions.

⑤ Increased calcium ion concentrations enhances neurotransmitters release, facilitating synaptic transmission to the subsequent neuron (more excitation)

Long term memory

Structural changes

- 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. The growth factors increase the synaptic connections. The more the synapses, the stronger is the transmission and maybe the longer is the transmission.
- 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.

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.

- When performing intellectual tasks, working memory is crucial. It facilitates the simultaneous processing of parallel thoughts & actions or the sequential linking of related actions. By organizing and integrating these thoughts and actions, we can develop a cohesive plan or holistic understanding of our thinking process.

- Working memory is a hot research topic, especially within the field of Alzheimer’s disease.

Classification of memory

Based on the **type of information stored**

- **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

Classification of memory

Declarative memory (الذاكرة التقريرية):

- It involves recalling a wide range of information types, including language, concepts, facts, and meanings. This encompasses the ability to remember details such as the names of ancestors, historical events, significant dates, and other factual knowledge

Skill memory:

- The acquisition of skill memory typically involves **repetitive practice** and the refinement of movements through trial-and-error. As the skill is repeatedly performed, the brain develops neural pathways and connections that optimize the coordination of the relevant muscle groups involved in the task. Once a skill is acquired and stored, it can be performed without conscious awareness.

- it's mostly stored in the subcortical areas (those related to cerebellum).

Not required. Not required... Not required.. Not required.. **Extra information I'd love to mention** *Not required. Not required... Not required....*

Declarative memory can be further divided into two subtypes:

- **Episodic Memory (ذاكرة عَرَضية):** involves the recollection of specific events and personal experiences. It enables us to remember details such as where and when an event occurred, the people involved, and the emotions associated with it.

- **Semantic Memory (ذاكرة دلالية):** refers to general knowledge and facts about the world, independent of personal experiences. It includes information about language, concepts, facts, and meanings. For instance, knowing that Paris is the capital of France or that water boils at 100 degrees Celsius and so on.

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.
- Repetition is the key.

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.

Memory consolidation

- One of the most important features of consolidation is that new memories are **codified** into different classes of information. The thalamus is responsible for the codifying process
- 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.

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.

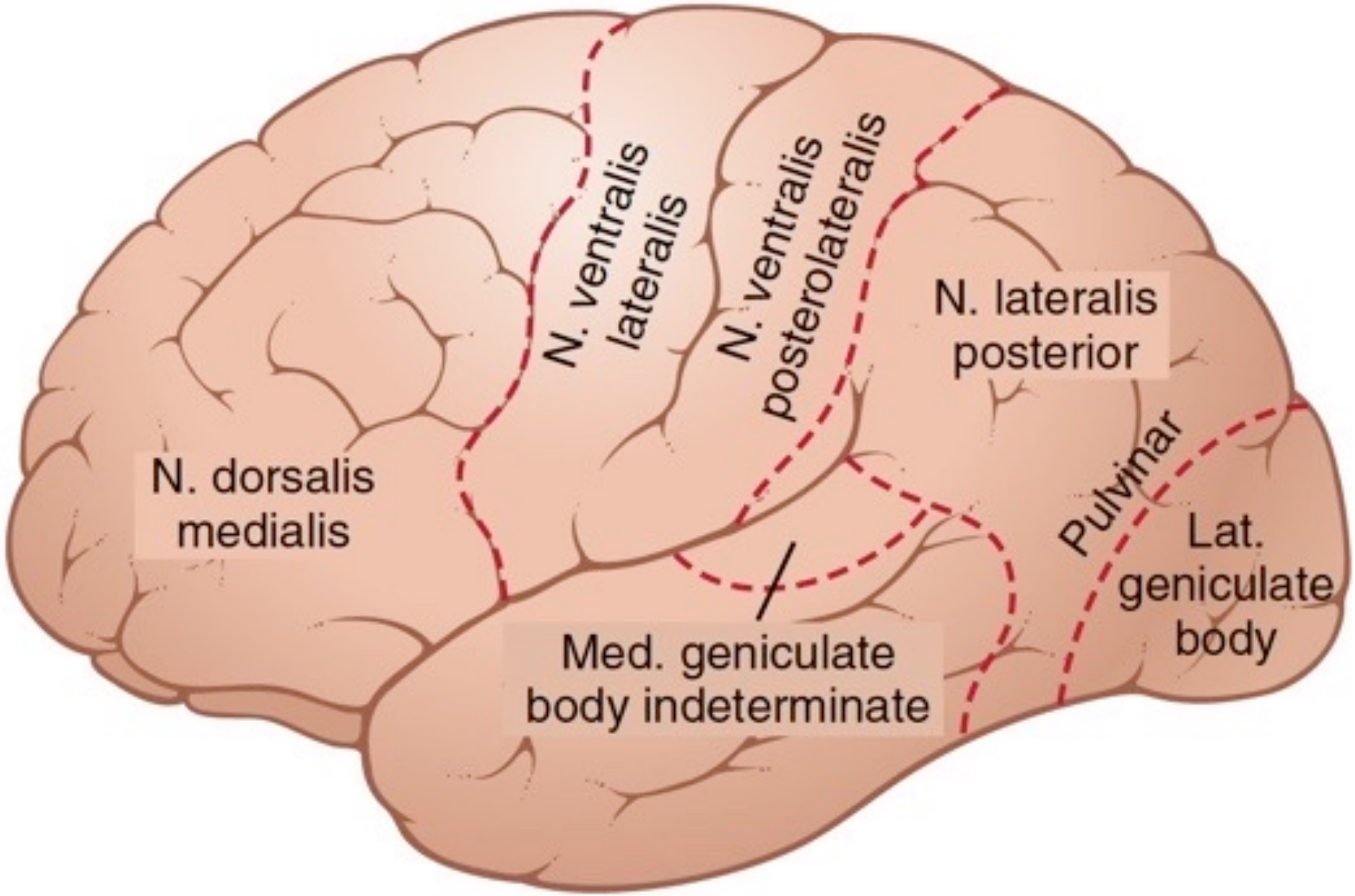
  - Because this kind of information is stored in subcortical regions, most likely the cerebellum.

