Neuro-circuitry of cognition

Dr. Bela Kosaras

The topics

Process of Cognition

- Learning
- Thinking
- Cognition

- **Brain's functional activity**
  - Neuronal process of learning
  - Neuronal process of thinking and cognition
  - Neuronal process of expression

- **Expression**
  - Verbal
  - Non-verbal
  - Combined

Human intellectual functions

Cognition

Learning → **Collecting data?**

Thinking

Cognition

→ **Comprehension**

Expression

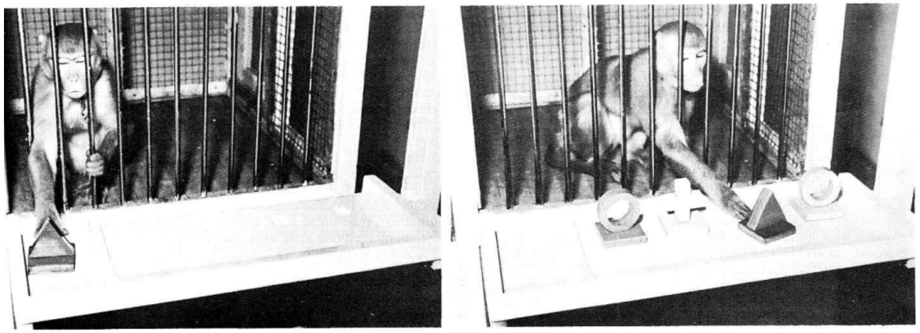
Verbal → speech

Non-verbal → prosody

Combined

Learning

- Animal
  - Circumstantial
  - Practicing
  - Conditioning→ Pavlov, instrumental
  - Perceptual
  - Complete problem solving



Learning-to-learn experiment by Harry F. Harlow.
The monkey has been trained to expect food after lifting an object. In the first picture, the monkey lifts the triangle after having been shown a sample triangular form. In the second picture, taken several minutes later, the monkey selects the triangle from among other forms. The process is repeated with the circle and the cross.

- Human
  - Association
  - Repetition
  - Reinforcement
  - Organization
  - Inhibition
  - Motivation
  - Classical conditioning
  - Verbal learning

Thinking

- Realistic thinking
  - Converge the components
- Problem solving
- Creative
  - Preparation
  - Incubation
  - Illumination
  - Verification
- Autistic
  - Free association
  - Fantasy
  - Dreaming
- Pathological
  - Behavioral disorder
  - Neurosis
  - Psychosis

Thinking is intellectual exertion aimed at finding an answer to a question or a means of achieving a desirable practical goal.

Thinking as internal problem-solving behavior.

Directed thinking
Mnemonic thinking

Autism→ 4 out of 10,000 births
boy dominant
Start at around 2.5 year old
Stops speech progression
Withdrawal, rhythmic body movement
Withdrawal from reality
Reverie, flights of fancy
Daydreaming, delusion, hallucination

Cognition

(Γ)γιγνώσκω-nosco-gnosco-cognosco-

To come to know, to get a knowledge of, to become acquainted with

To ascertain completely by the sense or the mind, to learn, to know,

To recognize, to discover, to perceive, to have acquired knowledge

Γνώμη- understanding

ή γνῶσις - knowledge, cognition

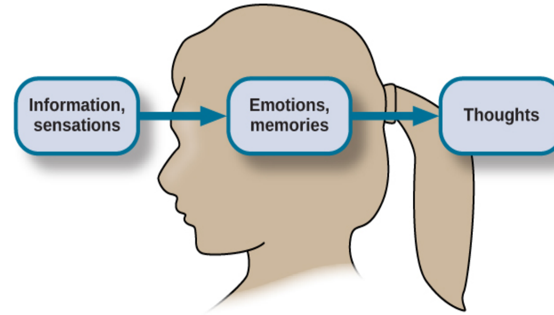
- Definition of cognition:
  - The use of handling of knowledge
  - The mental process involved in knowing, or the act of knowing, which in its completeness includes awareness and judgment.

The role of cognition in perception underlies the importance of knowledge-based processes in making sense of the 'neutrally coded' signals from the eye and other sensory organs.

It seems that man is different from other animals very largely because of the far greater richness of his cognitive processes. Associated with memory of individual events and sophisticated generalization, they allow subtle analogies and explanations – and ability to draw pictures and speak and write.

Cognition

?



Perception of common essence between two things!

"Rasa"!

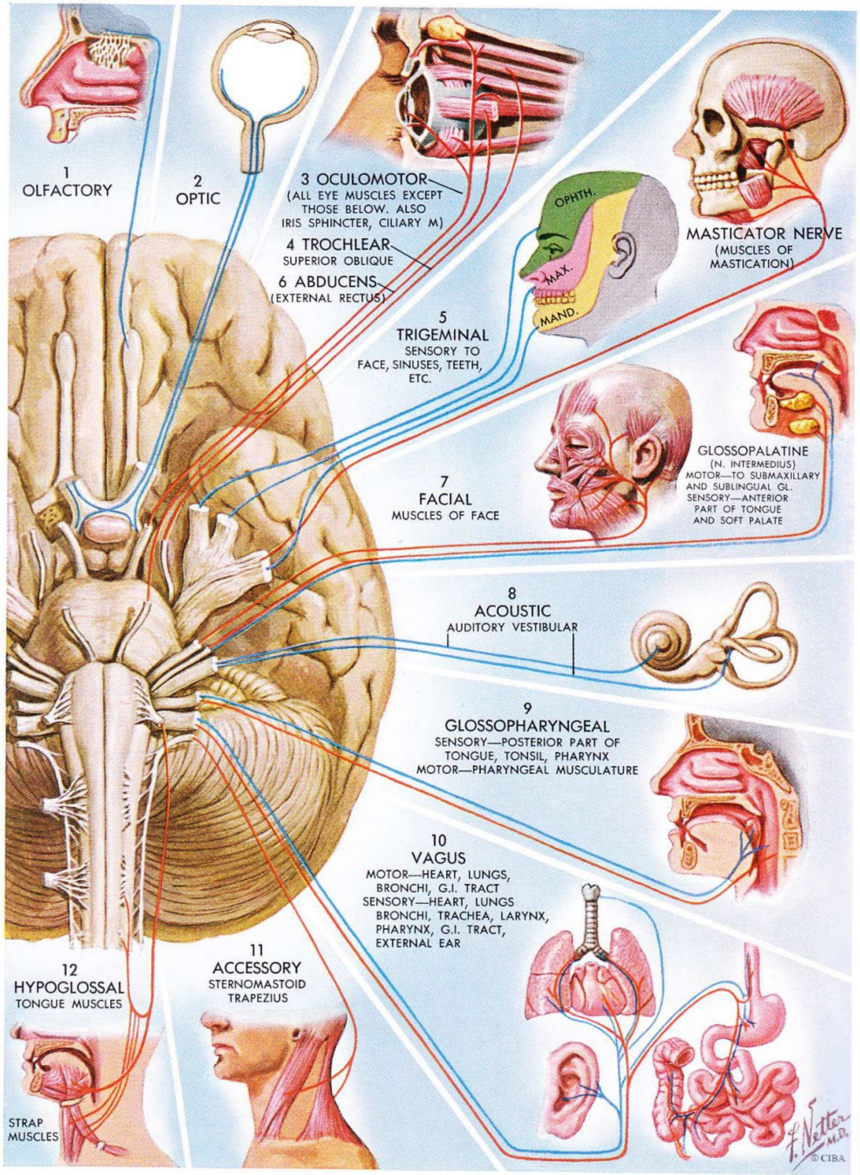
Analogical reasoning
Analogy making
Categorization
Analogy
    single-(pair)– repeated
Pluralization
Phrases
    Be my guest, out of blue, beat around the bushes
    Feel yourself at home, salt on wound, oil on the fire
    eye for an eye, tooth for a tooth

Proverbs
    Many small things make one big thing.
    Soft answer turns angry wrath.
    Fine feathers do not make fine birds.
    Sour grape

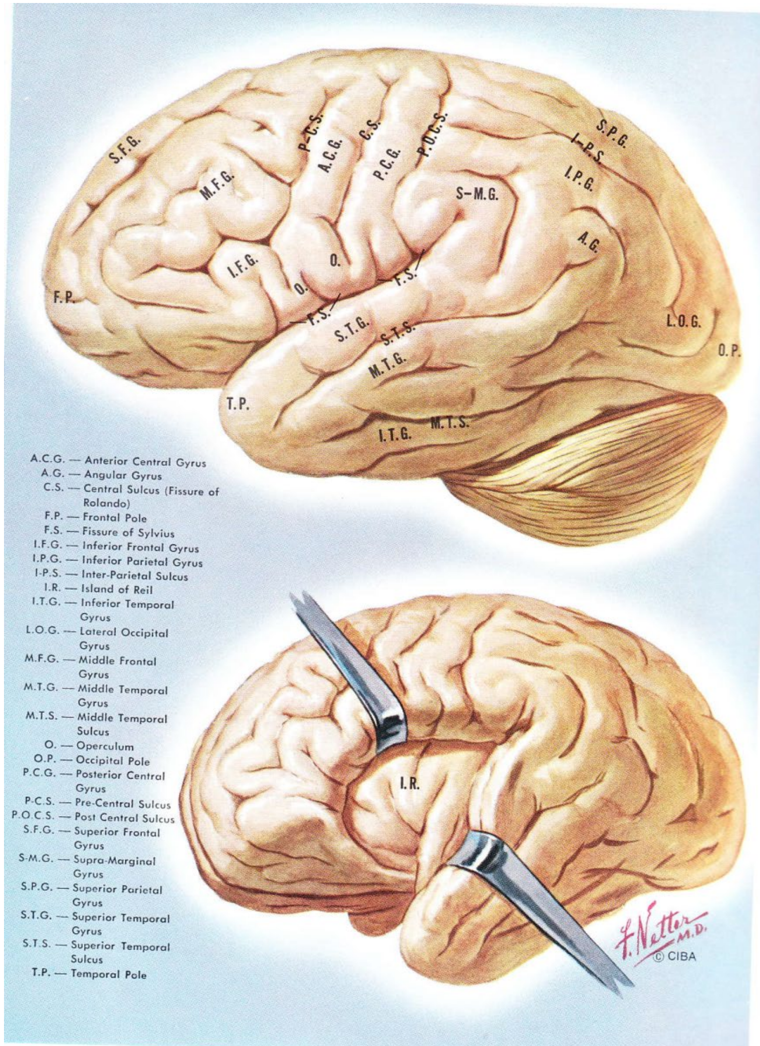
Source of Learning

Stimuli
from the external world

Stimuli
from the internal organs



The BRAIN


S.F.G.
M.F.G.
P-C.S.
A.C.G.
C.S.
P.C.G.
P.O.C.S.
S.P.G.
I-P.S.
I.P.G.
S-M.G.
A.G.
I.F.G.
O.
F.S.
F.P.
S.T.G.
S.T.S.
M.T.G.
L.O.G.
O.P.
T.P.
I.T.G.
M.T.S.
I.R.
A.C.G. — Anterior Central Gyrus
A.G. — Angular Gyrus
C.S. — Central Sulcus (Fissure of Rolando)
F.P. — Frontal Pole
F.S. — Fissure of Sylvius
I.F.G. — Inferior Frontal Gyrus
I.P.G. — Inferior Parietal Gyrus
I-P.S. — Inter-Parietal Sulcus
I.R. — Island of Reil
I.T.G. — Inferior Temporal Gyrus
L.O.G. — Lateral Occipital Gyrus
M.F.G. — Middle Frontal Gyrus
M.T.G. — Middle Temporal Gyrus
M.T.S. — Middle Temporal Sulcus
O. — Operculum
O.P. — Occipital Pole
P.C.G. — Posterior Central Gyrus
P-C.S. — Pre-Central Sulcus
P.O.C.S. — Post Central Sulcus
S.F.G. — Superior Frontal Gyrus
S-M.G. — Supra-Marginal Gyrus
S.P.G. — Superior Parietal Gyrus
S.T.G. — Superior Temporal Gyrus
S.T.S. — Superior Temporal Sulcus
T.P. — Temporal Pole
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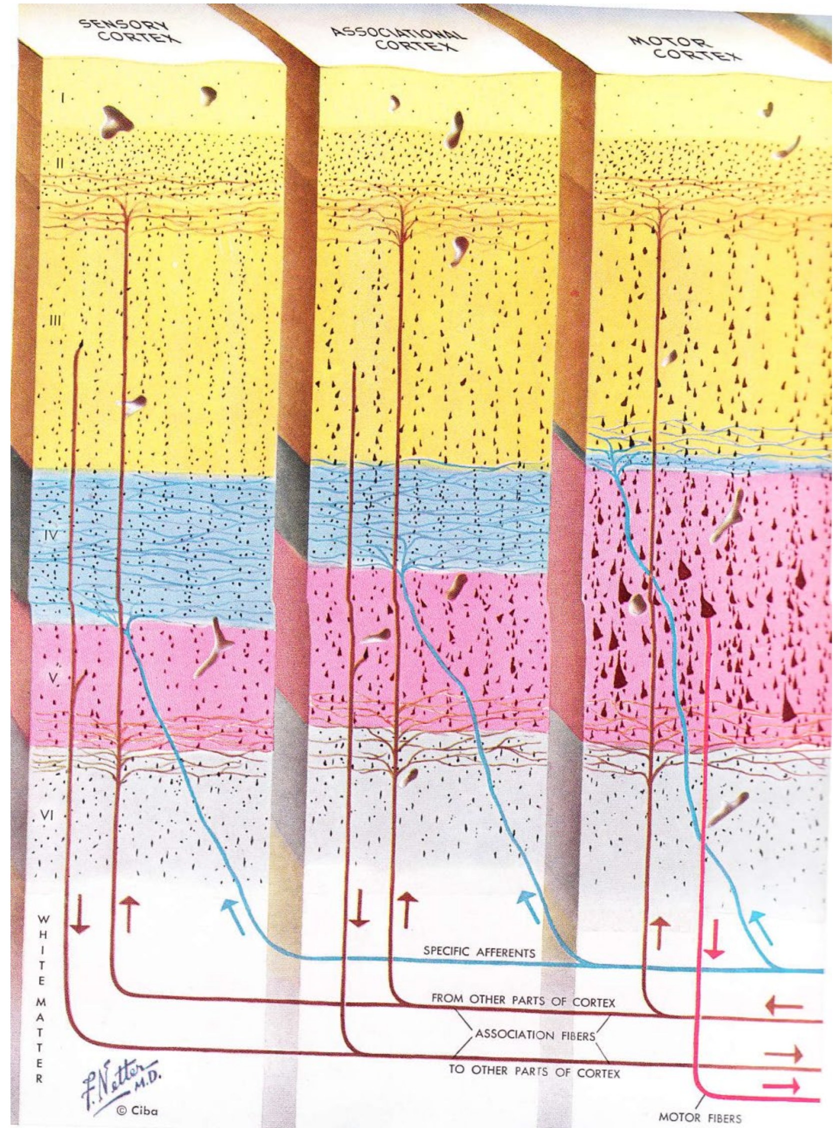
SENSORY CORTEX
ASSOCIATIONAL CORTEX
MOTOR CORTEX
I
II
III
IV
V
VI
WHITE MATTER
SPECIFIC AFFERENTS
FROM OTHER PARTS OF CORTEX
ASSOCIATION FIBERS
TO OTHER PARTS OF CORTEX
MOTOR FIBERS
F. Netter M.D.
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Neuronal Tissue

