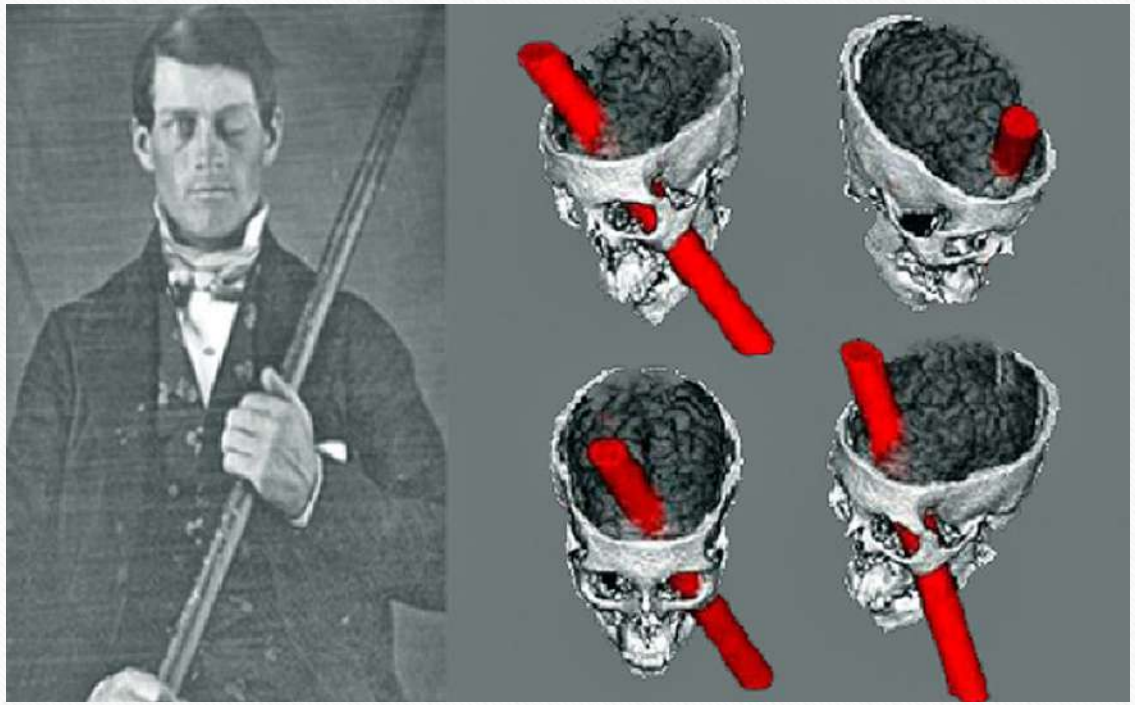
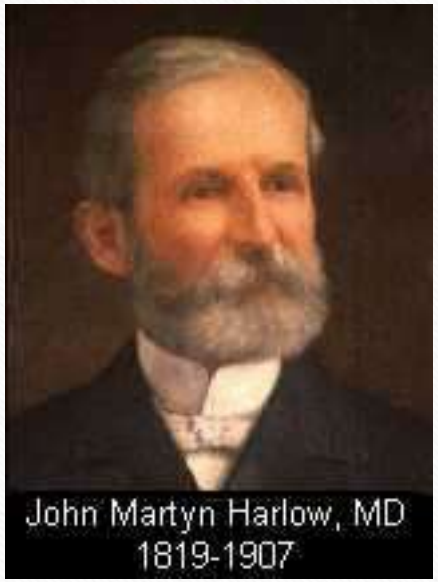
Functional Neuroanatomy of Frontal Lobes

Phineas Gage

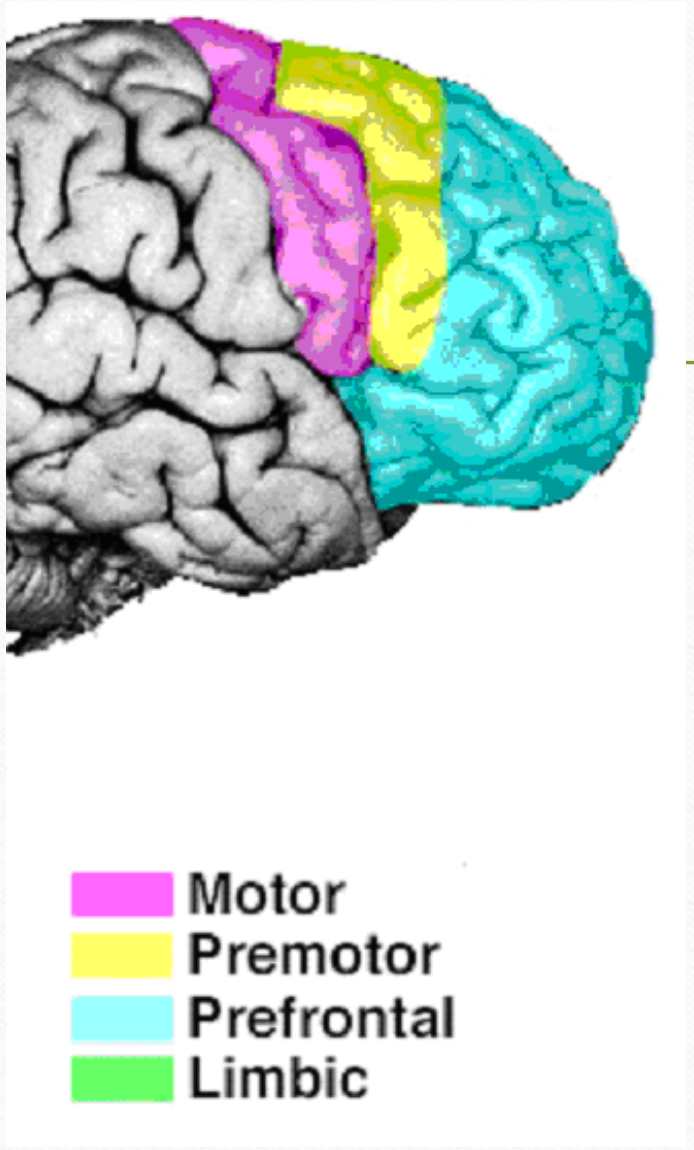




Dr Harlow

- **Classical case reports**
- The Case of Phineas Gage (Harlow 1868)

- tamping iron blown through skull: L frontal brain injury
- excellent physical recovery
- dramatic personality change: ‘no longer Gage’:stubborn, lacked in consideration for others, unreliable, lacking in social skills, had profane speech, failed to execute his plans