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.

Because the thalamus and the cortex come together to form a unified system known as the thalamocortical system.


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 **To the cortex and vise versa.**
- 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

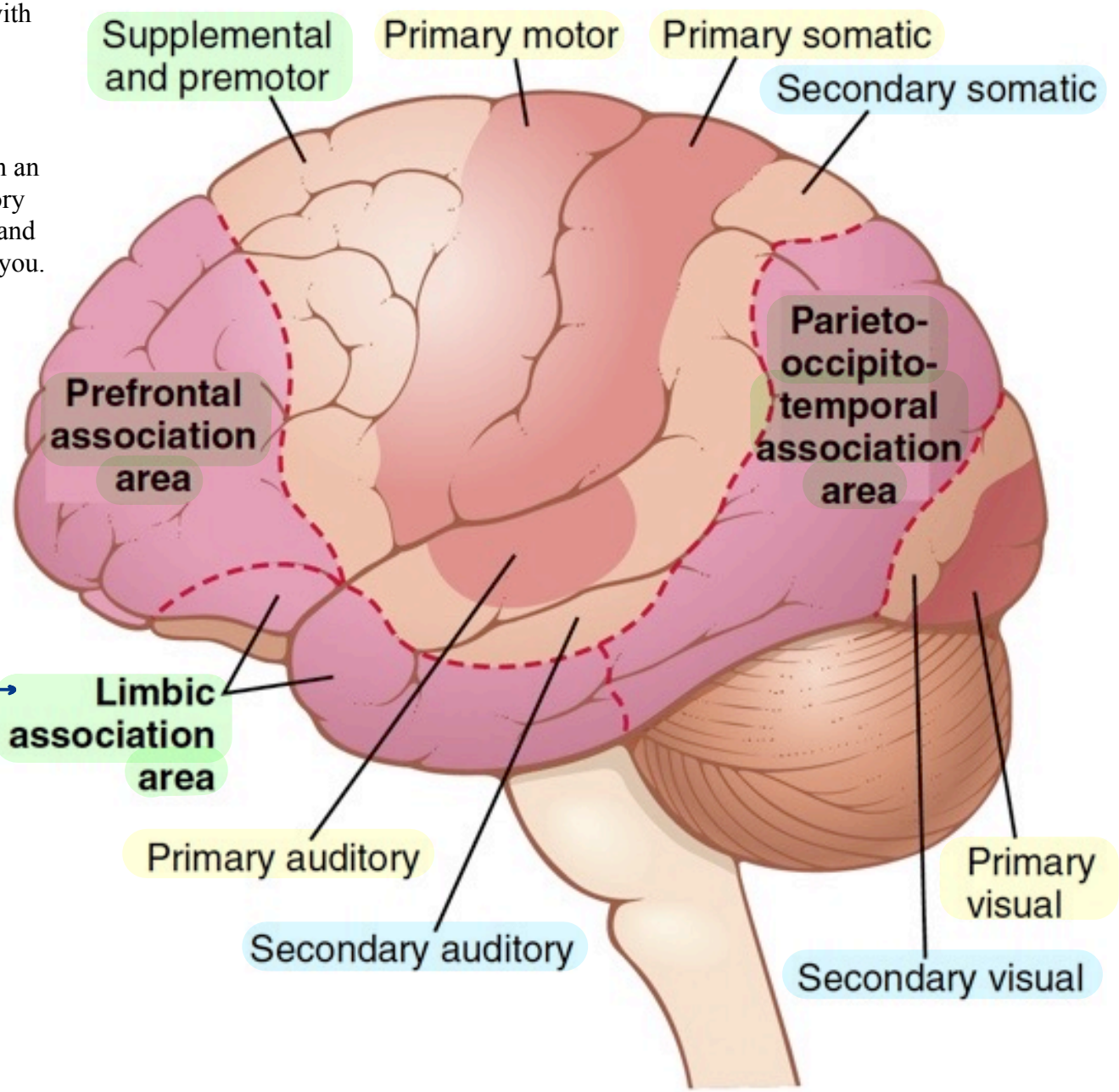
- The **primary** motor areas have direct connections with specific muscles for causing discrete muscle movements. The primary sensory areas detect specific sensations transmitted to the brain from peripheral sensory organs.
- The **secondary** areas make sense out of the signals in the primary areas (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.