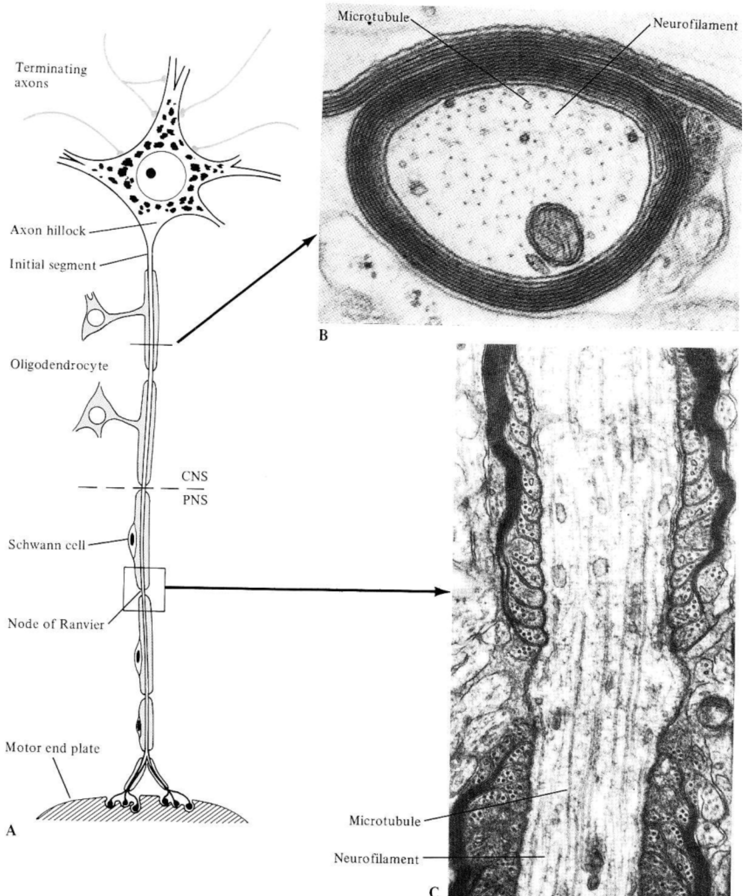


Fig. 84. The Axon

A. Schematic drawing of a motor neuron. The myelin sheath surrounding the axon is interrupted at regular intervals, and appears as a series of tubes in the light microscopic preparation.

B. Electron micrograph of a transversely sectioned axon indicates that the myelin sheath consists of thin lamellae, which form a regular pattern of concentric thin and thick lines.

C. Electron micrograph of a longitudinally cut axon at a node of Ranvier. When the myelin sheath approaches the node, it becomes increasingly thinner as successive lamellae terminate. Note that the axon contains both microtubules and neurofilaments. (C from Peters, A., S. L. Palay and H de F. Webster, 1976. The fine structure of the nervous system. With permission of the authors and W. B. Saunders Company. Philadelphia, London, Toronto.)

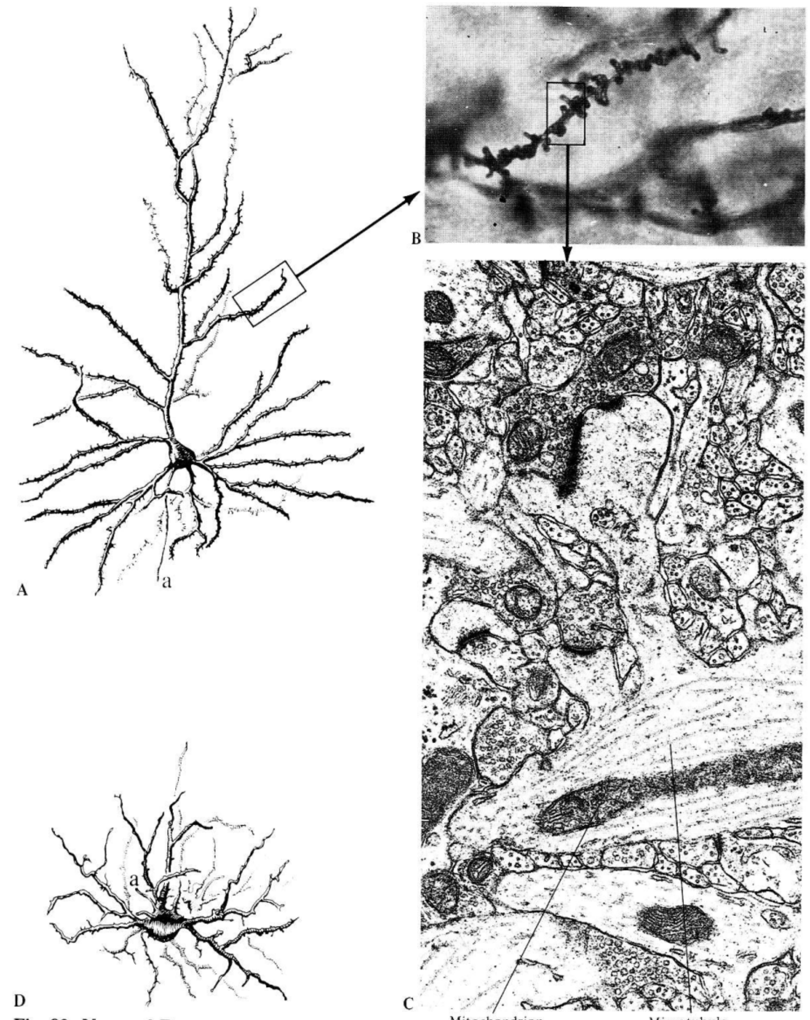


Fig. 82. Neuronal Processes

A. Pyramidal cell from the cerebral cortex stained with the Golgi method.

B. Enlargement of a dendritic spine.

C. The electron microscope reveals that the dendritic spines are specialized for synaptic contacts. Dendrite and dendritic spines, *yellow;* boutons, *red.*

D. Stellate cell from the dentate nucleus of the cerebellum. (A and D from Peters, A., S. L. Palay and H de F. Webster, 1976. The fine structure of the nervous system. With permission of the authors and W. B. Saunders Company, Philadelphia.)

Synapses

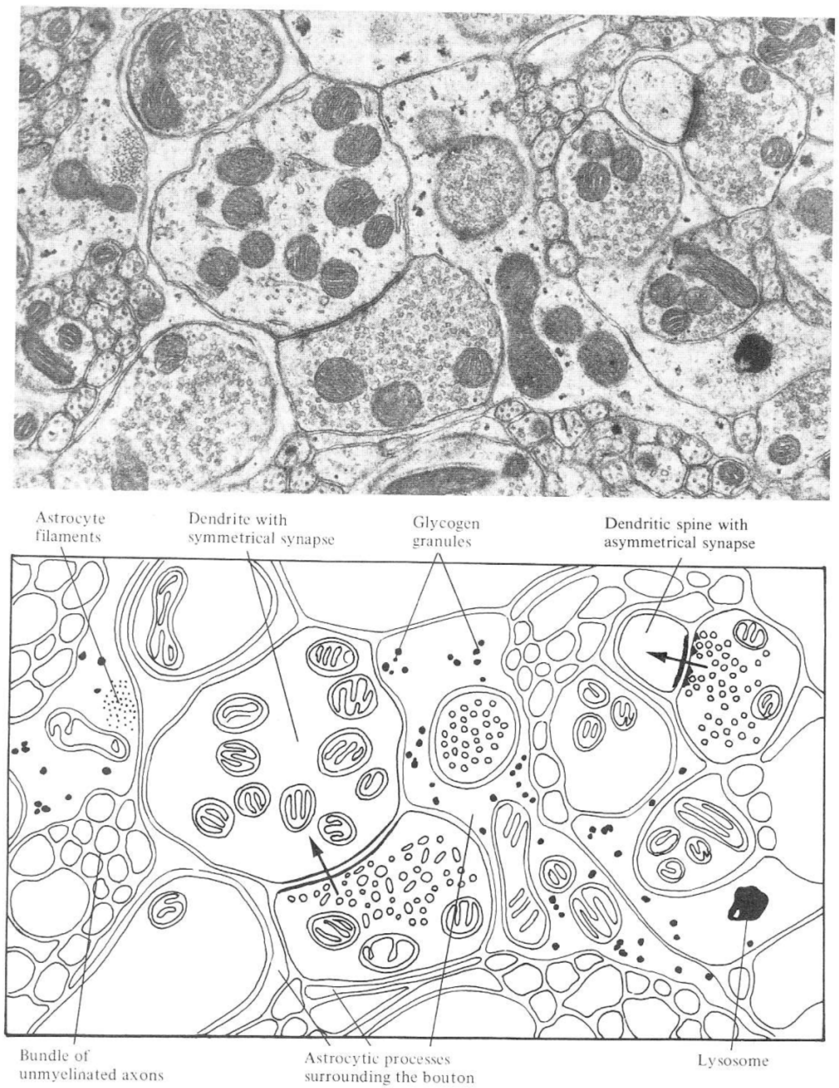


Fig. 87. Symmetric and Asymmetric Synapses
The symmetric synapse is characterized by a mixture of flattened and spherical vesicles, and the pre- and postsynaj tic membranes are of about equal density. The asymmetric synapse is characterized by spherical vesicles and prominent postsynaptic density. (The micrograph, which shows the neuropil in the dorsal cochlear nucleus ‹ the rat, was kindly provided by E. Mugnaini.)

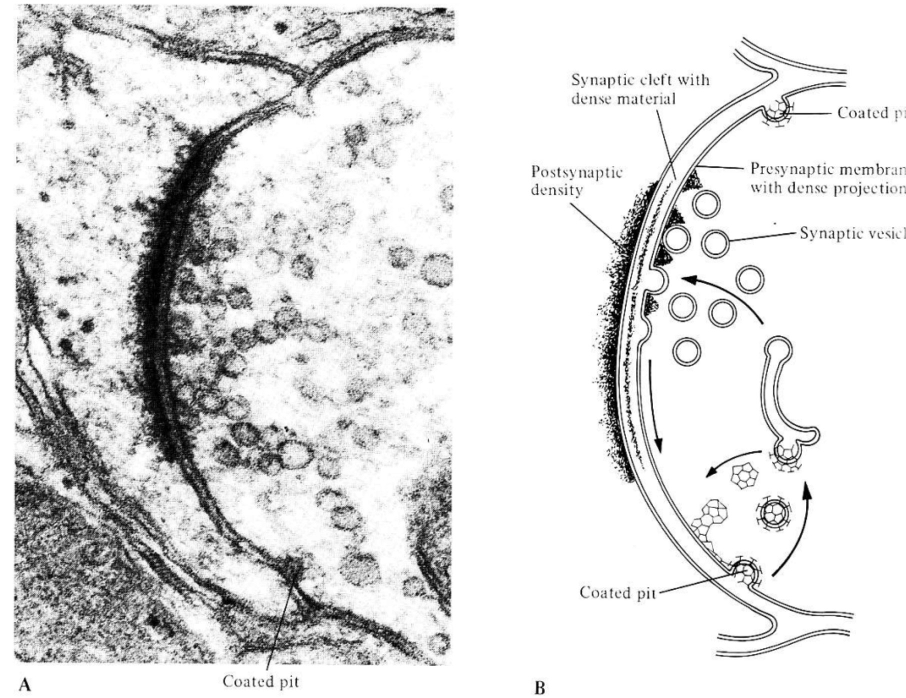


Fig. 86. The Synapse and the Synaptic Vesicles
A. The synapse consists of a presynaptic component, a synaptic gap, and a postsynaptic component. The presynaptic component is characterized foremost by the accummulation of synaptic vesicles, which contain the neurotransmitter.
B. Idealized drawing of the synapse in **A** illustrating the recycling of synaptic vesicle membrane. (Diagram modified after Heuser, J. E. and J. S. Reese, 1973. Evidence for recycling of synaptic vesicle membrane during transmitter release at the frog neuromuscular junction. J. Cell. Biol. 57:315–344.)

Neurotransmitters

Table 2.2. Common Neurotransmitter Responses in the Central Nervous System

Response	Neurotransmitter	Receptor
$\uparrow I_{Na}$, $\uparrow I_K$	Glutamate	Quisqualate/kainate
$\uparrow I_{Na}$, $\uparrow I_K$, $\uparrow I_{Ca}$	Glutamate	*N*-Methyl-D-aspartate (NMDA)
	Acetylcholine	Nicotinic
$\uparrow I_{Cl}$	γ-Aminobutryic acid	$GABA_A$
	Glycine	
$\uparrow I_{K,IR}$	Acetylcholine	M_2
	Norepinephrine	α_2
	Serotonin (5-hydroxytryptamine [5-HT])	$5\text{-}HT_1$
	GABA	$GABA_B$
	Dopamine	D_2
	Adenosine	A_1
	Somatostatin	SST_5
	Enkephalins	μ, δ
$\downarrow I_{AHP}$	Acetylcholine	Muscarinic
	Norepinephrine	β_1
	Serotonin	$5\text{-}HT_7$
	Histamine	H_2
	Glutamate	Glutamate metabotropic
$\downarrow I_{K,leak}$	Acetylcholine	Muscarinic
	Norepinephrine	α_1
	Serotonin	$5\text{-}HT_2$
	Glutamate	Glutamate metabotropic
$\downarrow I_{Ca}$	Multiple transmitters	

Synapses on neurons

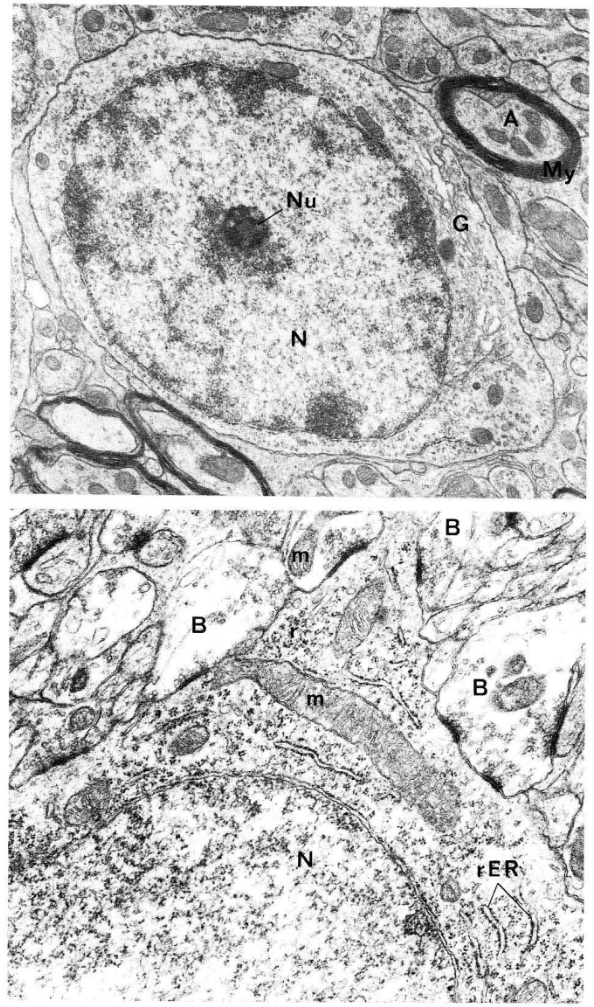


Fig. 1.8. *Ultrastructure of the neuron.* Electron micrograph showing the cell body of a small neuron (**above**) and parts of a larger neuron (**below**). Note the presence of rough endoplasmic reticulum (rER), free ribosomes (r), mitochondria, (m), and Golgi complex (G). Boutons (B) forming axo-somatic synapses are also present. N = nucleus, Nu = nucleolus, A = axon, My = myelin. Magnifications, ×9,000 and ×15,000, respectively.