Frontal Lobe

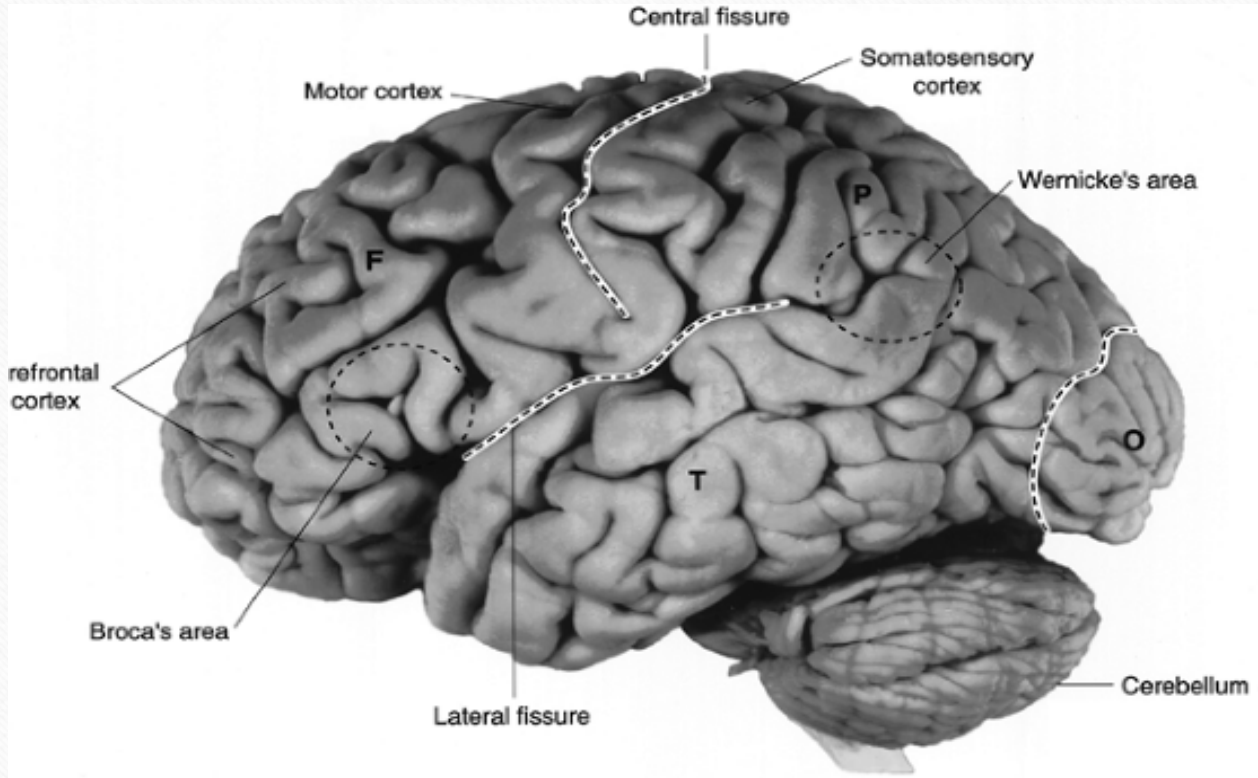
The frontal lobe is by far the largest of the four lobes of the Cerebrum

The frontal lobe is the largest lobe accounting for 41% of the total neocortical volume

Residing largely in the Anterior cranial fossa, lying on the orbital plate of the frontal bone

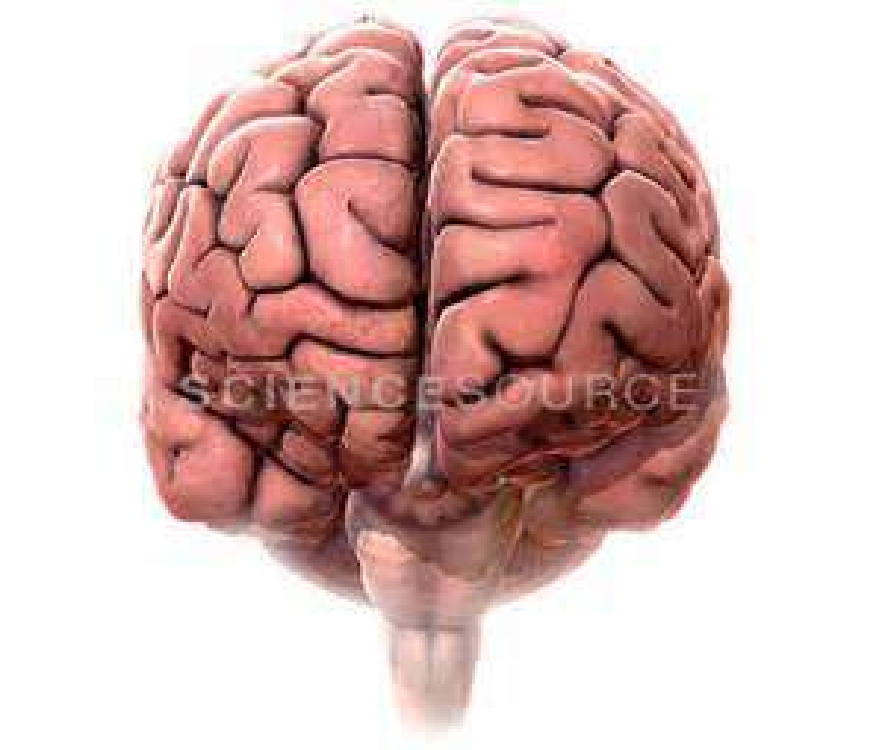
- Arise From Lateral Wall Of Diencephalon
- Derived From Rostral End Of Hemisphere

The frontal lobe is located anterior to the central sulcus and consists of the primary motor, premotor, and prefrontal regions



- Prefrontal cortex can be divided into dorsolateral and ventrolateral regions
- The Dorsolateral prefrontal cortex seems to more involved in the manipulation of data during working memory tasks
- The ventrolateral prefrontal cortex seems to be more involved with pure maintenance of information during working memory.