Primary areas → Are in communication with the periphery.

Secondary areas → Give a meaning for the information. For example, when you touch an object, the primary area receives the sensory input, while the secondary area interprets and communicates the texture of the object to you.

The association areas → Integrate different sensory information together in order to give this holistic picture

Limbic association area integrates information related to emotions, behavior & motivation.



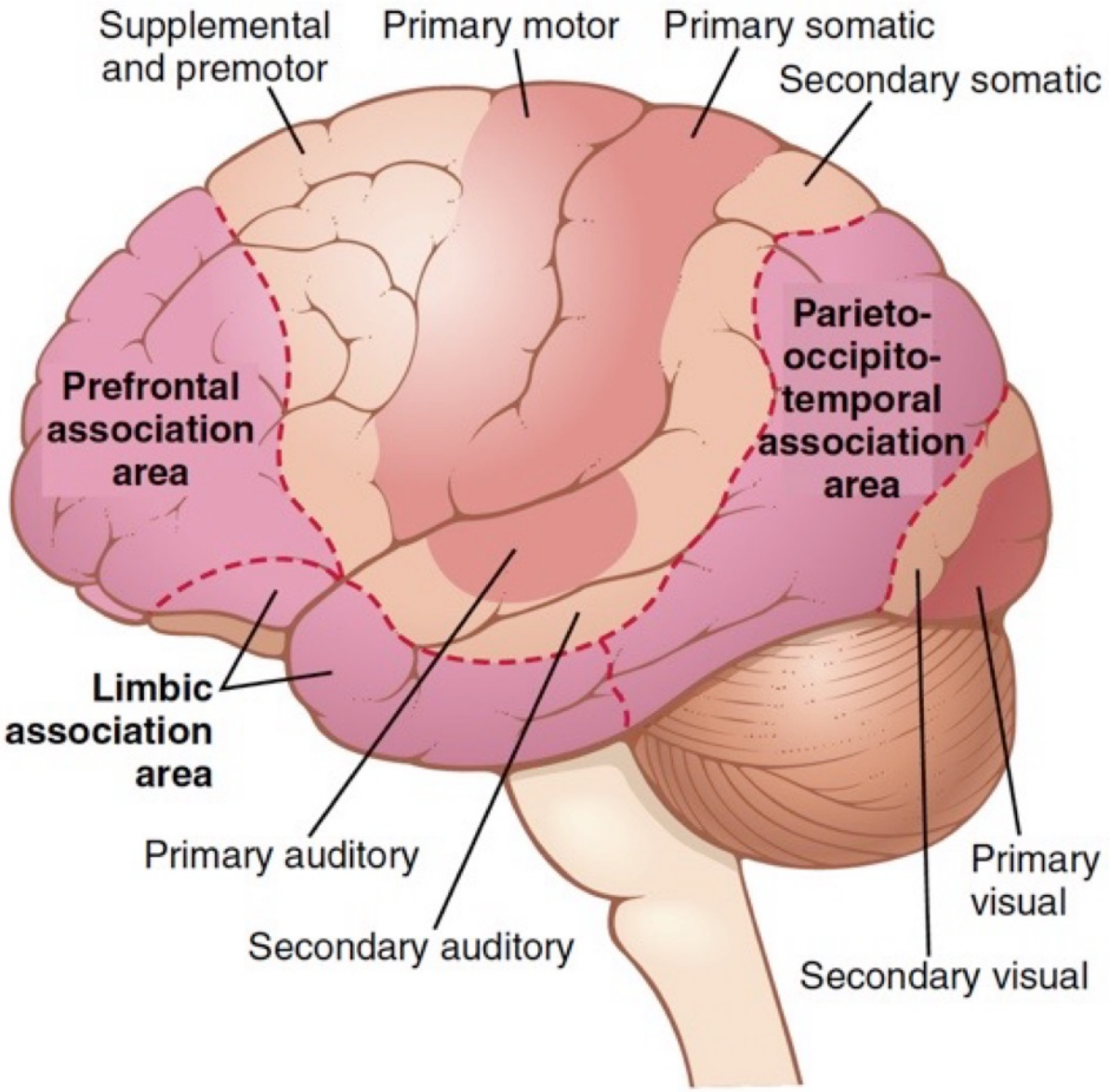
Yet, even within association areas, there are specialized regions. Key association areas include:

(1) The parieto-occipitotemporal association area.

(2) The prefrontal association area.

(3) The limbic association area.

These areas are further subdivided into subareas.