Development of the neural tube

Development of the brain and the intellectual function

Development of the cellular components of the human cerebral cortex

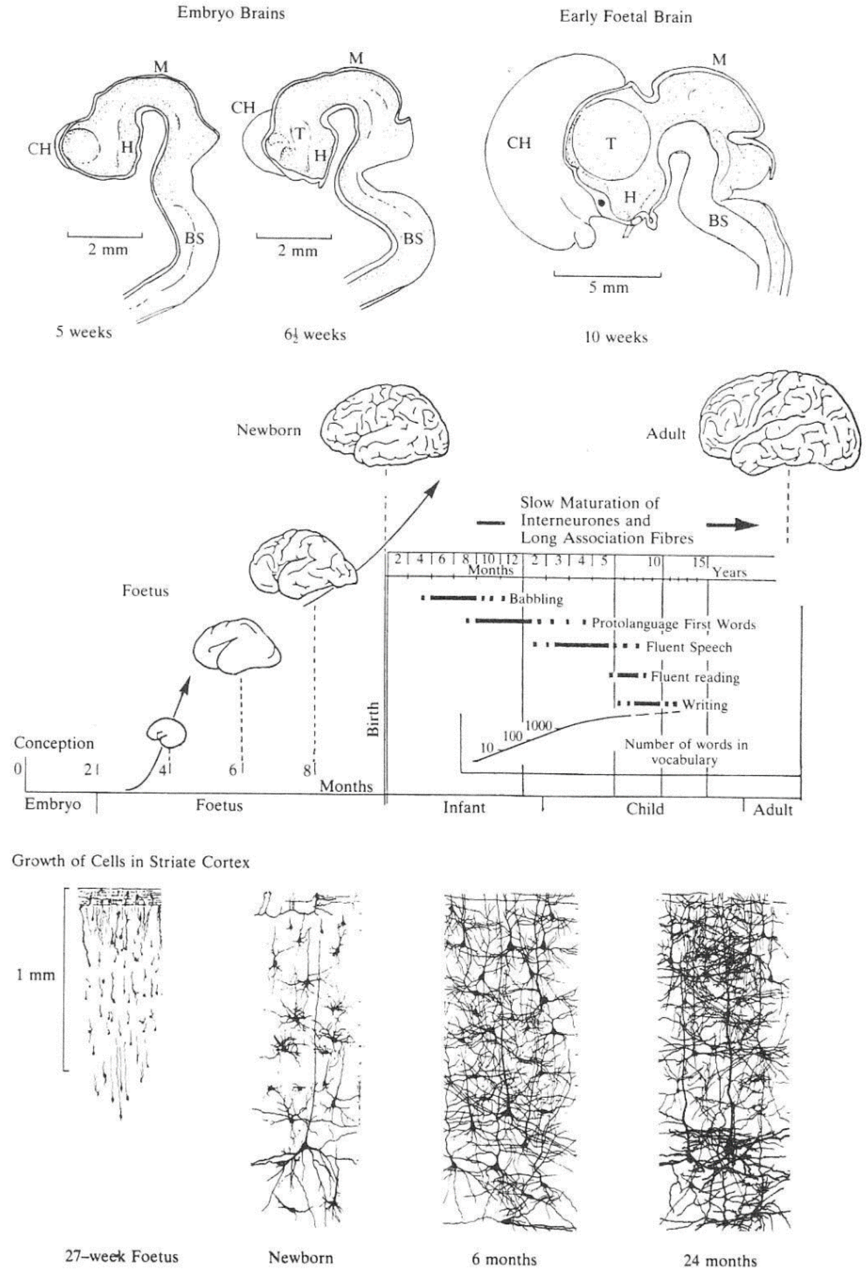


Fig. 2. The cerebral hemispheres appear in the mid-embryo (one month gestation), expanding in mid-foetal stages when cortical neurones multiply. A second surge of hemisphere growth occurs shortly after birth when cortical dendrites grow and glia cells multiply—synapses form at this stage. Cell maturation continues throughout psychological development. CH = Cerebral Hemisphere; T = Thalamus; M = Midbrain; B = Brainstem; C = Cerebellum; H = Hypothalamus.

Development of the human cerebral cortex

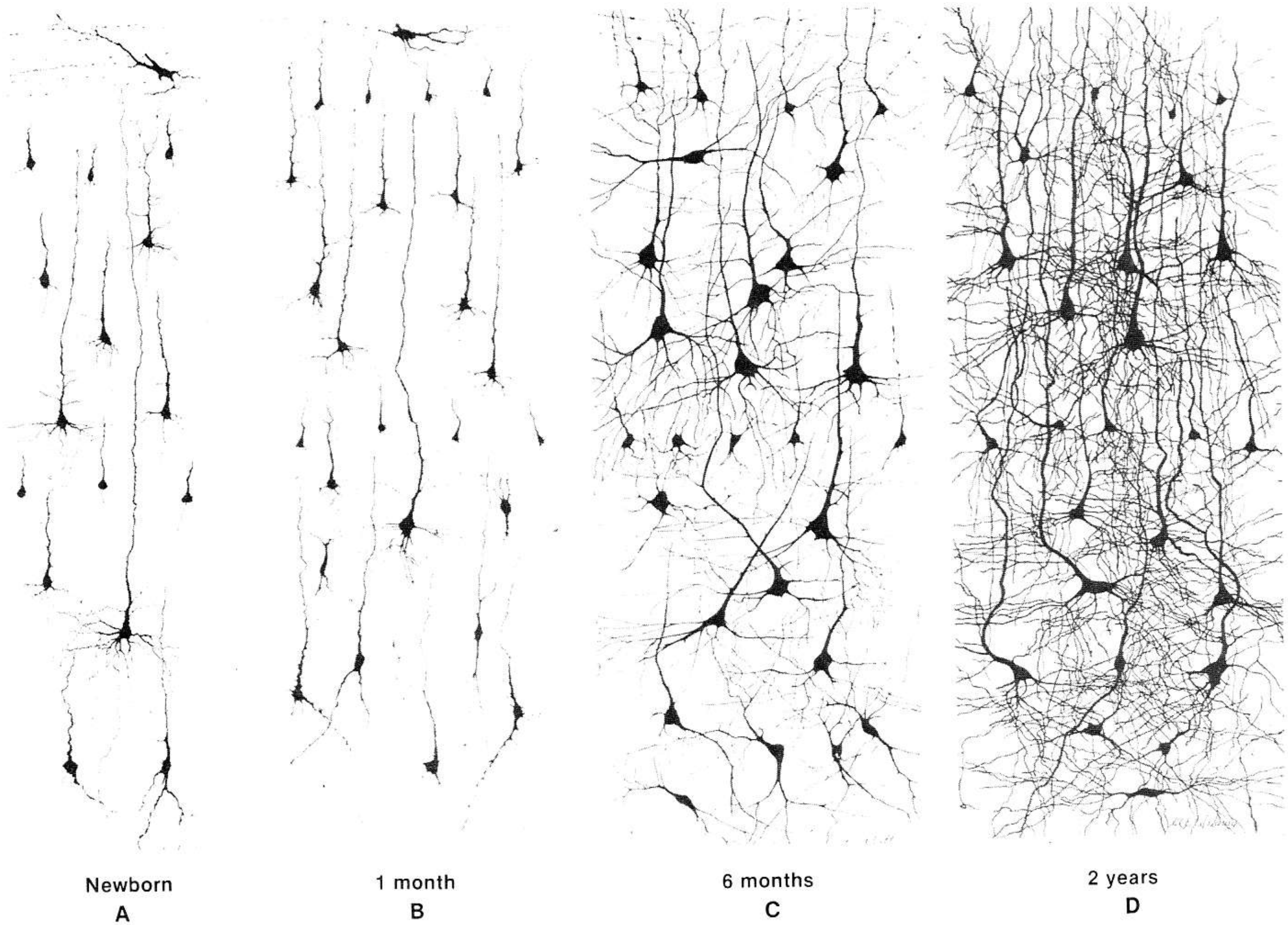
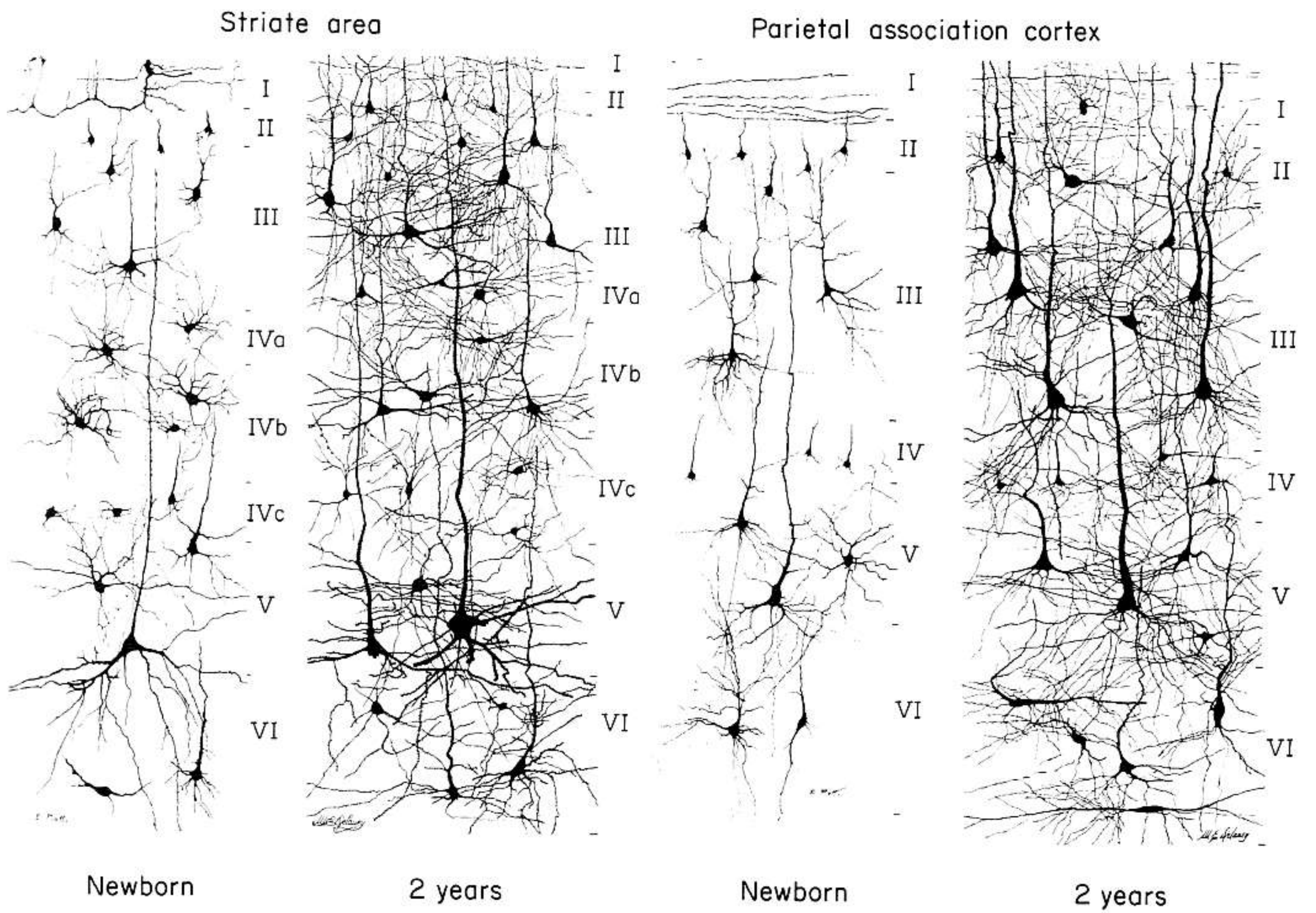


FIGURE 15-6

Golgi-stained sections of human cerebral cortex taken from equivalent areas of the anterior portion of the middle frontal gyrus at different ages. Note that although the packing density of cortical neurons does not appear to change, there is a tremendous increase in the complexity of dendritic arborizations with increasing age.

From Conel, J.L.: The postnatal development of the human cerebral cortex, Cambridge, Mass., Harvard University Press. **A**, Vol. I, 1939; **B**, vol. II, 1941; **C**, vol. IV, 1951; **D**, vol. VI, 1959. Reprinted by permission.