The frontal lobe is roughly pyramidal in shape, with three cortical surfaces



- Lateral surface (largest)
- Medial (inter-hemispheric) surface
- Inferior surface

Functional Frontal Lobe Anatomy

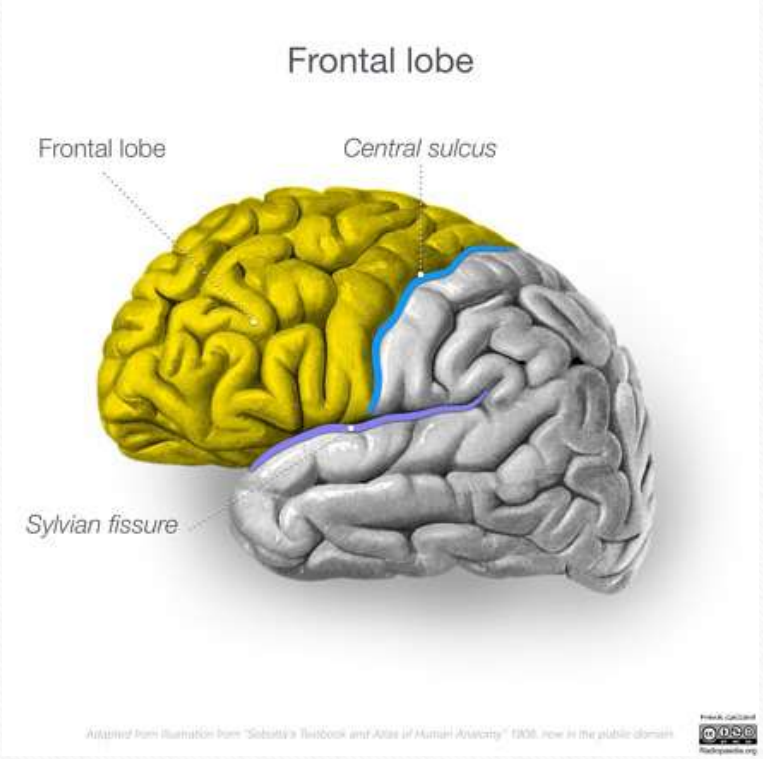
3 major areas in each lobe :-

Dorsolateral aspect

Medial aspect

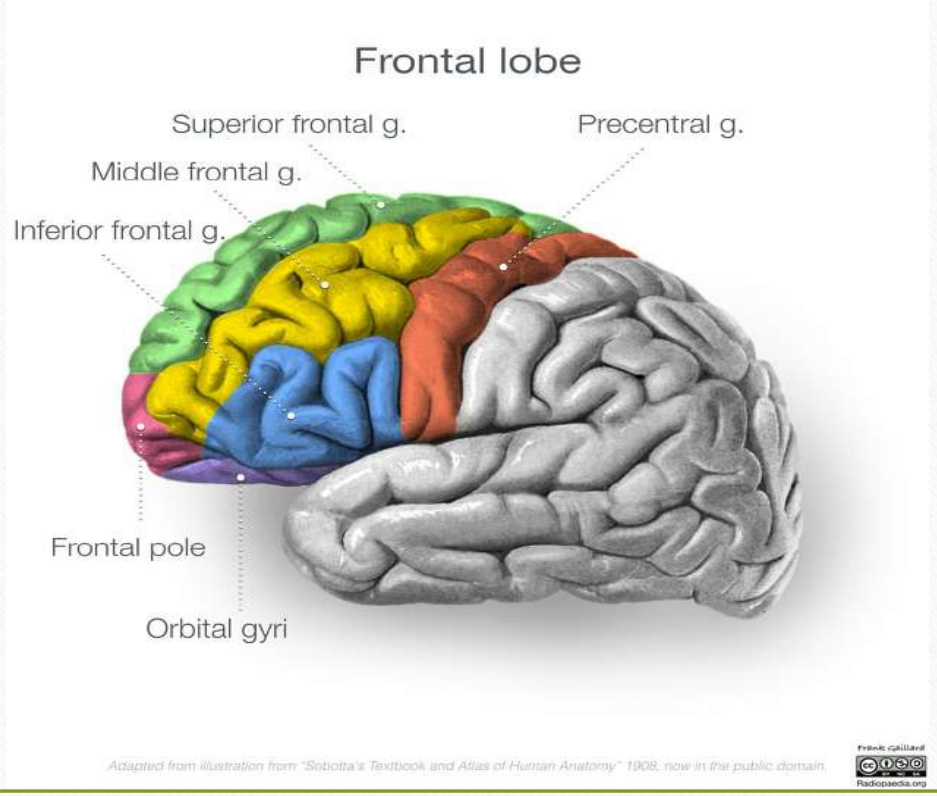
Inferior orbital aspect

Lateral surface



- The lateral surface is curved, conforming to the inner surface of the frontal and parietal bones.
- It is divided into four gyri, which in reality are more 'regions' than true gyri, in that each is convoluted and divided by smaller incomplete sulci, which in turn are separated from each other by three main sulci.

Lateral Gyri



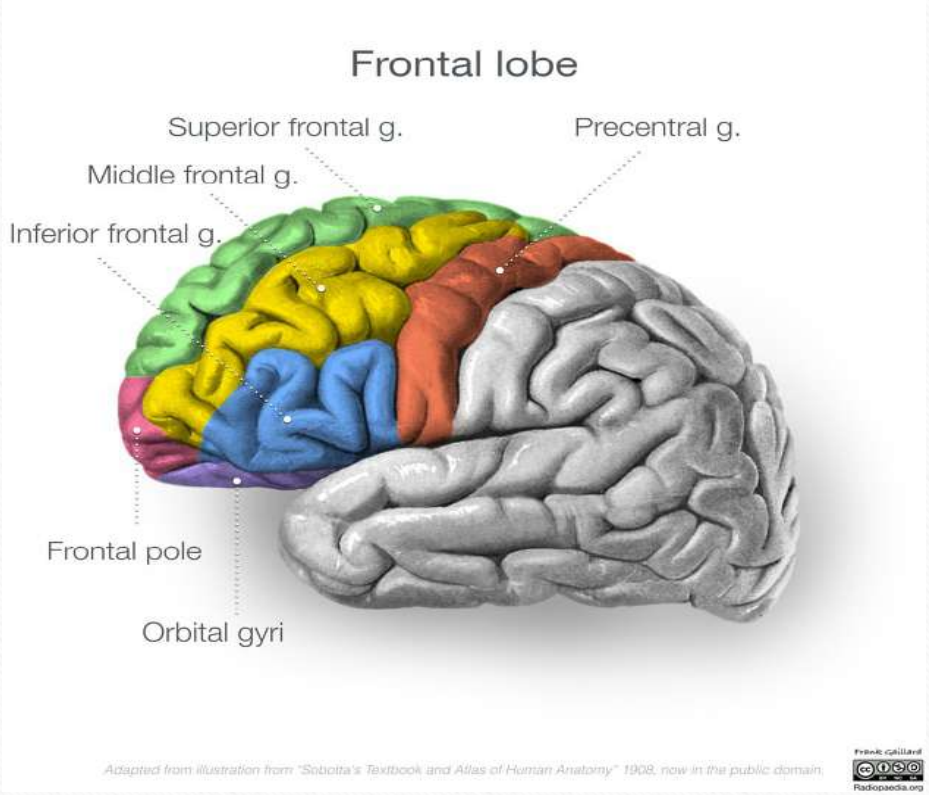
Superior frontal gyrus

- most medial and superior part of the frontal lobe, Laterally it is separated from the middle frontal gyrus by the superior frontal sulcus