Parieto-occipito-temporal association area

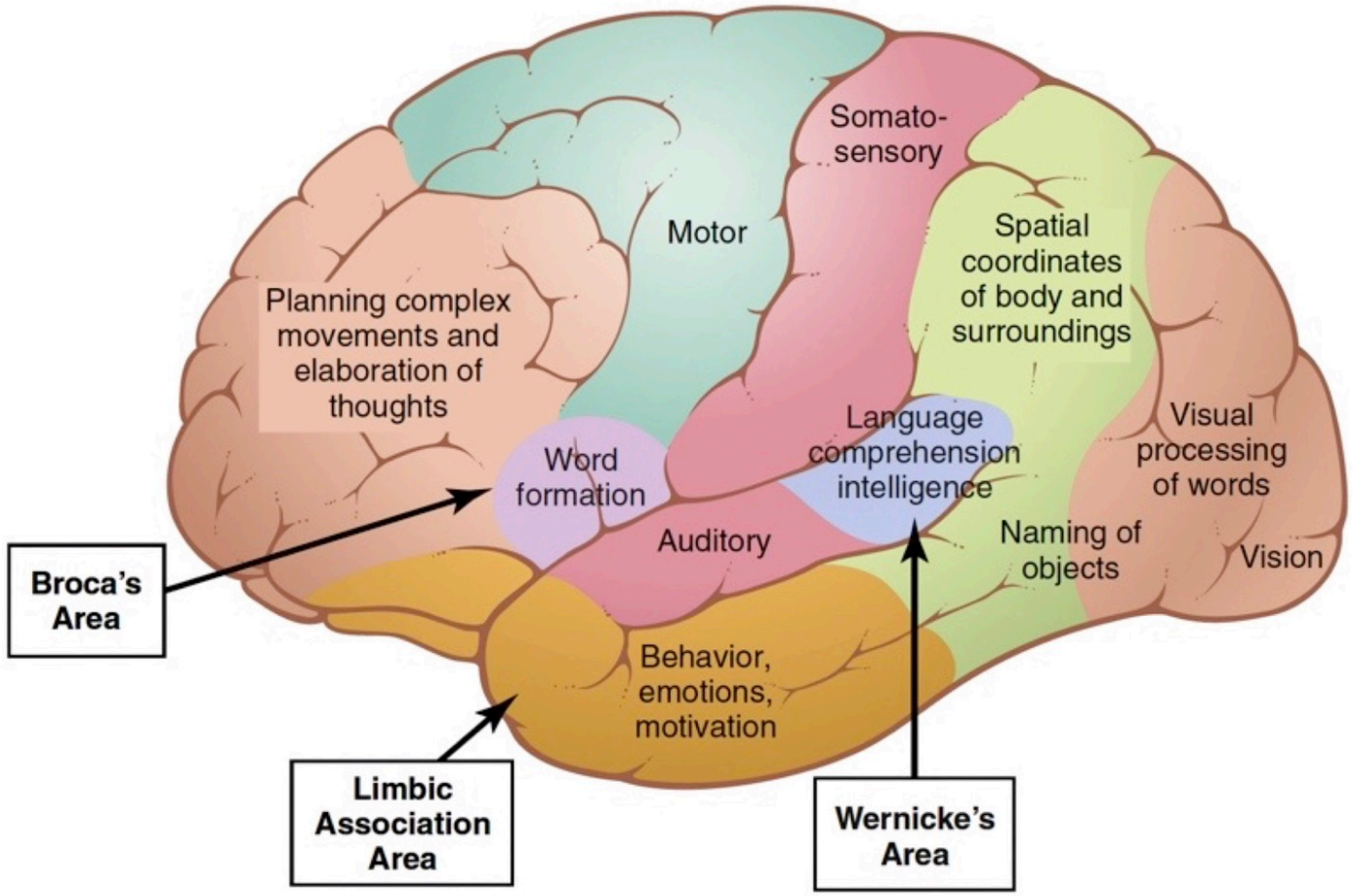
- Functional subareas:

- 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.

- It receives **visual sensory information** from the posterior occipital cortex and simultaneous **somatosensory information** from the anterior parietal cortex. It processes this information to compute the coordinates of the visual, auditory, and bodily surroundings.