Development of the nervous tissue

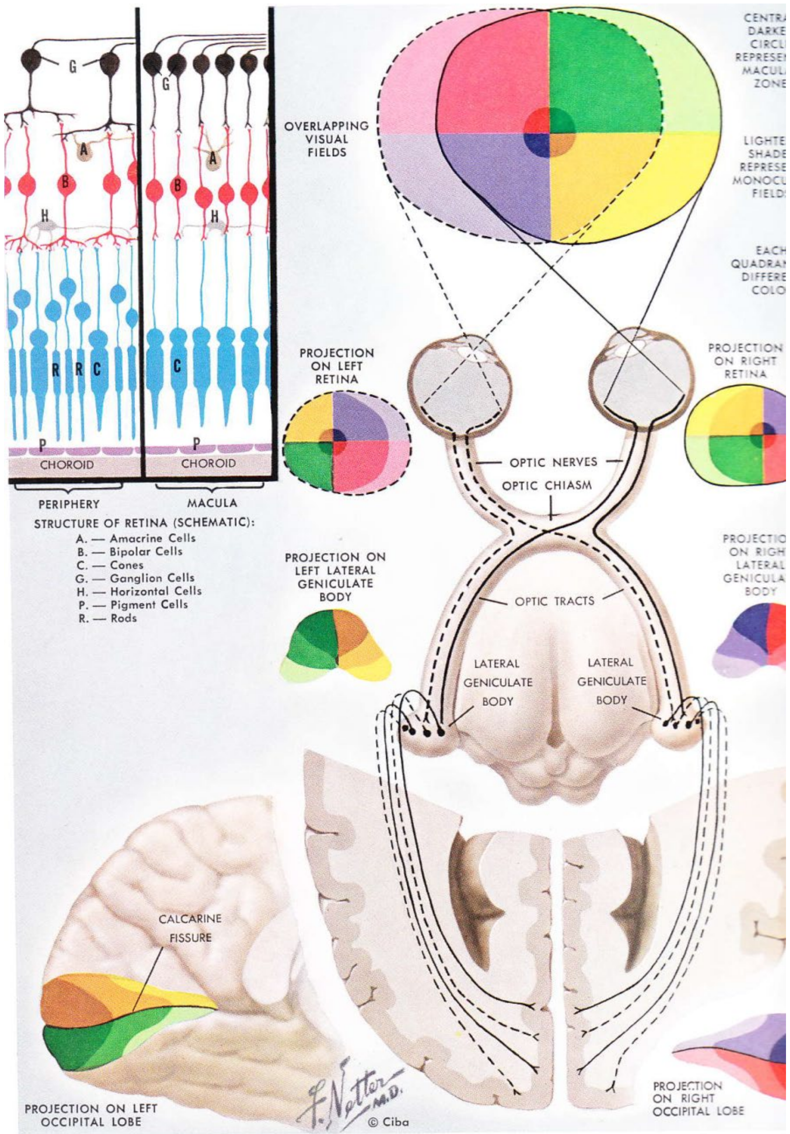


Human intellectual development

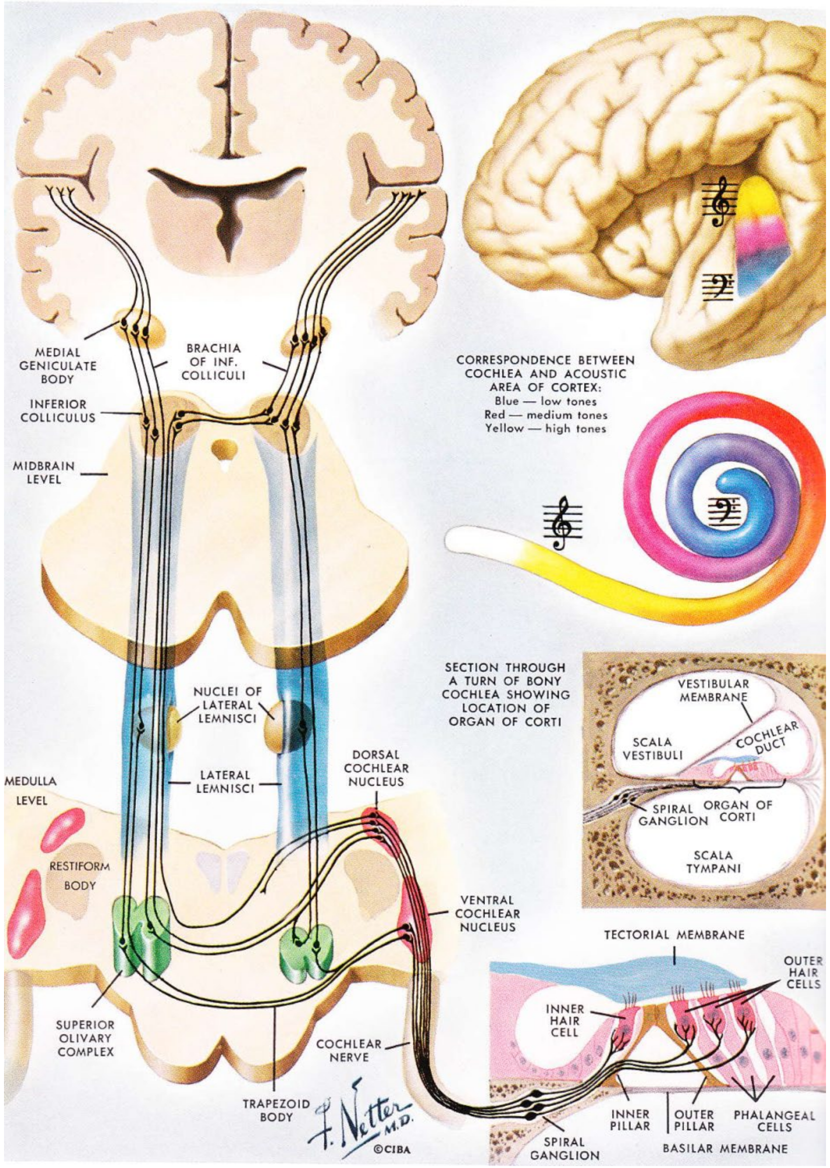
Stage	Age or Period	Description
Sensorimotor stage	Infancy (0–2 years)	Intelligence is present; motor activity but no symbols; knowledge is developing yet limited; knowledge is based on experiences/ interactions; mobility allows child to learn new things; some language skills are developed at the end of this stage. The goal is to develop object permanence; achieves basic understanding of causality, time, and space.
Pre-operational stage	Toddler and Early Childhood (2–7 years)	Symbols or language skills are present; memory and imagination are developed; nonreversible and nonlogical thinking; shows intuitive problem solving; begins to see relationships; grasps concept of conservation of numbers; egocentric thinking predominates.
Concrete operational stage	Elementary and Early Adolescence (7–12 years)	Logical and systematic form of intelligence; manipulation of symbols related to concrete objects; thinking is now characterized by reversibility and the ability to take the role of another; grasps concepts of the conservation of mass, length, weight, and volume; operational thinking predominates nonreversible and egocentric thinking
Formal operational stage	Adolescence and Adulthood (12 years and on)	Logical use of symbols related to abstract concepts; Acquires flexibility in thinking as well as the capacities for abstract thinking and mental hypothesis testing; can consider possible alternatives in complex reasoning and problem solving.[19]

Neuronal pathways

Visual

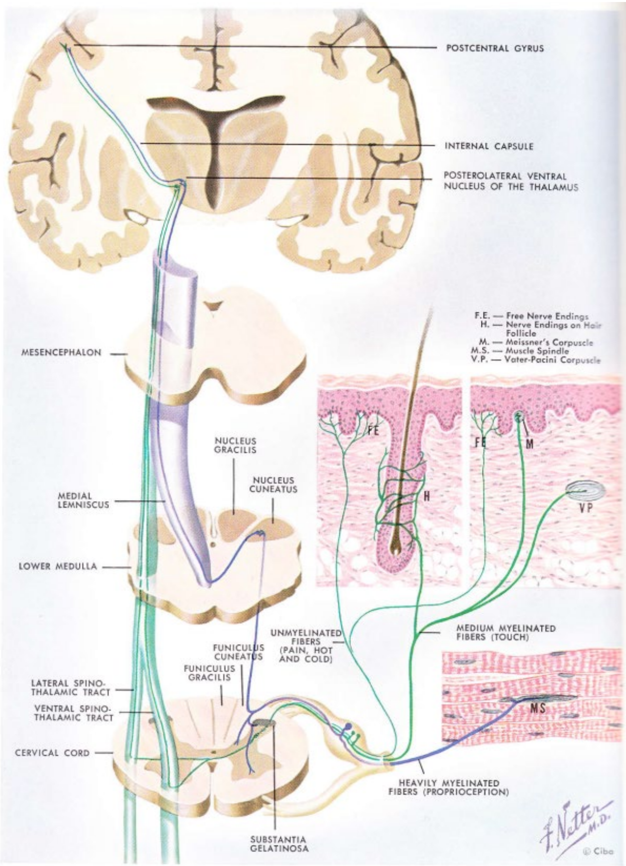


Acoustic

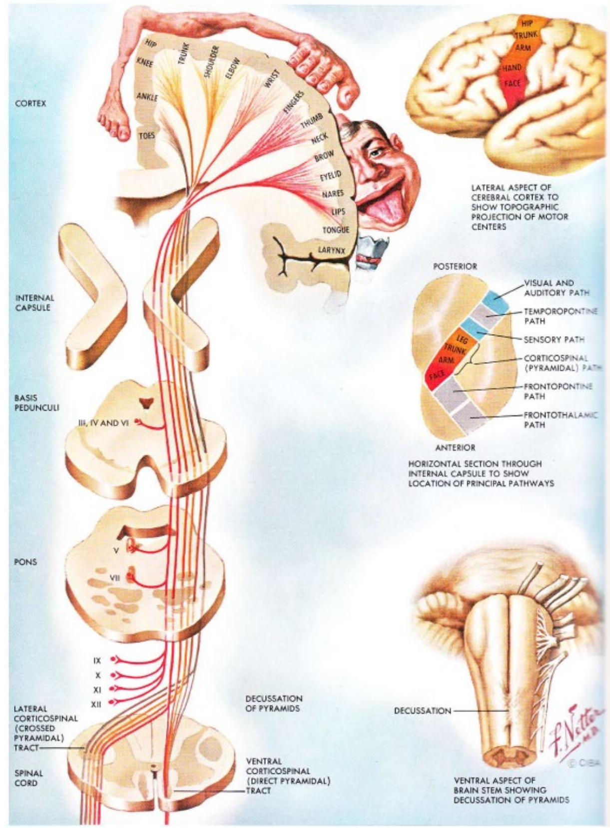


Neuronal pathways

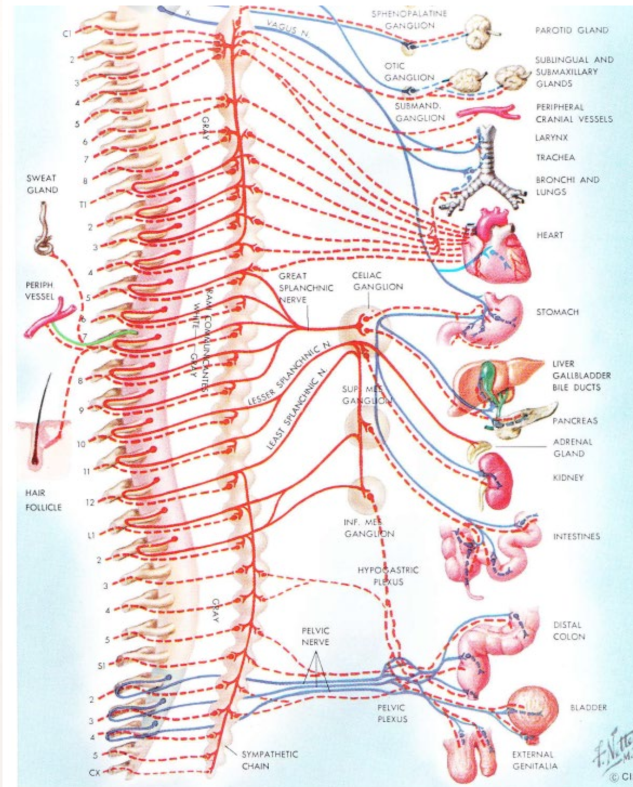
somatosensory



motor



autonomic



Representation of the Body parts in the Sensory and motor cortex

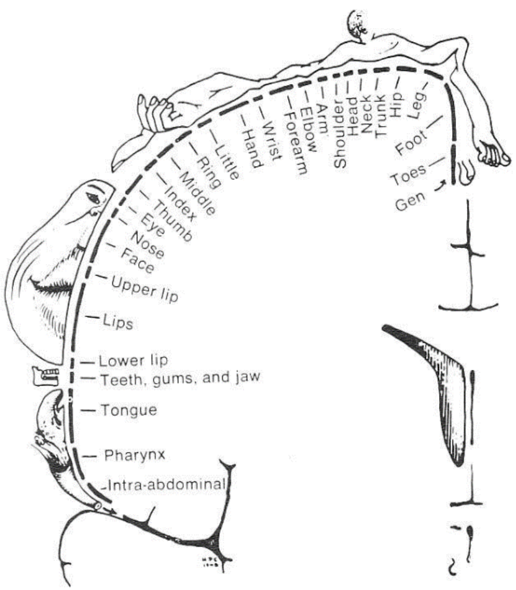


Fig. 4.21. *Relative size of the cortical regions representing various body parts.* Schematic section through the postcentral gyrus (SI) of the human brain. Based on electrical stimulation during brain surgery under local anesthesia. From Penfield and Rasmussen (1950).

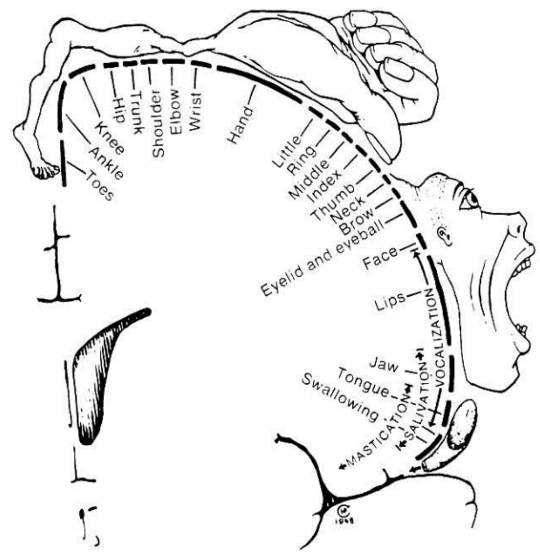


Fig. 9.8. *The relative size of the regions of the MI representing various body parts.* Based on electrical stimulation of the exposed human MI. From Penfield and Rasmussen (1950).