Middle frontal gyrus

- runs parallel to the superior frontal gyrus, from frontal pole to precentral sulcus, inferolaterally it is separated from the inferior frontal gyrus by the inferior frontal sulcus

Lateral Gyri



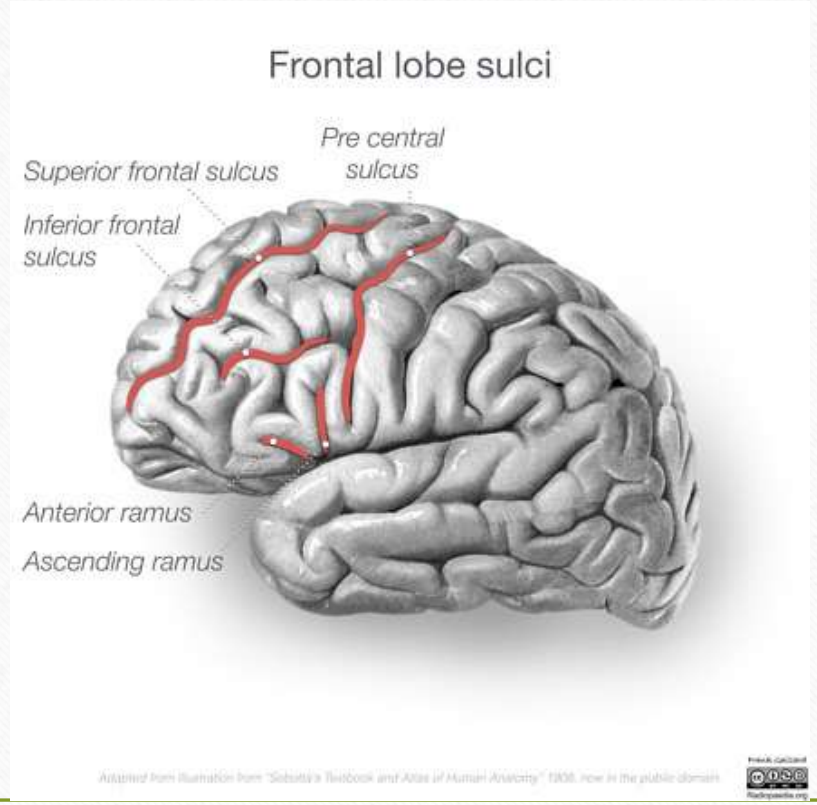
Inferior frontal gyrus

- runs parallel to the middle frontal gyrus, from the lateral border of the orbital gyri anteroinferiorly , a large part of the inferior frontal gyrus forms the frontal operculum, which covers the insular cortex
- Contains Broca's area 1, 2

Precentral gyrus

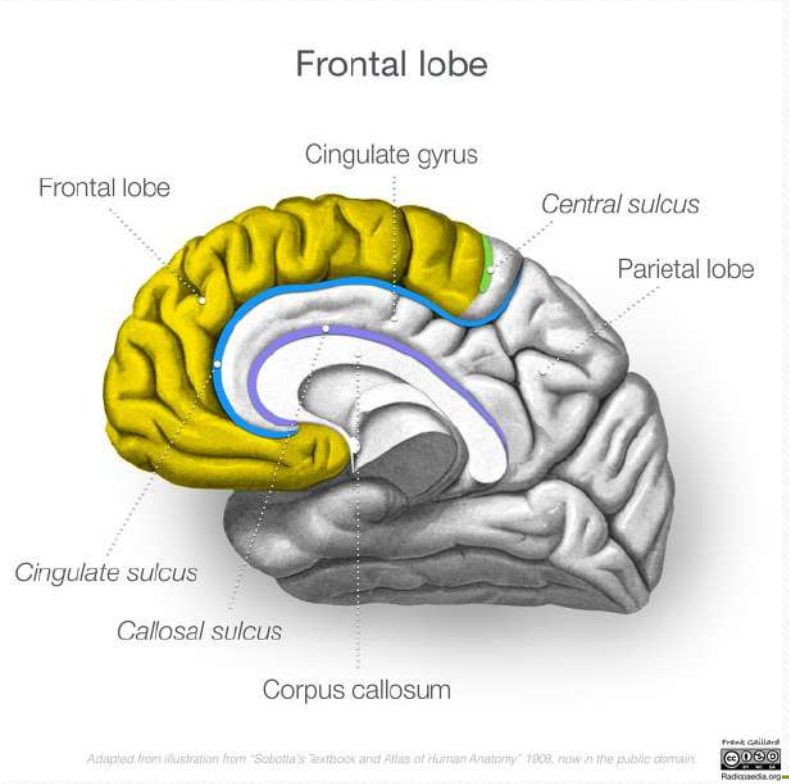
- Anteriorly it is separated from the posterior parts of the superior, middle and inferior frontal gyri by the precentral sulcus
- Contains the primary motor cortex