Association areas

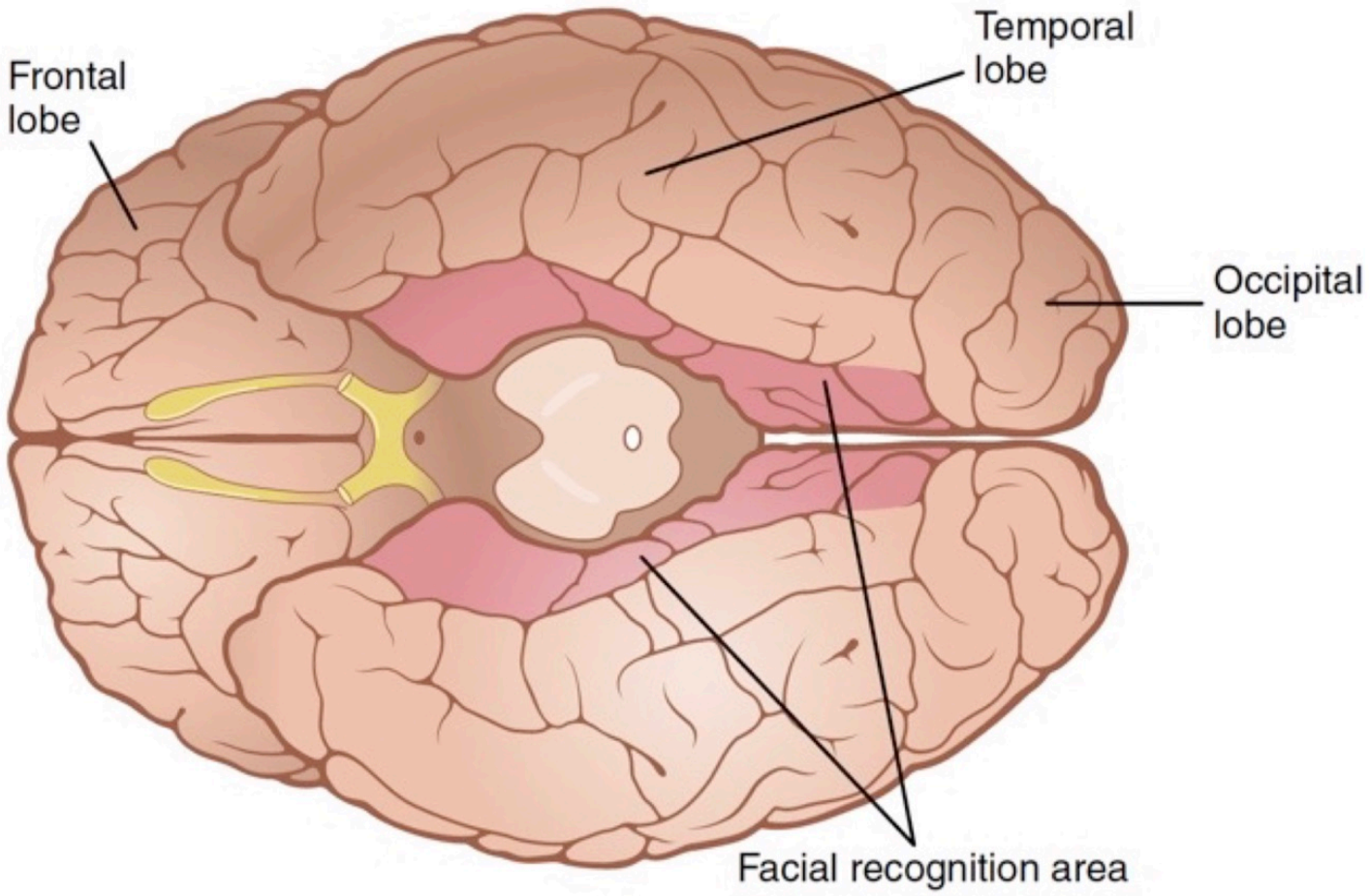
The location of these areas can give you an idea of their function. For example The parieto-occipitotemporal association area is located in the parietal and occipital regions of the cortex, surrounded by the somatosensory, visual, and auditory cortices. This area plays a crucial role in providing interpretative meaning for signals received from the nearby sensory areas.



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.

Facial recognition areas



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

- Limbic system is involved since seeing certain faces is linked to certain emotional responses.