Sensory cortex

Motor cortex

Mapping the brain areas for functions

1. **Clinico-pathological methods**
   a. Clinical observations
   b. Histology
   c. Imaging techniques
      MRI, fMRI

2. **Experimental**
   a. Histology
   b. Electrophysiology

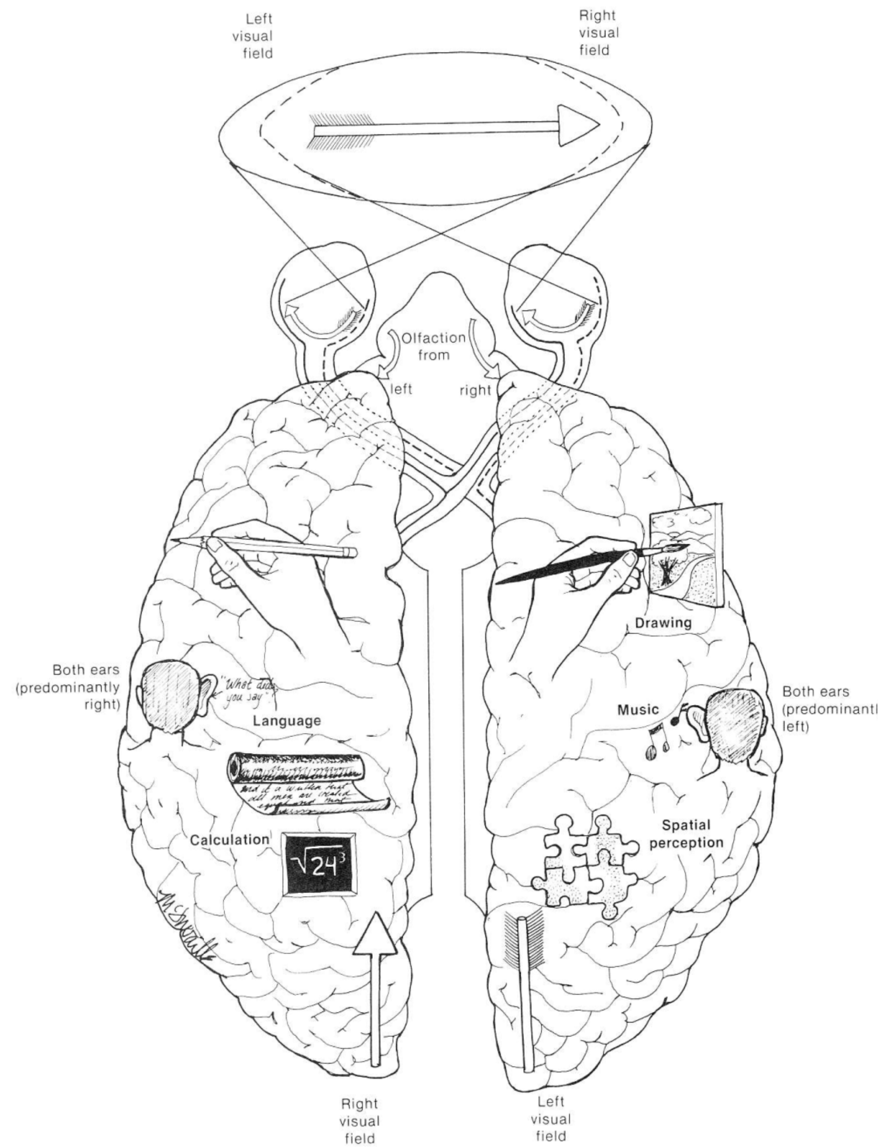


FIGURE 15-21
Schematic illustration of the different functional specializations of the two hemispheres as determined from studies of patients after callosal section.
Modified from Sperry, R.W.: Lateral specialization in the surgically separated hemispheres. In Schmitt, F.O., and Worden, F.G., editors: The neurosciences: third study program, Cambridge, Mass., 1974, The MIT Press.

Brain: views from lateral and superior side

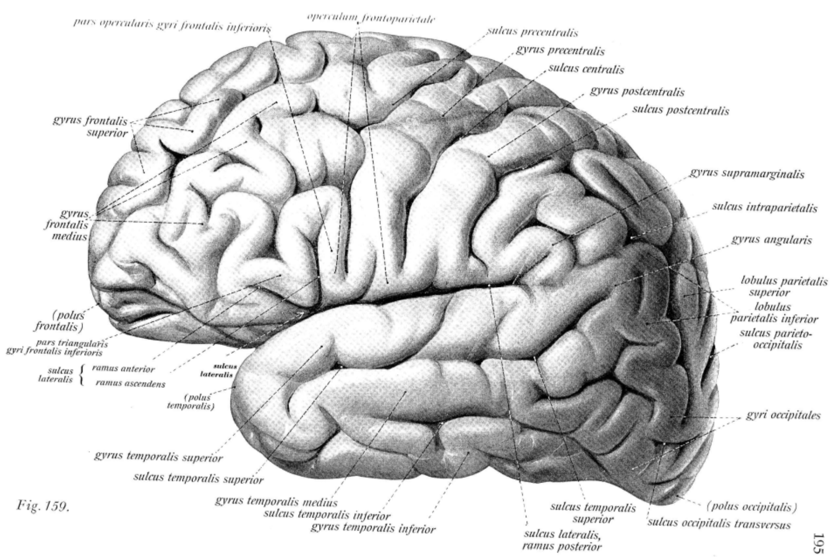
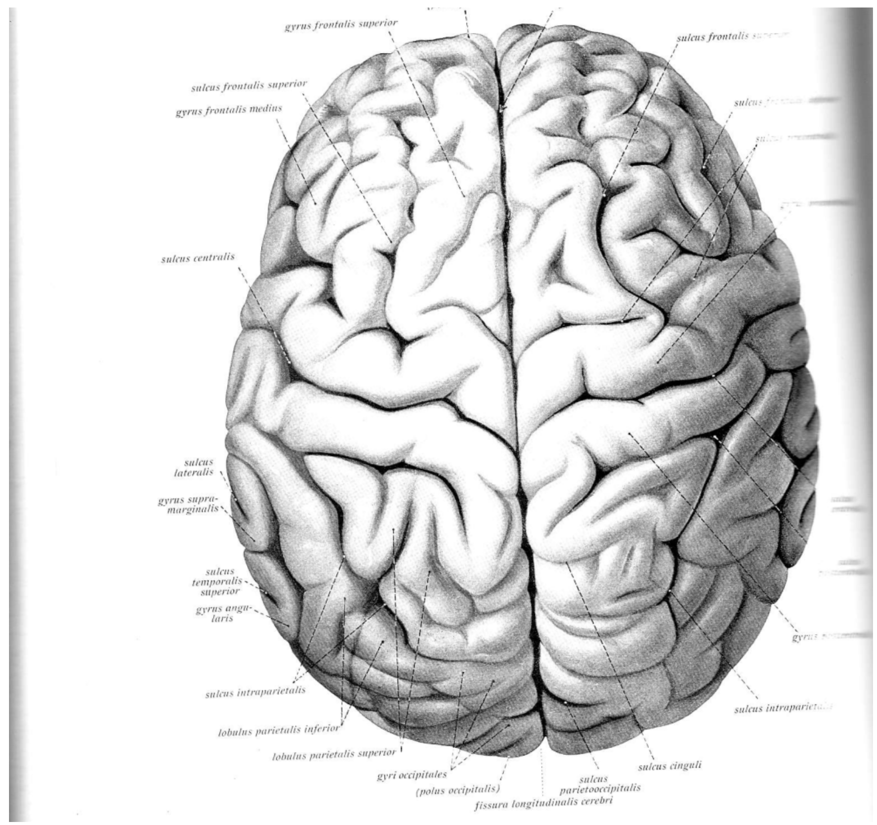


Fig. 159.



Sobotta: Atlas of descriptive human anatomy

Cytoarchitectonic map of the brain

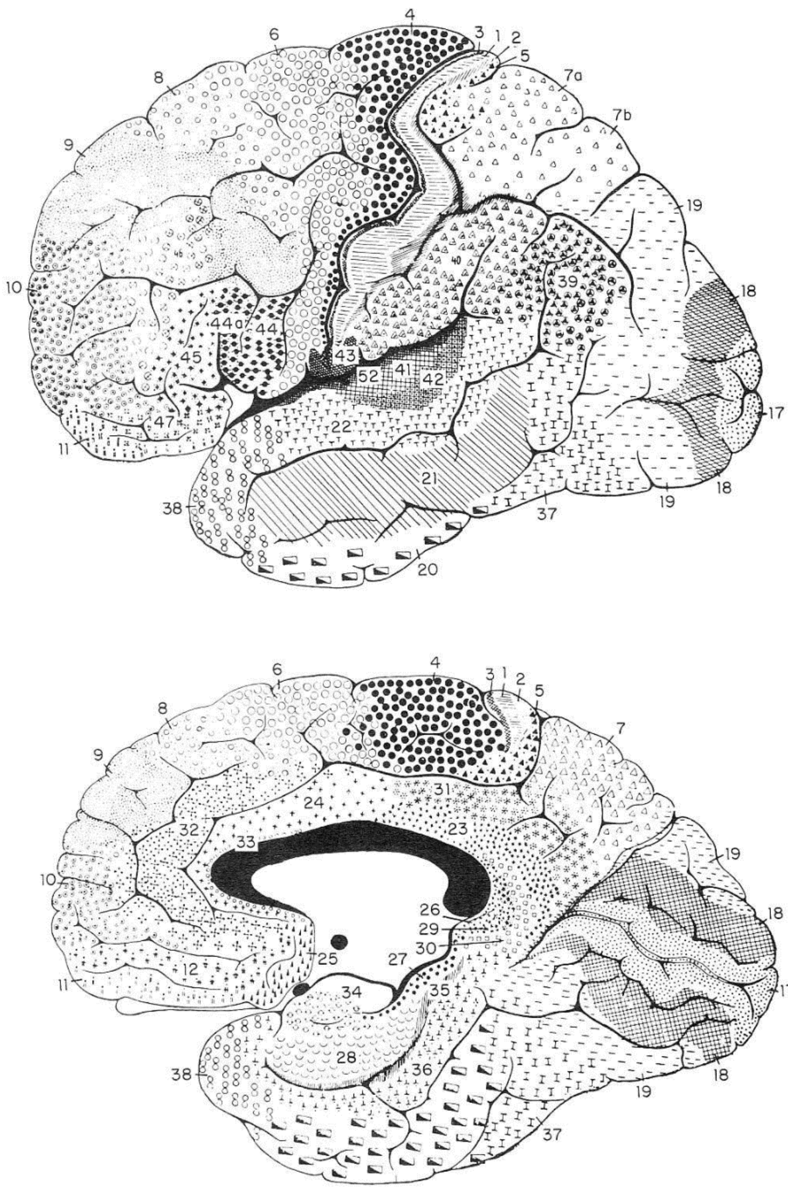
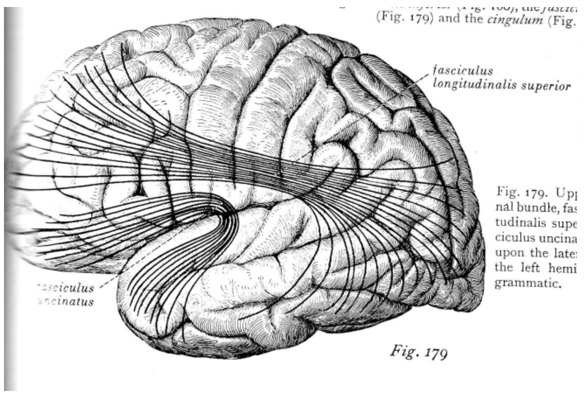
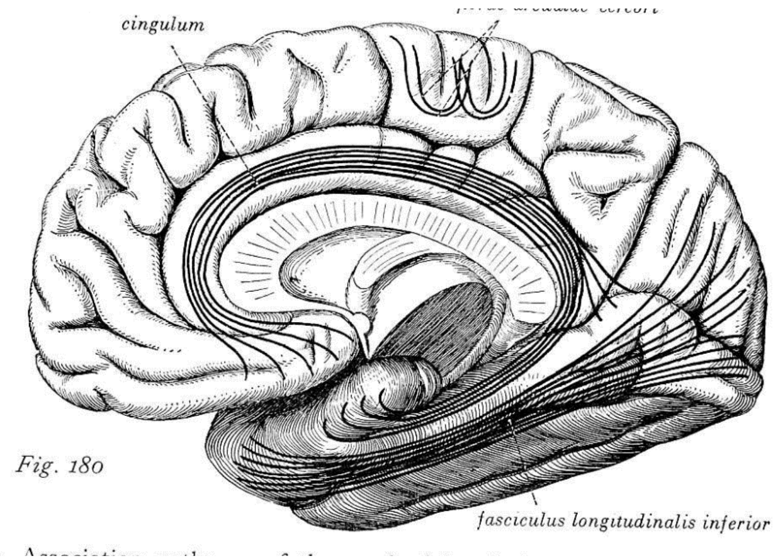
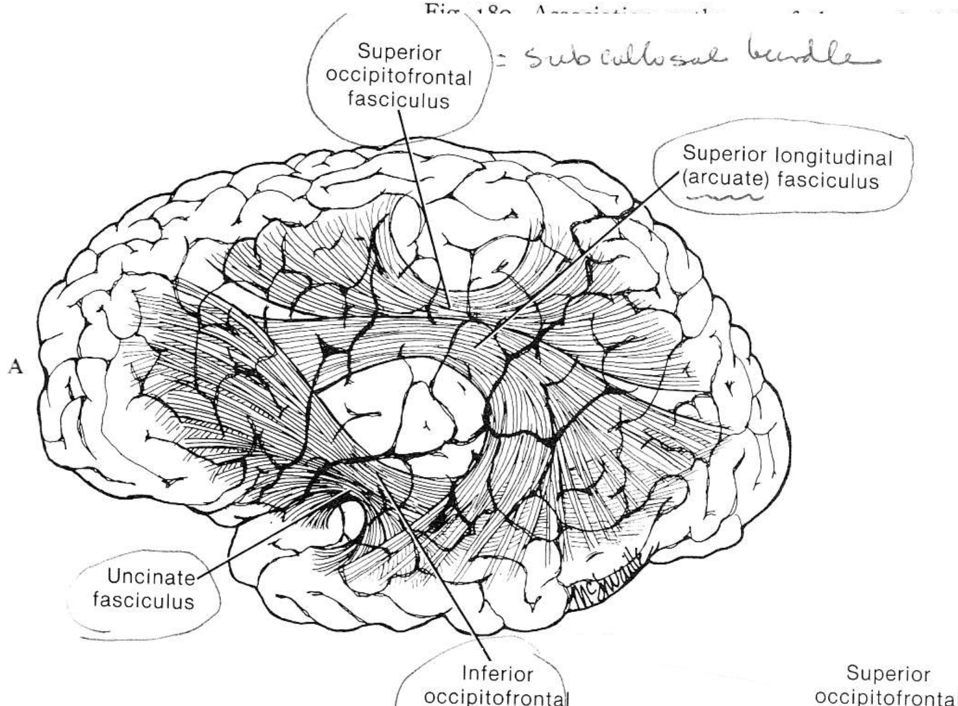


Fig. 17.3. *Brodmann's cytoarchitectonic map of the human brain.* The various areas are labeled with different symbols and numbers.

Neuronal connections of the brain







Sobotta: Atlas of descriptive human anatomy

How the BRAIN works?

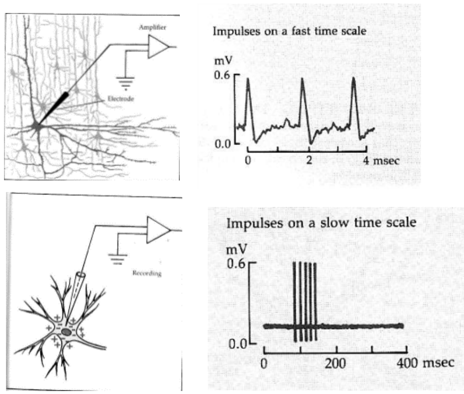
Analog stimuli converted into electrical signal

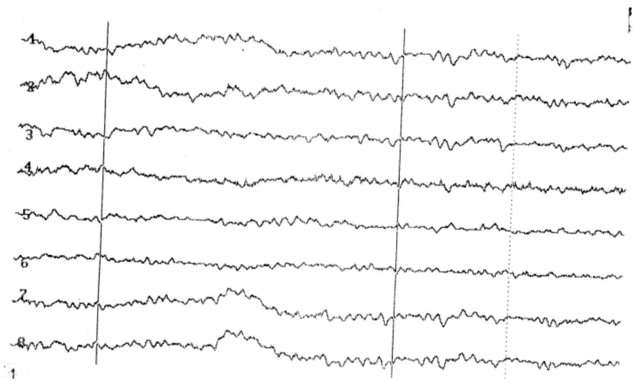
Through the sensory neurons

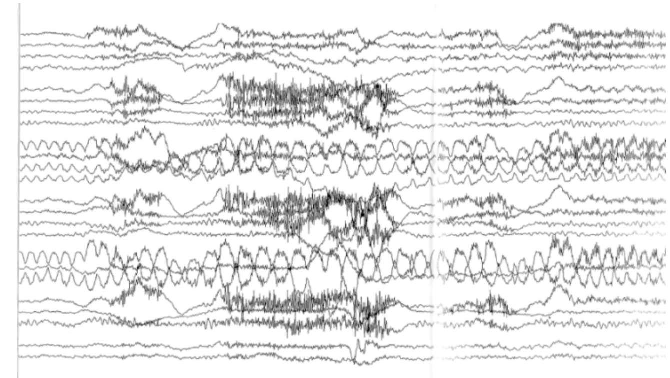
What kind of form the electrical signal is?