Lateral Sulci



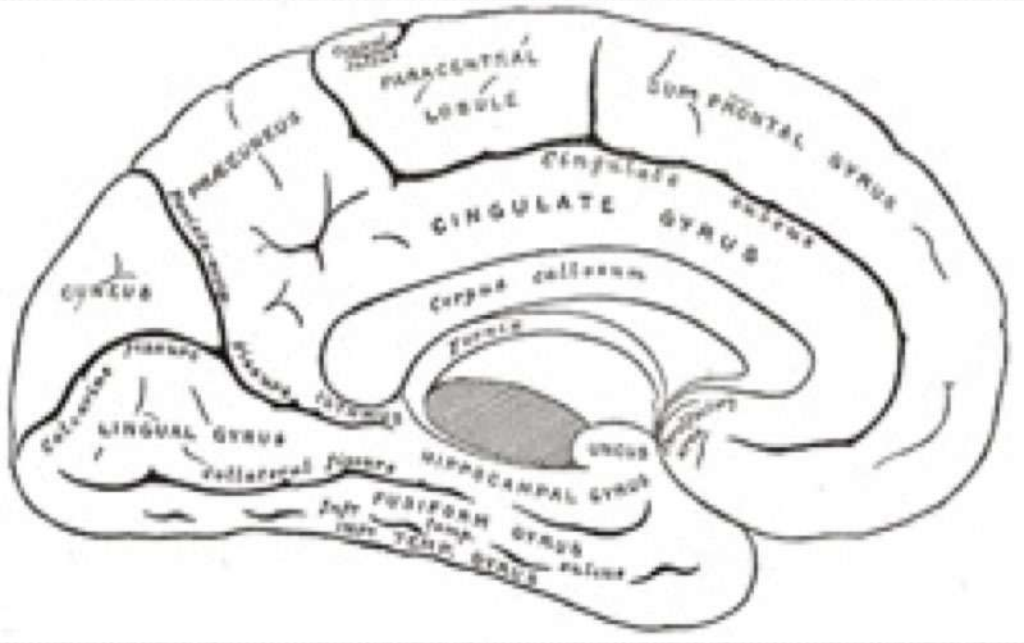
- Superior frontal sulcus
- Inferior frontal sulcus
- Precentral sulcus

Medial surface



- The medial surface of the frontal lobe, abutting the Falx in the midline, is primarily divided by the curving Cingulate sulcus, which parallels the outer outline of the corpus callosum.
- Above the cingulate sulcus is the medial continuation of the superior frontal gyrus, which is usually divided into two parts by a short ascending branch from the cingulate sulcus.

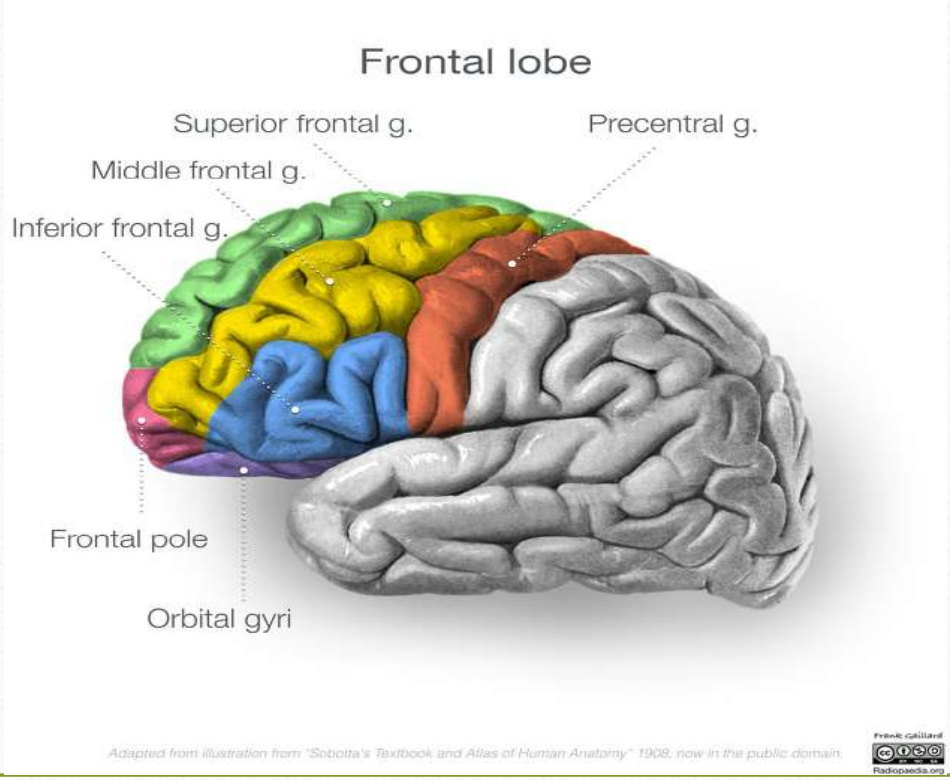
Medial Gyrus



- Medial frontal gyrus
  Anterior to the ascending branch of the cingulate sulcus
- Paracentral lobule
  Posterior to the ascending branch of the cingulate Sulcus

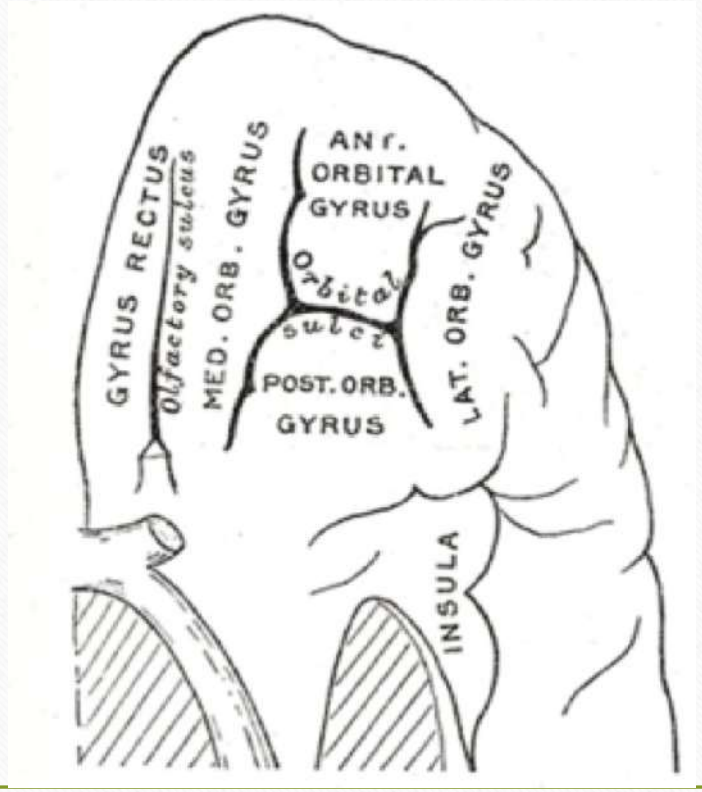
Below the cingulate sulcus is the cingulate gyrus, which is variably included partially as part of the frontal lobe, or sometimes considered part of the limbic lobe.