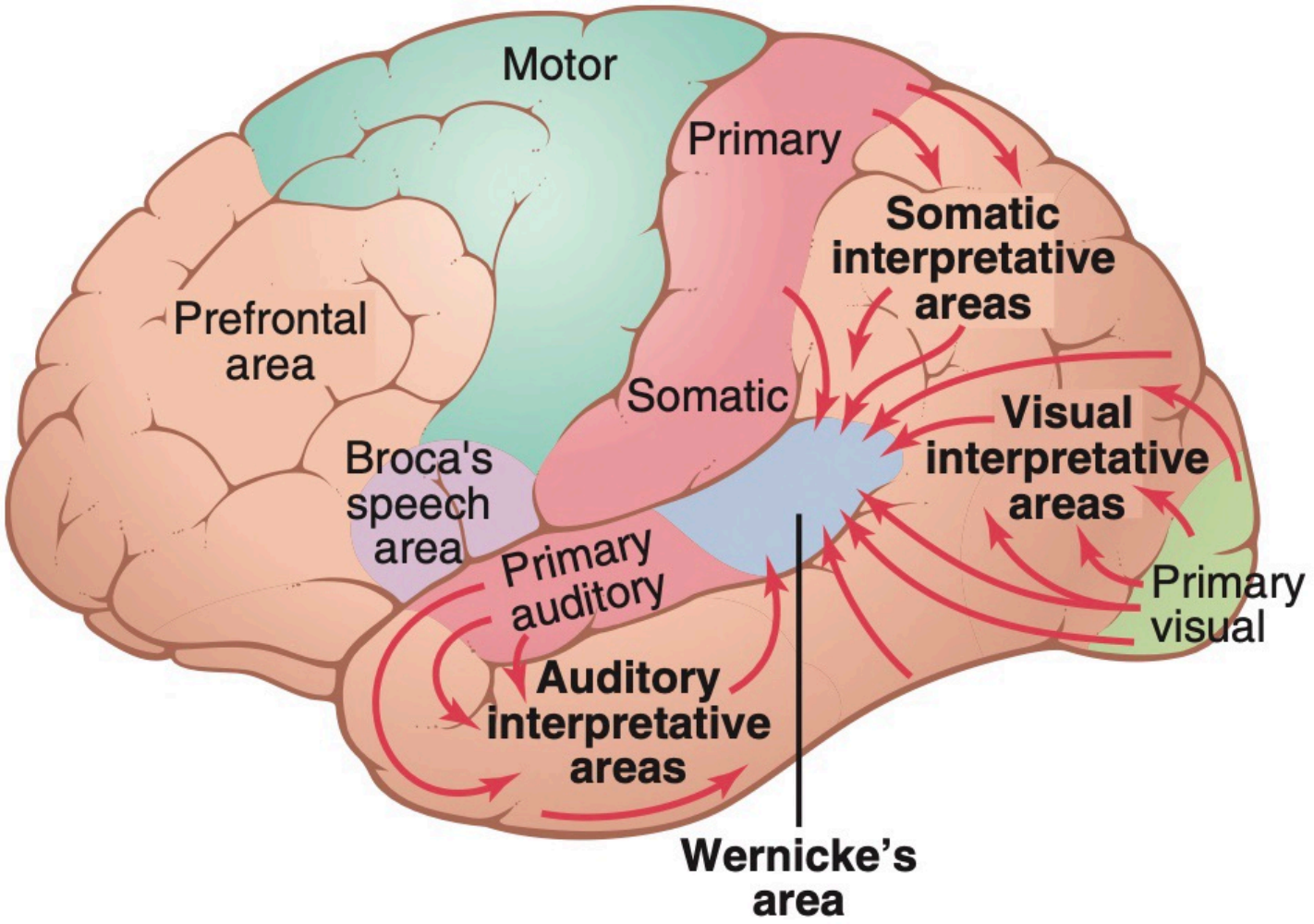
Wernicke’s area

- 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.

- Without Wernicke's area, our ability to communicate and understand what we hear or see would be impaired, leading to difficulties in expressing ourselves and engaging in coherent thinking.
- Language plays a crucial role in thinking. Generally, our memories are stored more as language than as images or mere sounds.

- Note the wernicke’s area receives many inputs from many areas. These inputs contribute to the coordination of **somatic**, **auditory**, and **visual** association areas, forming a comprehensive mechanism for interpreting sensory experiences. All of these inputs converge onto Wernicke’s area, situated in the posterosuperior portion of the temporal lobe.



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.

- The patient may exhibit a condition known as '**word salad**', where they are able to articulate or verbalize words, but the words may lack coherence or meaningful connection.

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.

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.

NOTE: due to discrepancies between what we learned in anatomy about global aphasia (which includes both Broca's and Wernicke's areas), the doctor won't ask about it in the exam.

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.

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.