Is the digital electrical signal binary or…?

Tracking the functional activity of the brain







Scalp recording

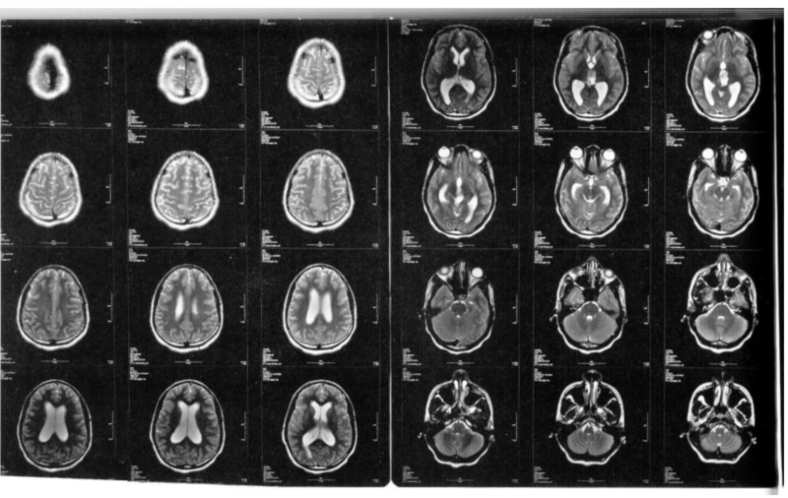
Single cell recording

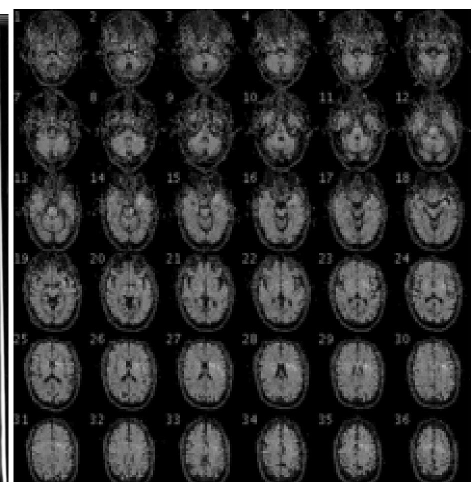
Normal EEG

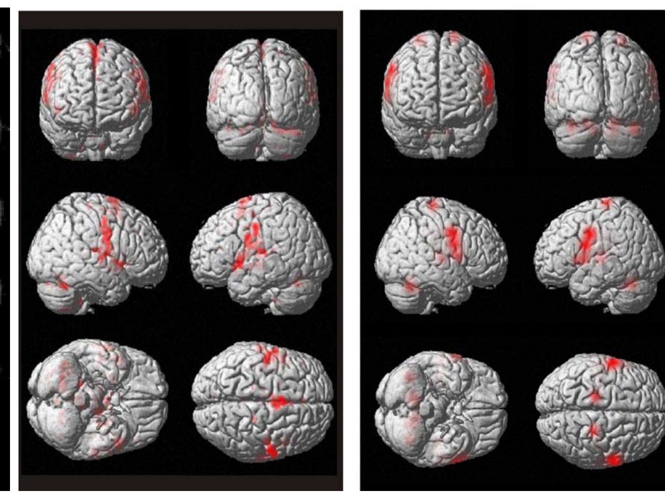
Epileptic seizure

S.Kuffler: From Neuron to Brain

Schoonover: Portraits of the Mind





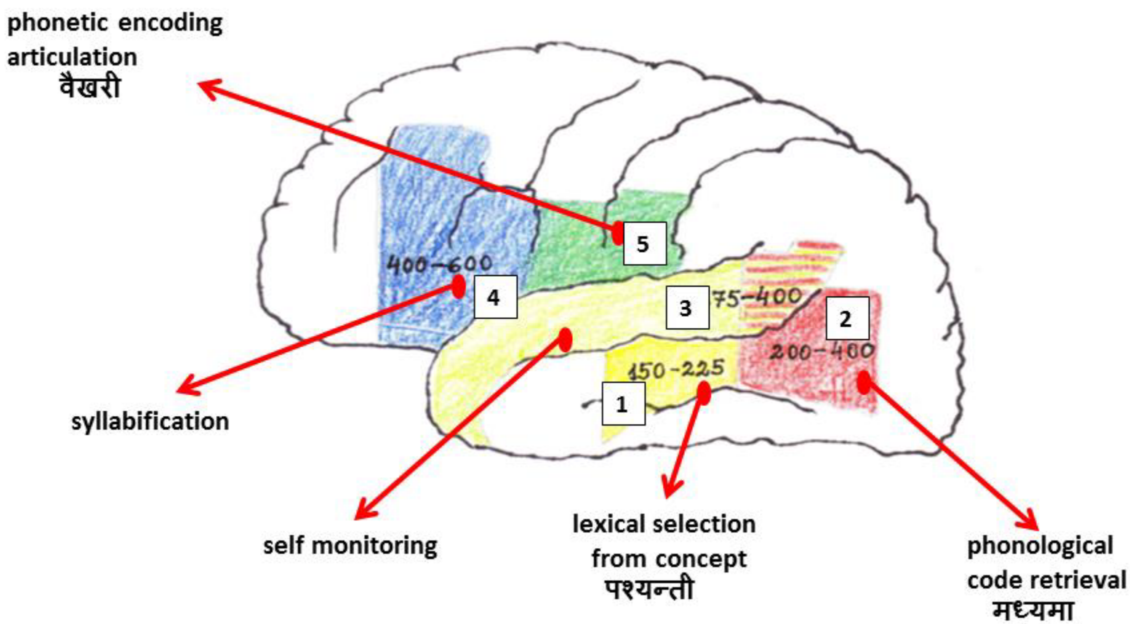


MRI images

fMRI images

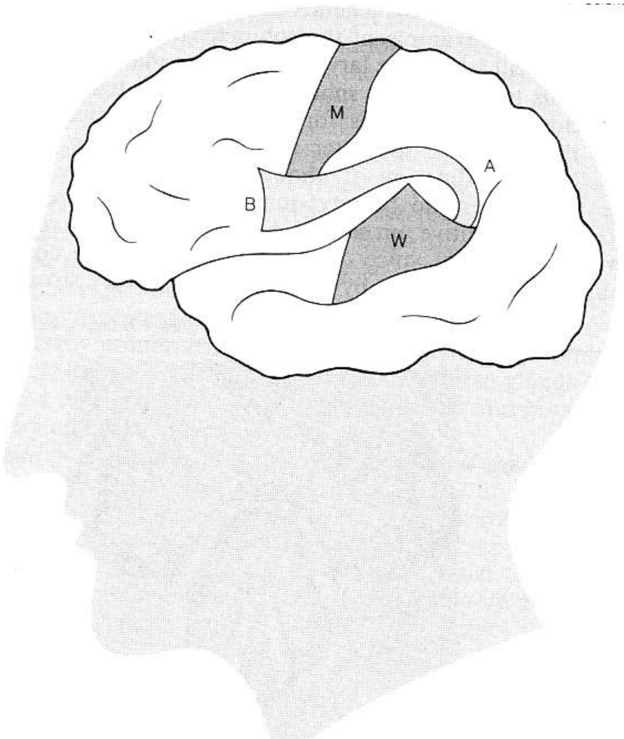
fMRI images, assembled

Brain areas involved in learning and language processing



	Brain Area	Activity	Time-Scale	Indian Grammatical Term
1	Middle and inferior temporal gyri	lexical selection from concept	150-225 msec	पश्यन्ती
2	Middle temporal gyrus and parieto-occipital gyrus	phonological code retrieval	200-400 msec	मध्यमा
3	Superios temporal gyrus	self monitoring	275-400 msec	
4	Middle and inferior frontal gyri	syllabification	400-600 msec	
5	Pre-and postcentral gyri	phonetic enclding and articulation	600- msec	वैखरी

Speech-circuitry



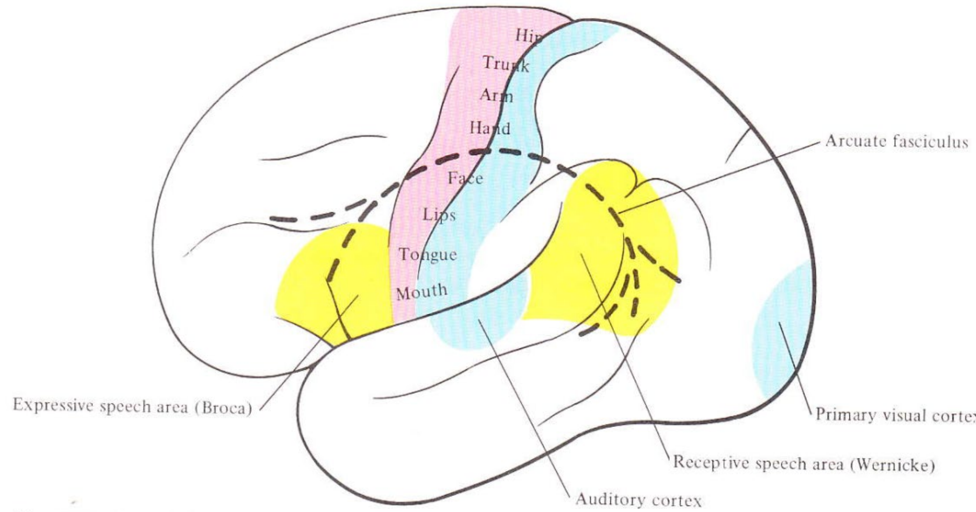
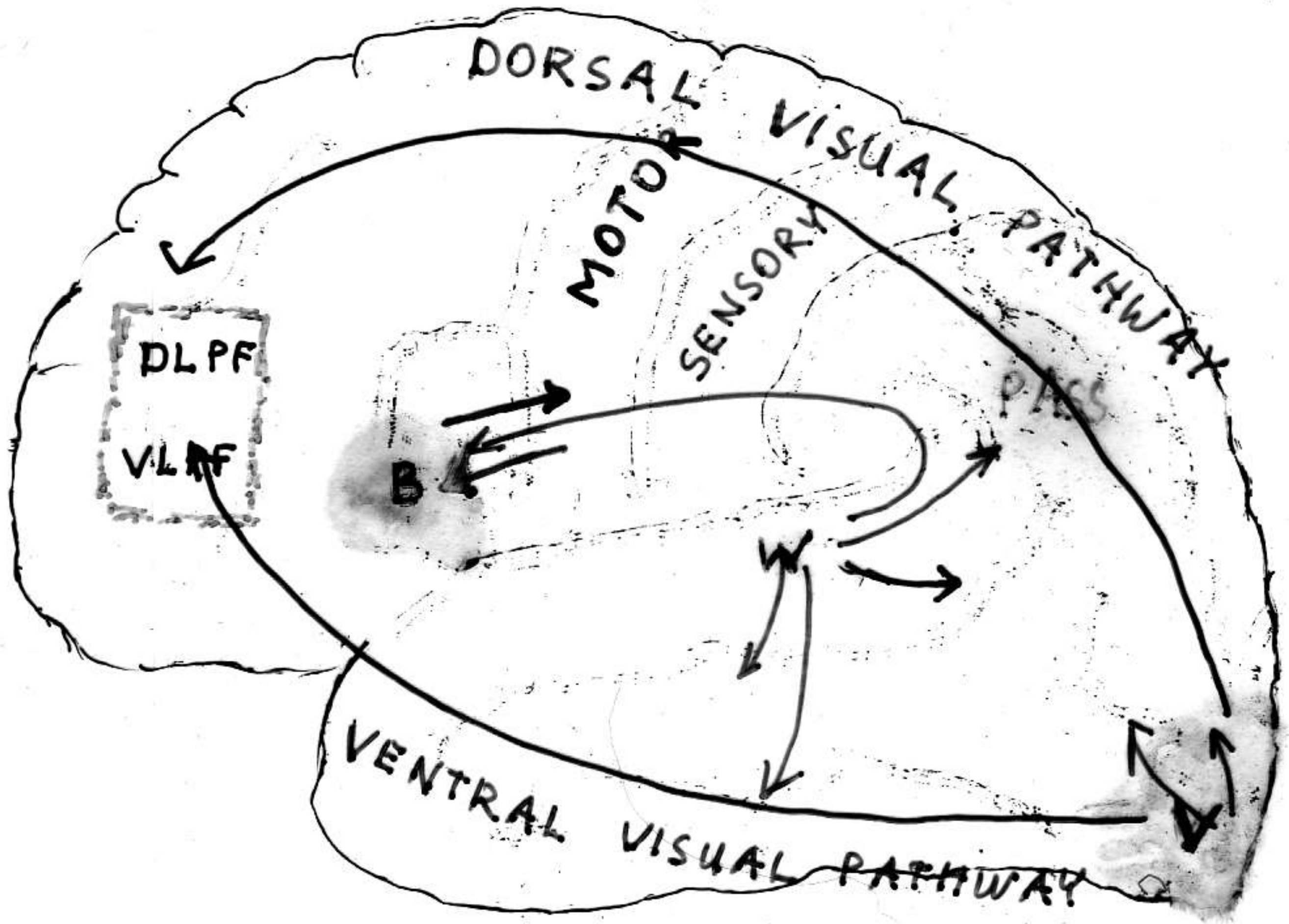


Fig. 179. Speech Areas
The expressive and receptive speech areas have been indicated by yellow color in this diagram of the lateral surface of the left cerebral hemisphere. Note that the expressive speech area of Broca is located immediately in front of the motor area for mouth, tongue and lips. (Modified from Geschwind, N. 1979. Specializations of the human brain. Scientific American, 241:3, 158–171.)