Inferior surface



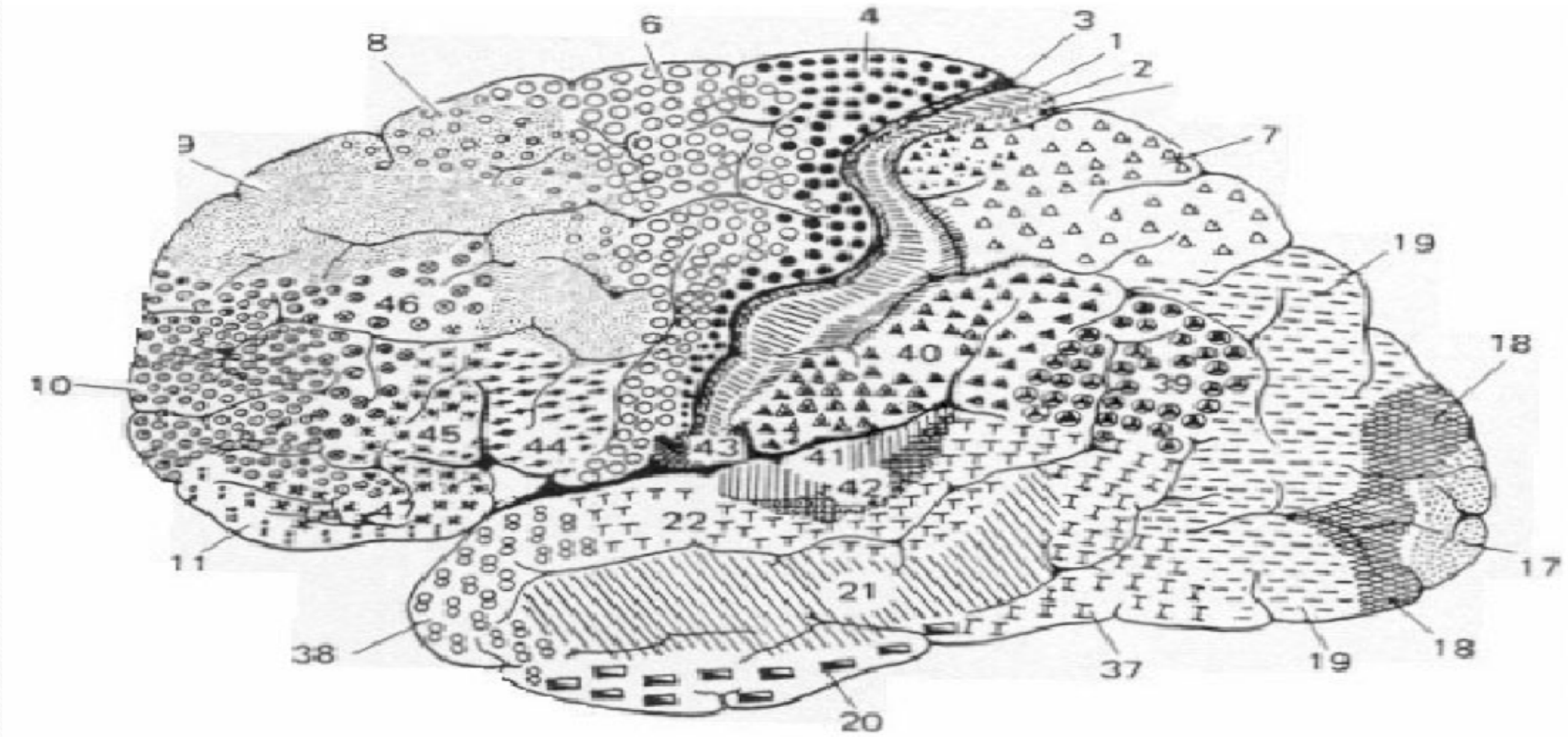
- The inferior surface of the frontal lobe is the smallest cortical surface of the lobe, located anterior to the stem of the sylvian fissure, lying on the floor of the anterior cranial fossa.

Inferior Gyrus and Sulci



Most medial, and running antero-posteriorly is the Olfactory Sulcus which separates the long thin medial gyrus recti (straight gyrus), from the larger orbital gyri

The orbital gyri are in turn divided by the "H" shaped Orbital Sulcus, into four gyri, two located above and below the transverse part of the "H" (the anterior and posterior orbital gyri), and two located on either sides of the "H" (the medial and lateral orbital gyri)