Motor aphasia

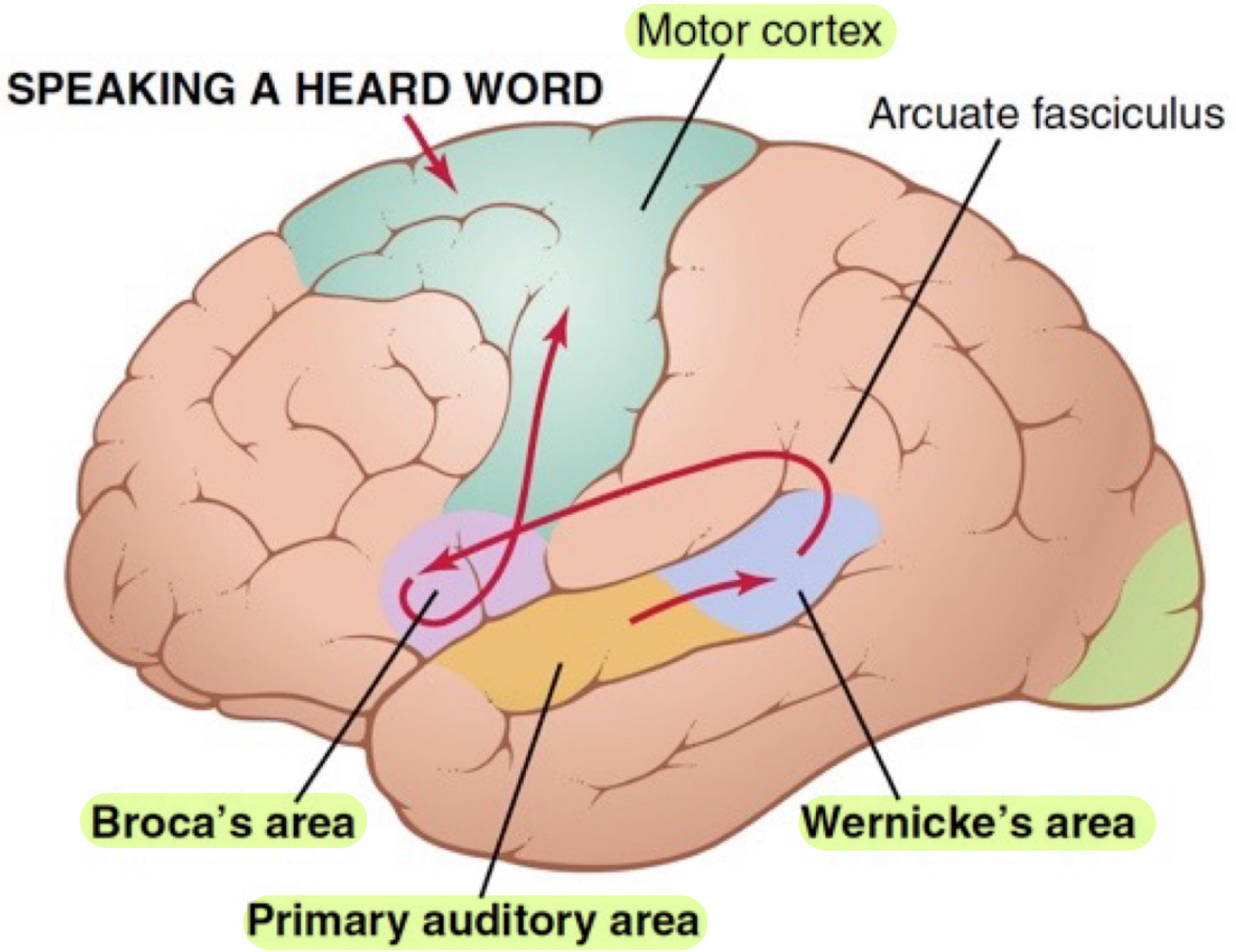
Expressive aphasia

- 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.

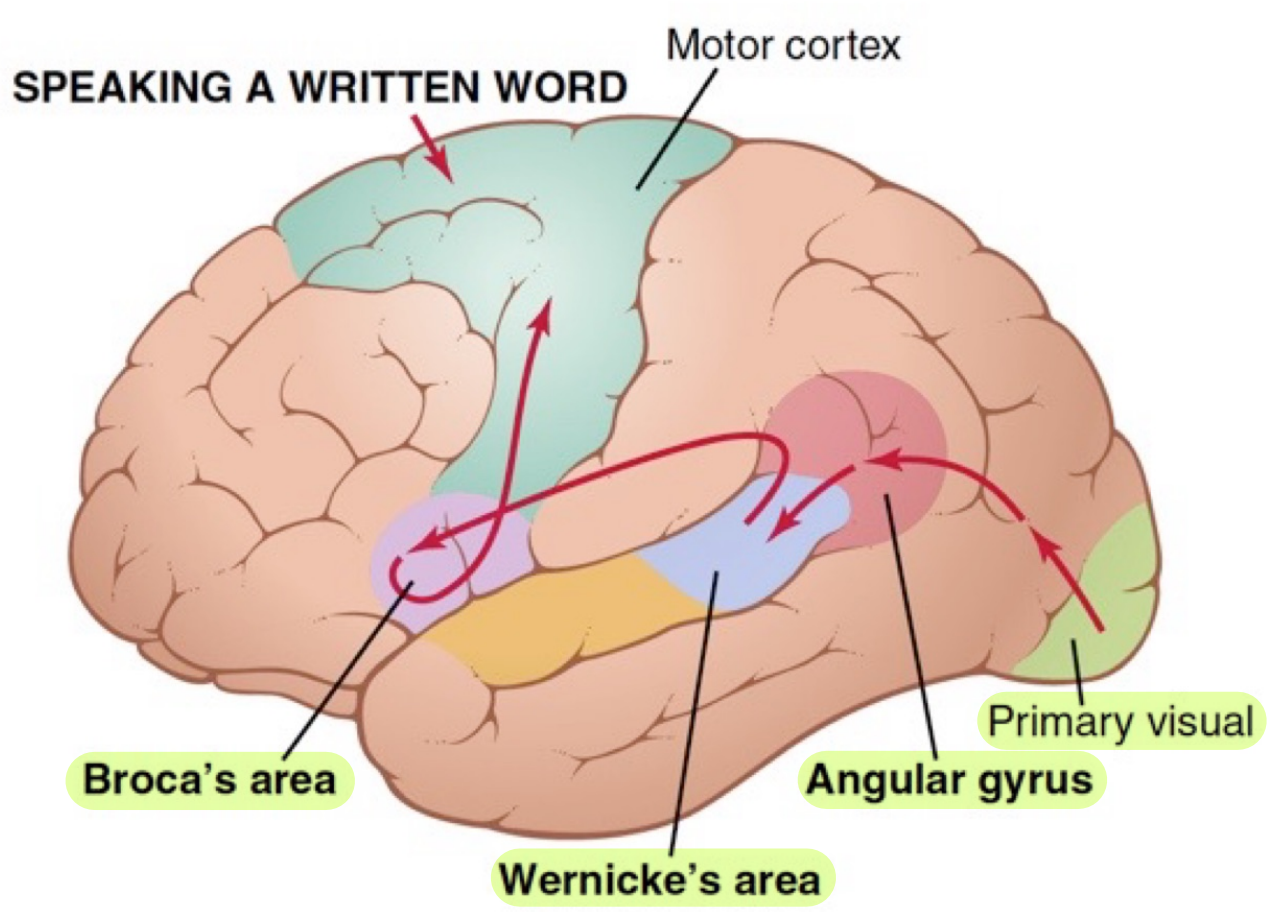
Articulation

- 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.

1. The information is received through auditory neurons.
2. It is then processed in Wernicke's area and sent to Broca's area for word selection and formulation.
3. Finally, it reaches the primary motor area.