Outflows from the visual cortex



Connections of the parietal association cortex

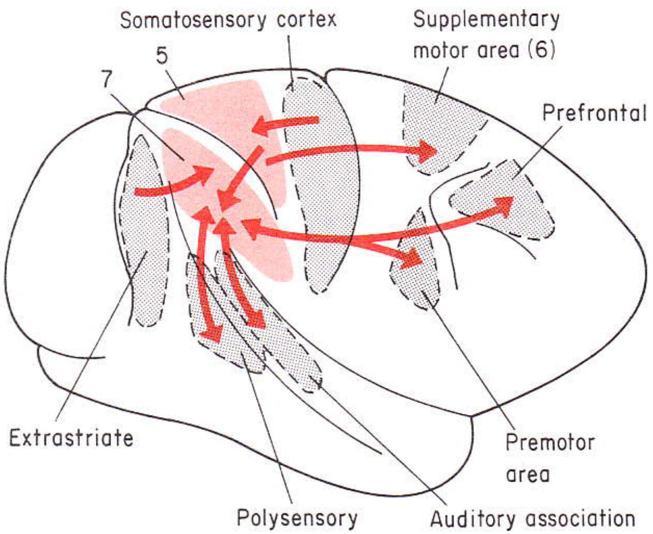


Fig. 17.12. *The association connections of the posterior parietal cortex* (monkey). Connections with the limbic cortical areas are not shown (see Fig. 17.9). Note the convergence of visual and somatosensory information in area 7.

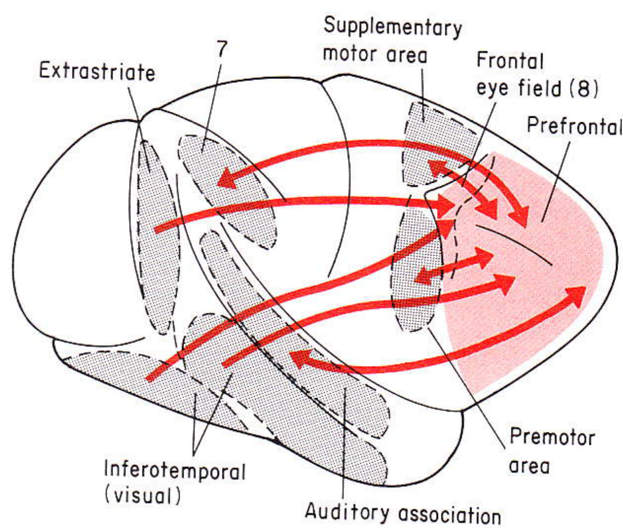
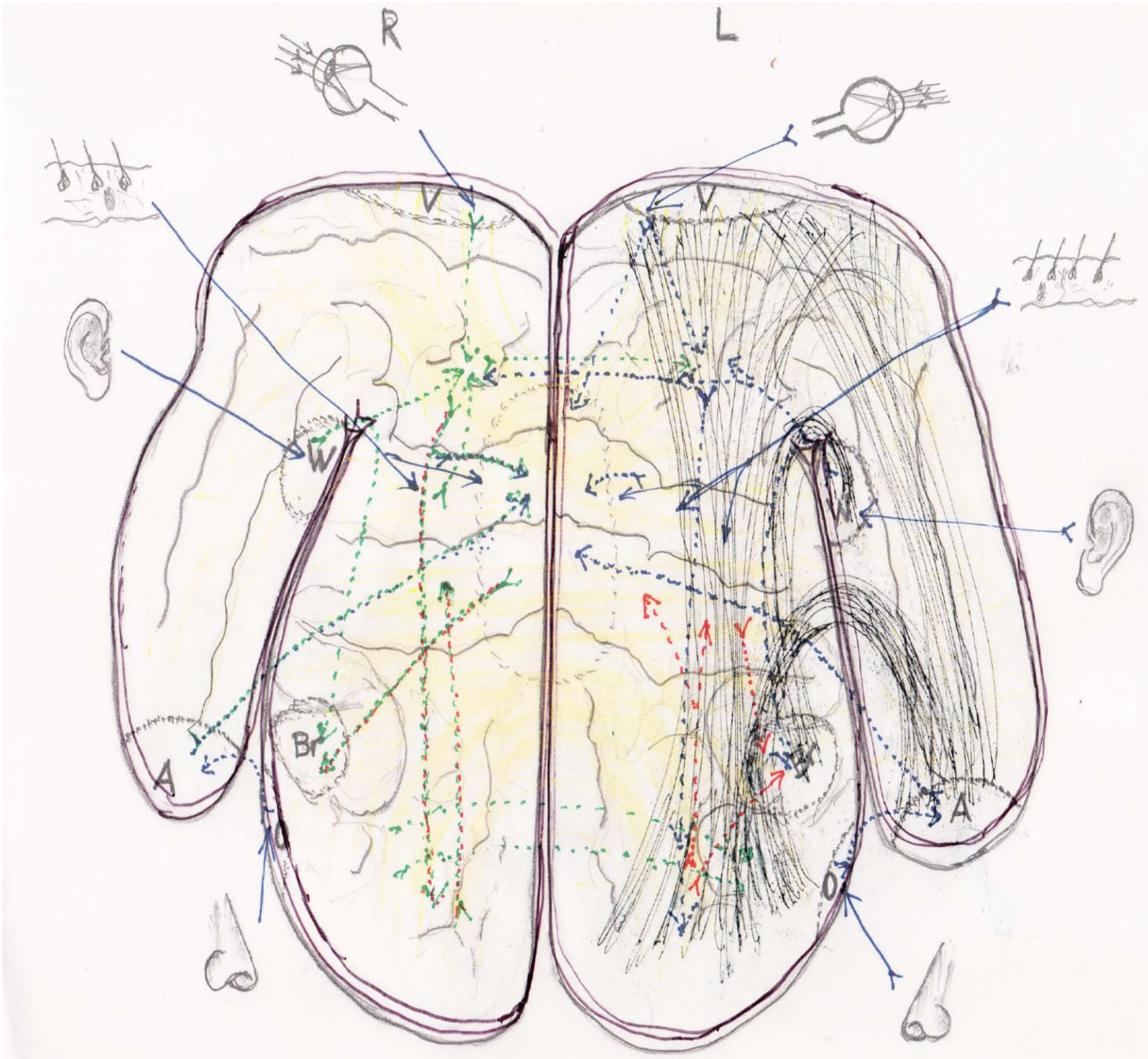


Fig. 17.13. *The association connections of the prefrontal cortex* (monkey). Note the convergence of all kinds of processed sensory information and the connections with PMA and SMA. Connections with limbic cortical areas are not shown (see Figs. 16.3 and 16.4).

External stimuli into the brain



Pathway of the taste

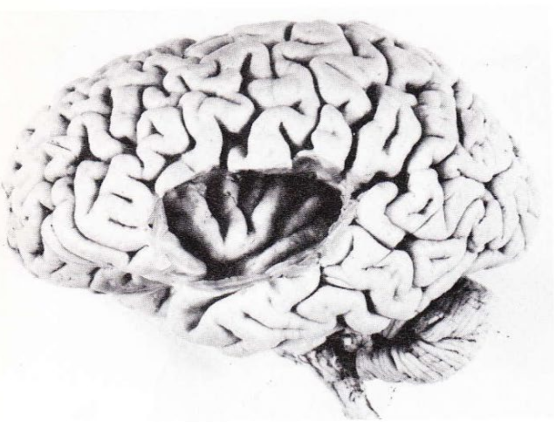


FIGURE 2-6
Location of the insula. The frontal, temporal, and parietal opercula were removed from the brain shown in Figure 2-2 to expose this cortical area.

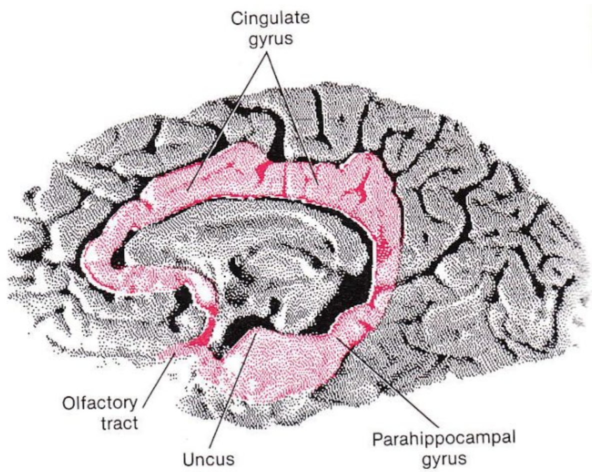


FIGURE 2-7
Limbic lobe as seen on the medial surface of a hemisected brain from which the brainstem and cerebellum were removed.

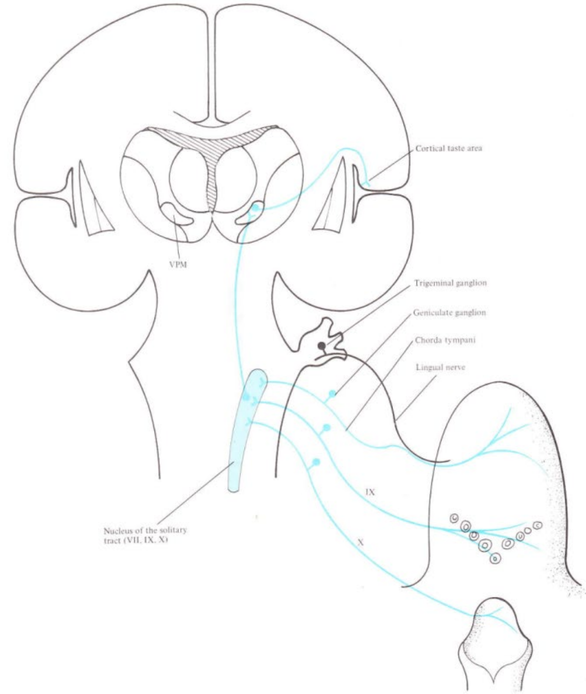


Fig. 137. Pathways for Taste
The rostral part of the nucleus of the solitary tract is concerned with the transmission of taste impulses travelling in the facial (VII), glossopharyngeal (IX) and vagal (X) cranial nerves. Impulses from the nucleus of the solitary tract reach the ventral posteromedial nucleus (VPM) before being transmitted to the gustatory cortex in the opercular part of the inferior frontal gyrus on the ipsilateral side. The caudal part of the nucleus of the solitary tract receives viscerosensory impulses through the glossopharyngeal and vagal nerves. These impulses are important for cardiovascular, respiratory and other visceral reflexes.

Neurotransmitters in the brain

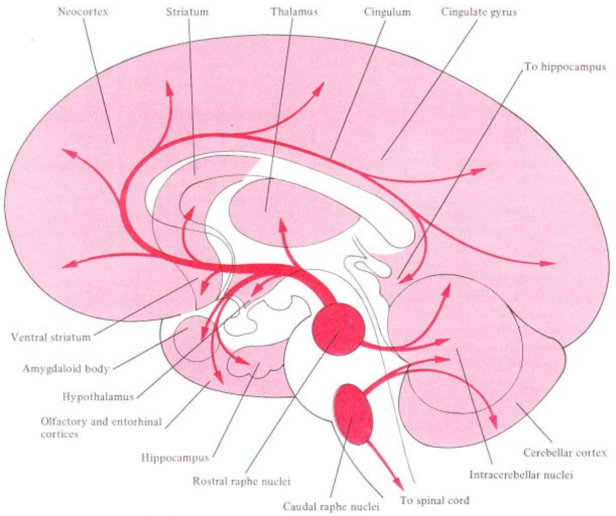


Fig. 131. Serotonergic Pathways
The raphé nuclei form a more or less continuous collection of cell groups close to the midline throughout the brain stem, but for the sake of simplicity they have been subdivided into a rostral and a caudal group in this drawing. The rostral raphé nuclei project to a large number of forebrain structures. The fibers that project laterally through the internal and external capsules to widespread areas of the neocortex are not indicated in this highly schematic drawing.

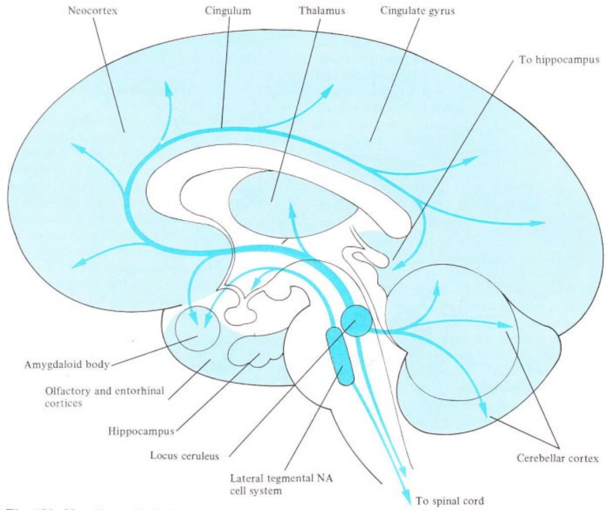


Fig. 132. Noradrenergic Pathways
Locus ceruleus, which is located immediately underneath the floor of the fourth ventricle in the rostrolateral part of pons, is the most important noradrenergic nucleus in the brain. Its projections reach many areas in the forebrain, cerebellum and spinal cord. Noradrenergic neurons in the lateral brain stem tegmentum innervate several structures in the basal forebrain including the hypothalamus and the amygdaloid body.

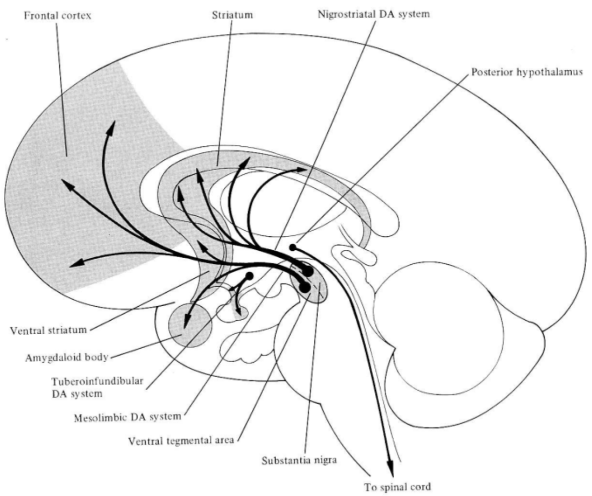
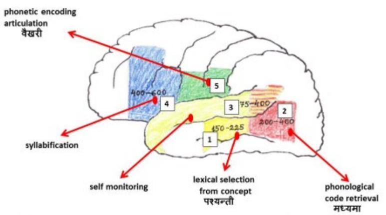


Fig. 133. Dopaminergic Pathways
The nigrostriatal DA system originates in the substantia nigra and terminates in the main dorsal part of the striatum. The ventral tegmental area gives rise to the mesolimbic DA system, which terminates in the ventral striatum, amygdaloid body, frontal lobe, and some other basal forebrain areas. The tuberoinfundibular system innervates the median eminence as well as the posterior and intermediate lobes of the pituitary, and dopamine neurons in the posterior hypothalamus project to the spinal cord.