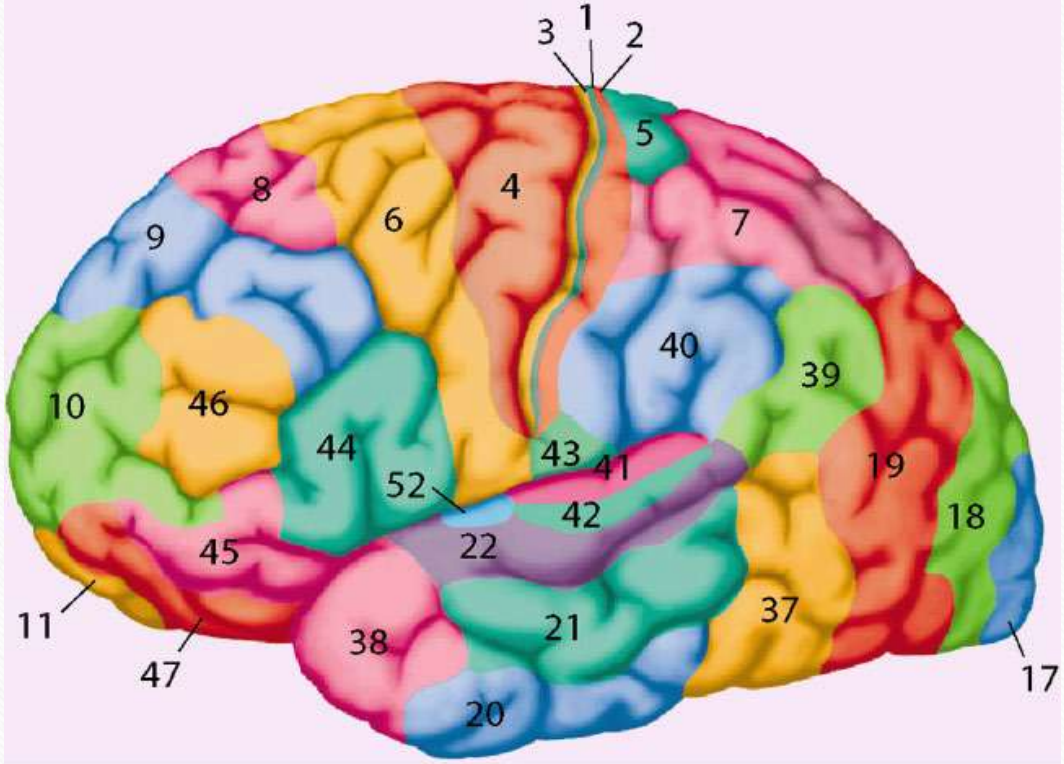
BRODMANN'S AREAS

TABLE 4.1. Frontal Lobe Anatomy

Brodmann's area	Anatomical description	Cortical type	Functional region
4	Primary motor cortex	Primary motor	Motor
6	Premotor/supplementary motor area	Primary motor (caudal) Unimodal motor (rostral)	Premotor
44[a,b]	Pars opercularis	Unimodal motor	
8[c]	Motor association cortex	Unimodal motor (caudal) Heteromodal (rostral)	
46	Dorsolateral prefrontal cortex	Heteromodal	Prefrontal (dorsolateral)
9	Superior prefrontal cortex	Heteromodal	
10	Inferior prefrontal cortex	Heteromodal	
45[a,b]	Pars triangularis	Heteromodal	Prefrontal (ventrolateral)
47[a]	Pars orbitalis	Heteromodal	
11[d]	Lateral orbitofrontal cortex	Heteromodal	Prefrontal (orbitofrontal)
12[d]	Medial orbitofrontal cortex	Heteromodal (rostral) Paralimbic (caudal)	
32	Medial frontal cortex	Heteromodal (rostral) Paralimbic (caudal)	Paralimbic (medial frontal)
24	Anterior cingulate	Paralimbic	
25	Paraolfactory region (subcallosal area)	Paralimbic	

Note. After Mesulam (1985) and Damasio and Damasio (1989).
[a] Frontal operculum.
[b] Broca's area (left hemisphere).
[c] Frontal eye fields.
[d] Region numbers are reversed in nonhuman primates (Walker, 1940).

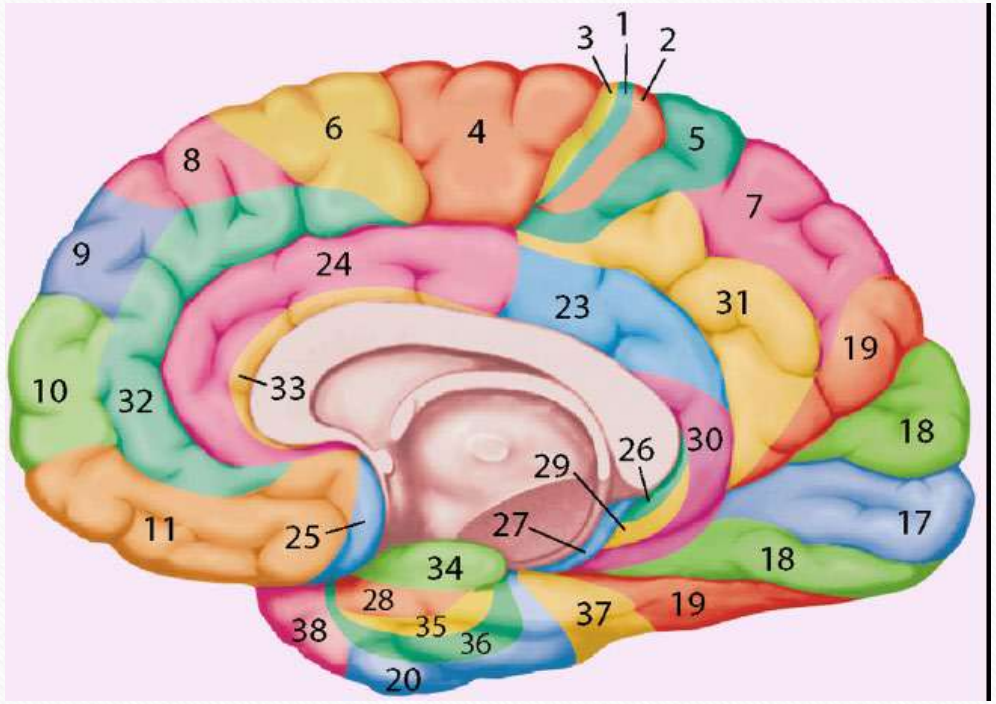
Functional Frontal Lobe Anatomy



Motor/premotor

1. Precentral gyrus (4)
2. Premotor cortex (6)
3. Supp. Motor (mesial area 6)
4. Broca's (44,45)
5. Frontal eye fields (8)