For written words, the signals do not transmit directly from visual area to Wernicke's & Broca's areas; instead, they might first pass through the **angular gyrus**



Angular gyrus area

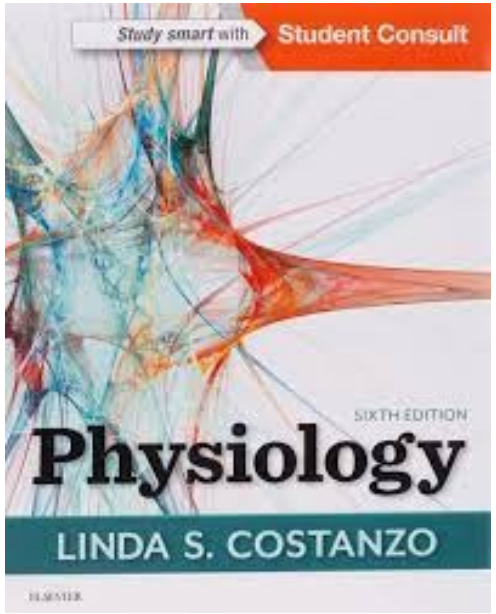
- angular gyrus area is needed to make meaning out of the **visually** perceived words.

- 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.

References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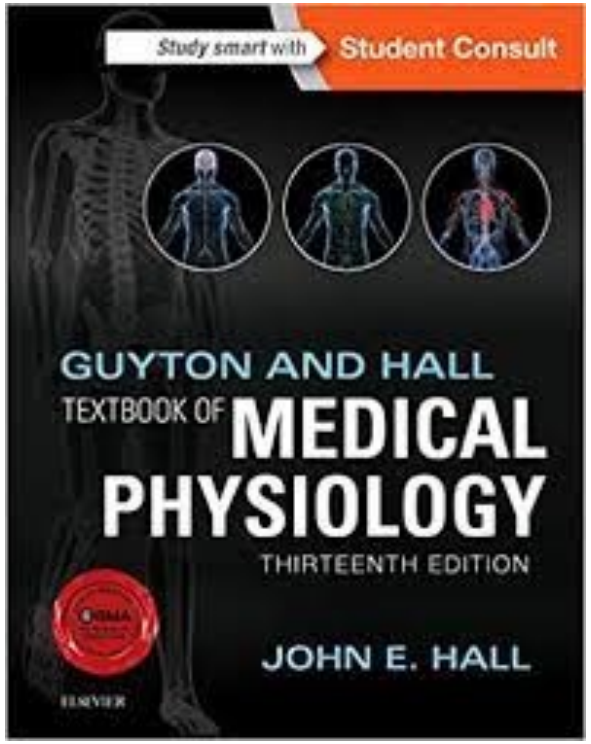
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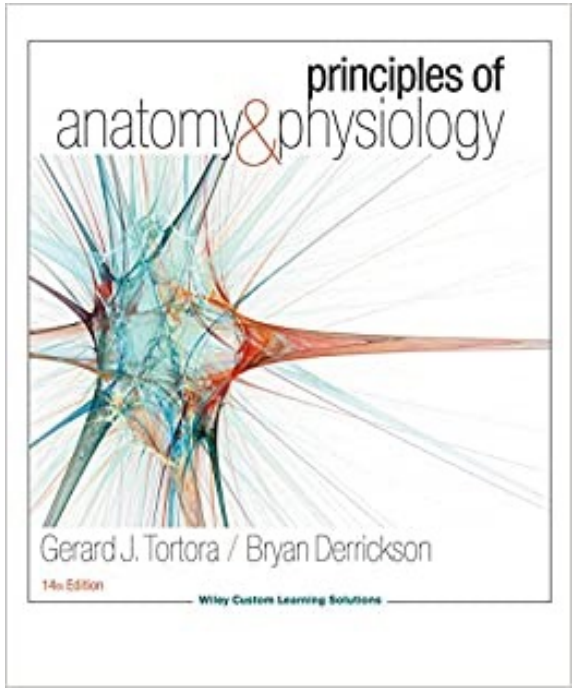
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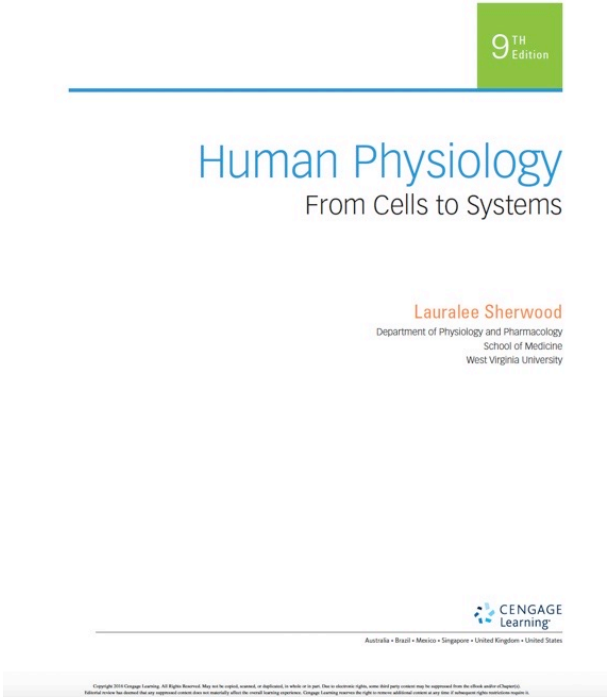
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