Neuronal structures involved in the speech production



	Brain Area	Activity	Time-Scale	Indian Grammatical Term
1	Middle and inferior temporal gyri	lexical selection from concept	150-225 msec	पश्यन्ती
2	Middle temporal gyrus and parieto-occipital gyrus	phonological code retrieval	200-400 msec	मध्यमा
3	Superios temporal gyrus	self monitoring	275-400 msec	
4	Middle and inferior frontal gyri	syllabification	400-600 msec	
5	Pre-and postcentral gyri	phonetic encloding and articulation	600- msec	वैखरी

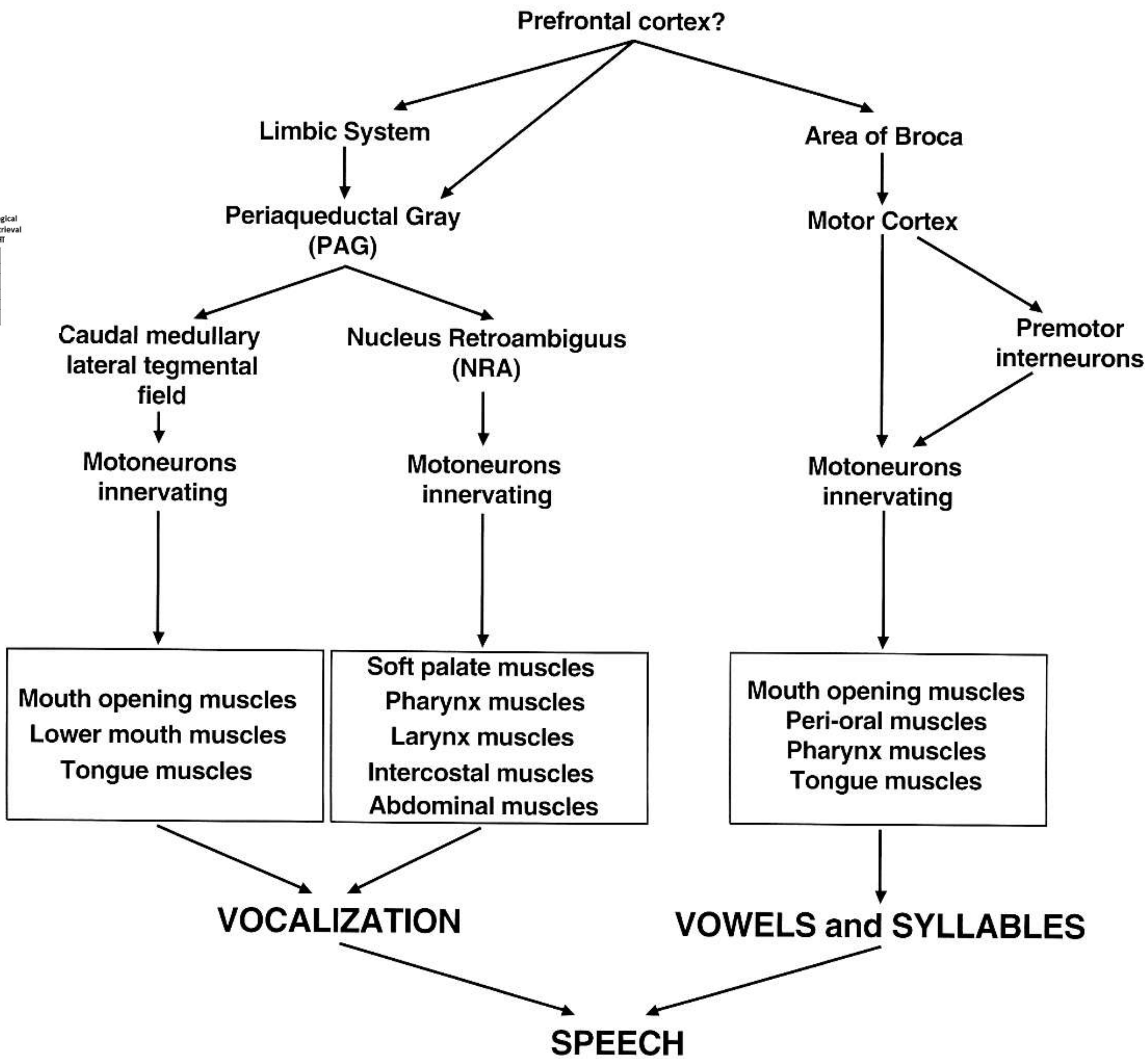


FIGURE 36.12 Schematic overview of the pathways possibly involved in the production of speech.

Somatic and Emotional motor system

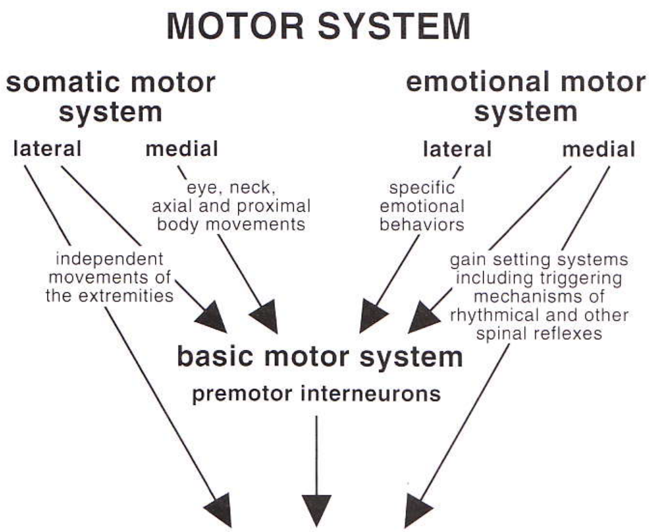
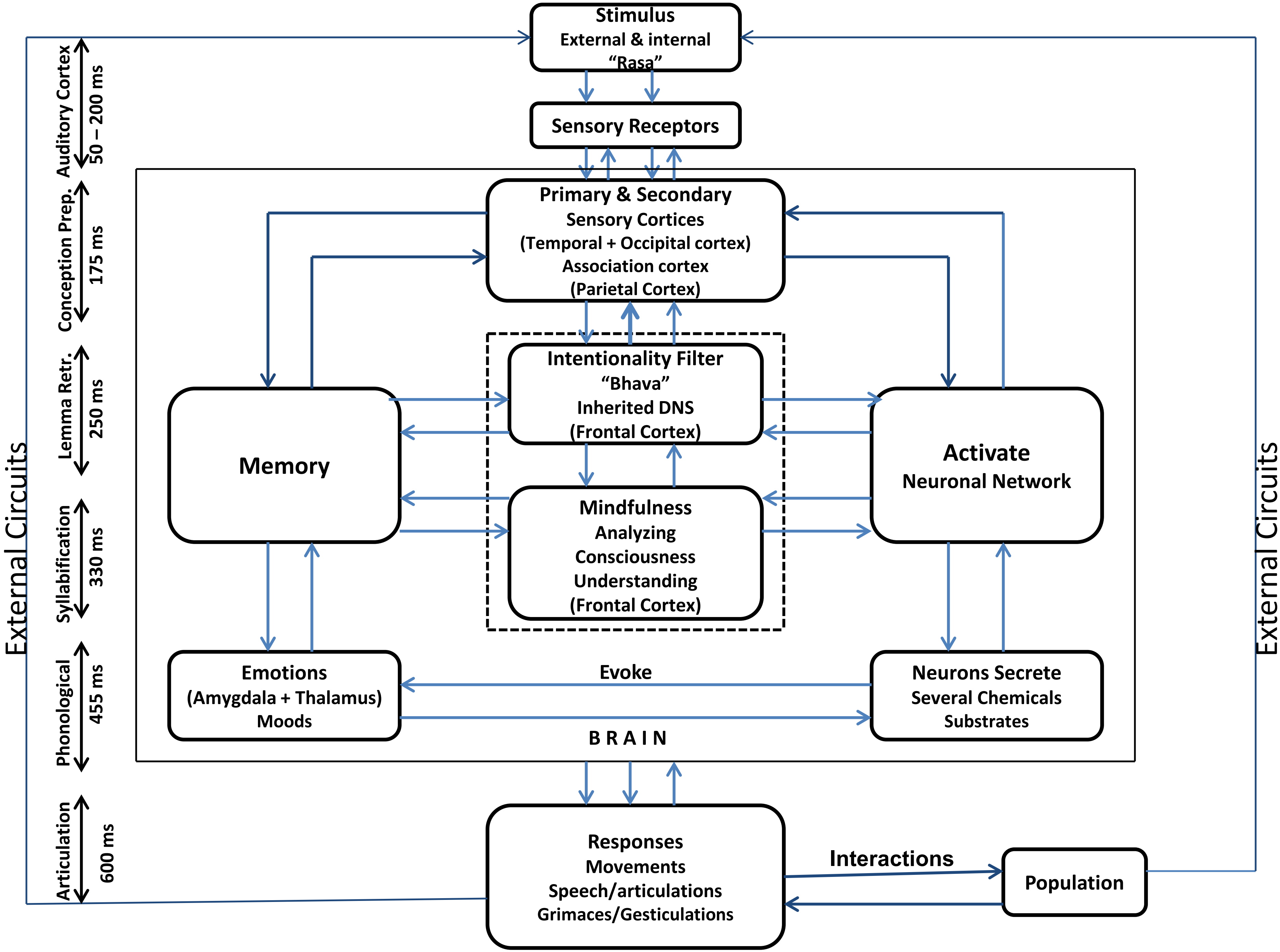
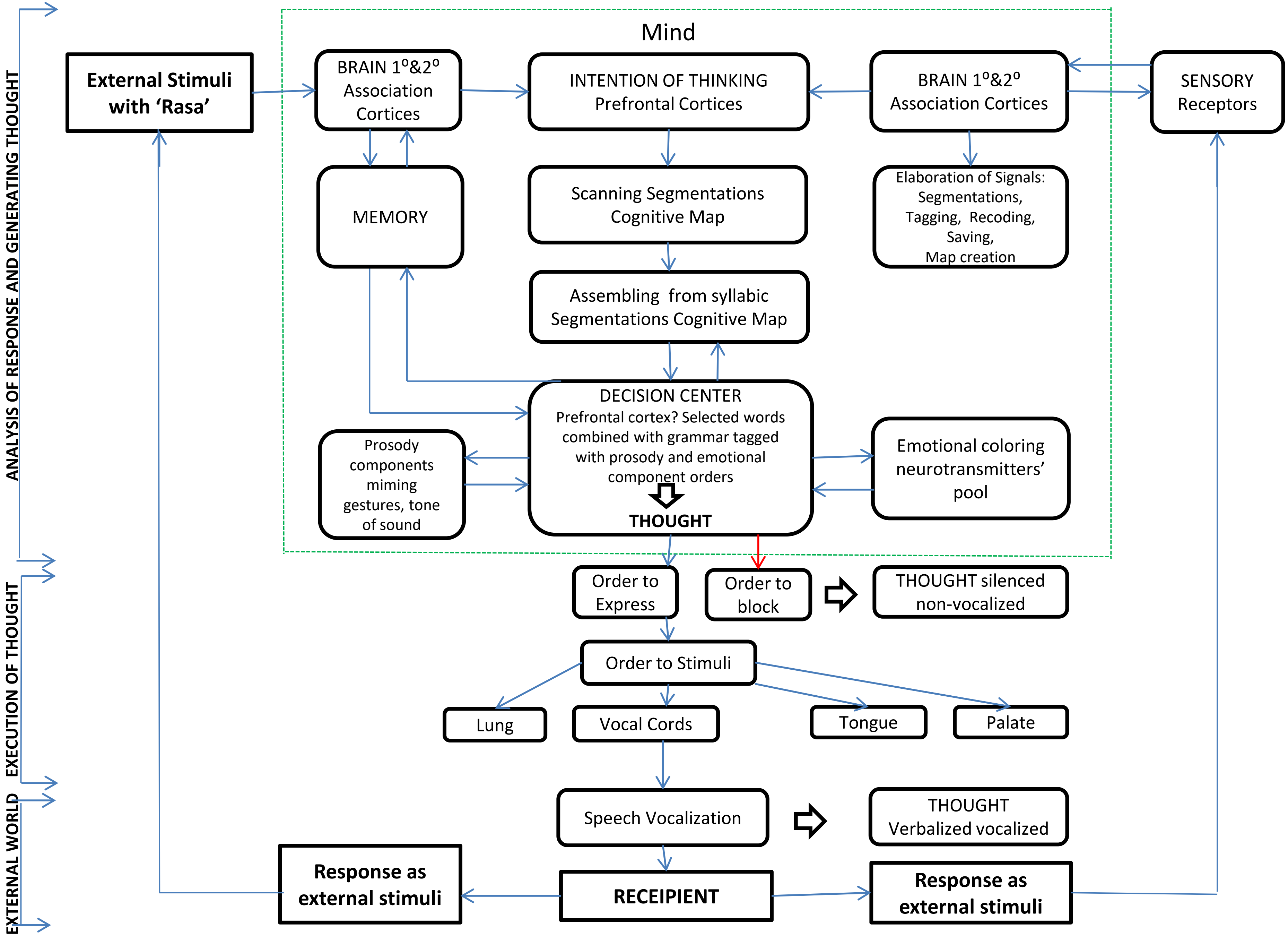


FIGURE 36.2 Scheme of the motor system consisting of a voluntary and an emotional motor component.

FIGURE 36.1 A patient suffering from a lesion in the white matter nearby the the face area of the primary and premotor cortex. The patient is not able to show her teeth on the contralateral side of the lesion *(left)*, but on the same side she is able to smile *(right)*.


Stimulus
External & internal
"Rasa"
Sensory Receptors
Primary & Secondary
Sensory Cortices
(Temporal + Occipital cortex)
Association cortex
(Parietal Cortex)
Intentionality Filter
"Bhava"
Inherited DNS
(Frontal Cortex)
Memory
Activate
Neuronal Network
Mindfulness
Analyzing
Consciousness
Understanding
(Frontal Cortex)
Emotions
(Amygdala + Thalamus)
Moods
Evoke
Neurons Secrete
Several Chemicals
Substrates
B R A I N
Responses
Movements
Speech/articulations
Grimaces/Gesticulations
Interactions
Population
External Circuits
External Circuits
Auditory Cortex
50 – 200 ms
Conception Prep.
175 ms
Lemma Retr.
250 ms
Syllabification
330 ms
Phonological
455 ms
Articulation
600 ms

Process Of Thought Expression



If the human brain were so simple that we could understand it, we would be so simple that we couldn't.

George Edgin Pugh, nuclear physicist

Although the field is by no means neglected, we have no clear-cut approach as yet for investigating the cellular basis of memory, learning, consciousness, or even how a simple act of movement is initiated in a higher animal. But perhaps we should feel encouraged by the vivid awareness of our many glaring deficiencies and by our ability to define many areas of ignorance.

Stephen W. Kuffler, neuroscientist

We shall not fail or falter we shall not weaken or tire. … Give us the tools and we finish the job.

Sir Winston Churchill, politician

Imre Farkas, Hungarian poet

Titok

Ha nem volna probléma, és volna
a megoldások háreme nyitott,
akkor is volna kutatnivalóm.
Tudnom kellene: miért nincs titok.

Secret

If there wouldn't be problem, and
the solutions' harem would be open,
even then I would have something to investigate.
I ought to know: why there is no problem.

Thank you for your attention!