Functional Frontal Lobe Anatomy



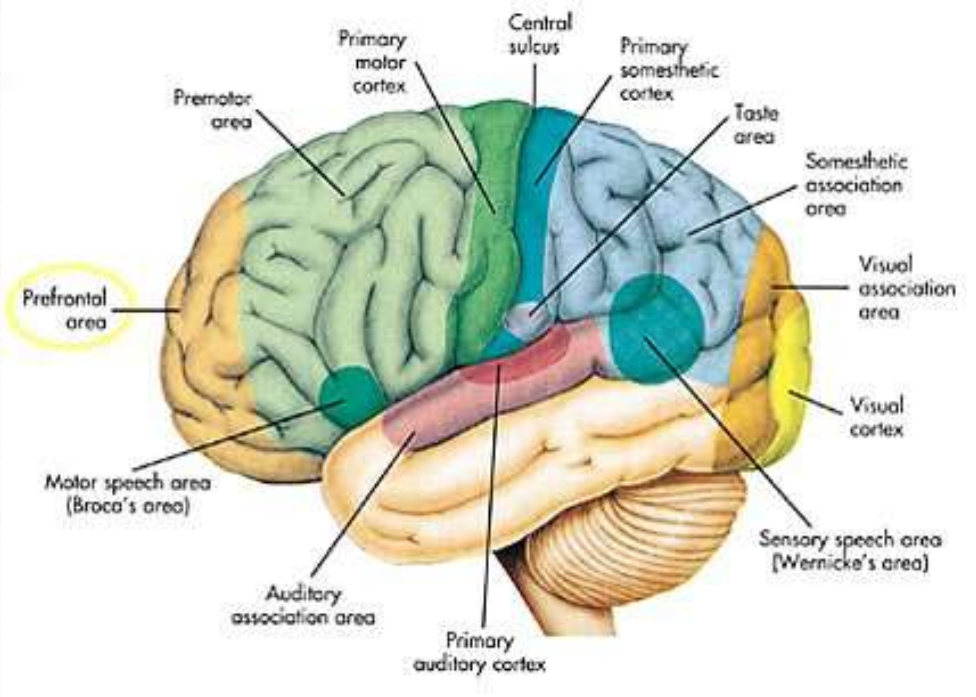
Paralimbic cortex

1. Ant. Cingulate/sub callosal (24,25,32)

Prefrontal cortex –

1. Mesial cortex (9,10)
2. Dorsolateral (9,10,46)
3. Orbito frontal cortex (11,12,47)

Frontal Lobes Area's



Primary Motor Cortex

Planning & Refining of motor movements

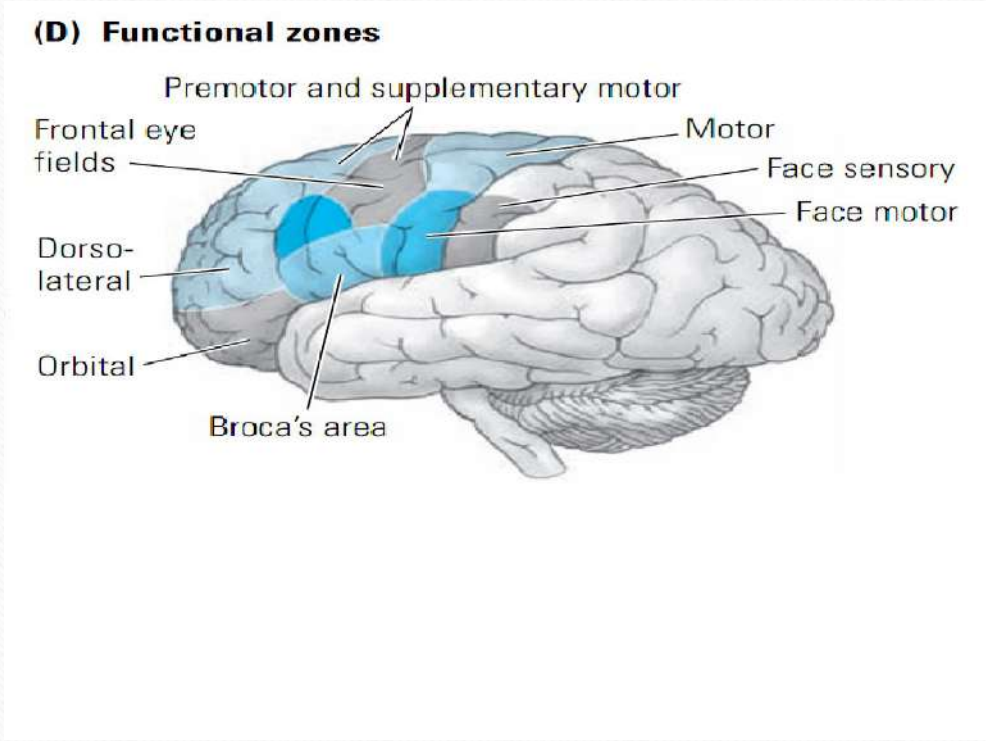
Area 4 of Broad man's

Pre Motor Cortex

Planning complex motor movements

Broad man's area 6,8

Frontal Lobes Area's



Frontal Eye Field

Voluntary saccades

Smooth pursuit eye movements

Fast brain pathway

Broca's Area

Motor movements of Tongue & larynx

Speech formation

Broadman's area 44,45

A Cortical Homunculus

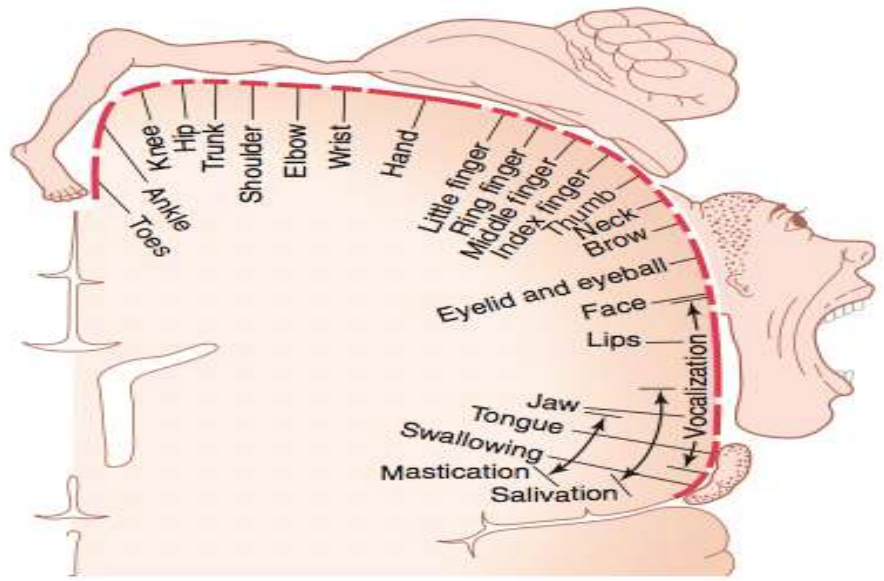
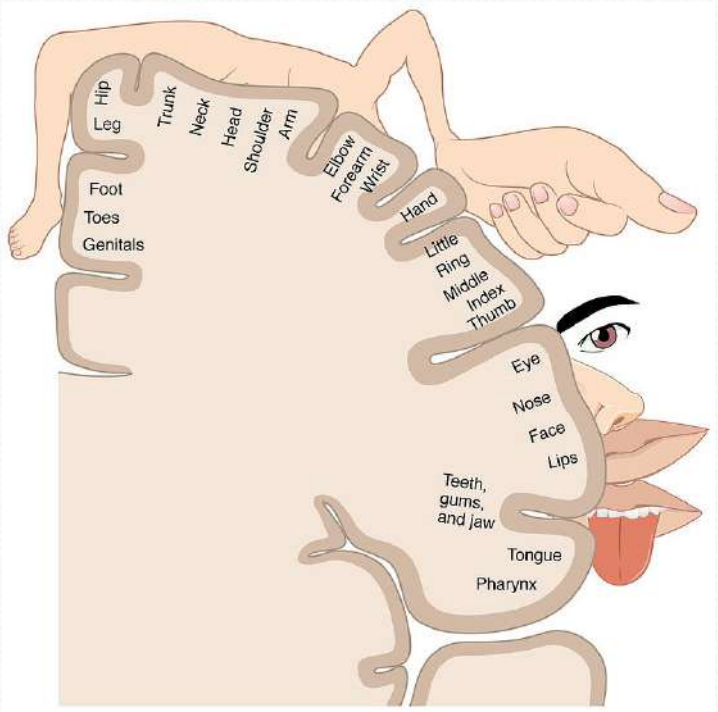


Figure 56-2. Degree of representation of the different muscles of the body in the motor cortex. *(Modified from Penfield W, Rasmussen T: The Cerebral Cortex of Man: A Clinical Study of Localization of Function. New York: Hafner, 1968.)*



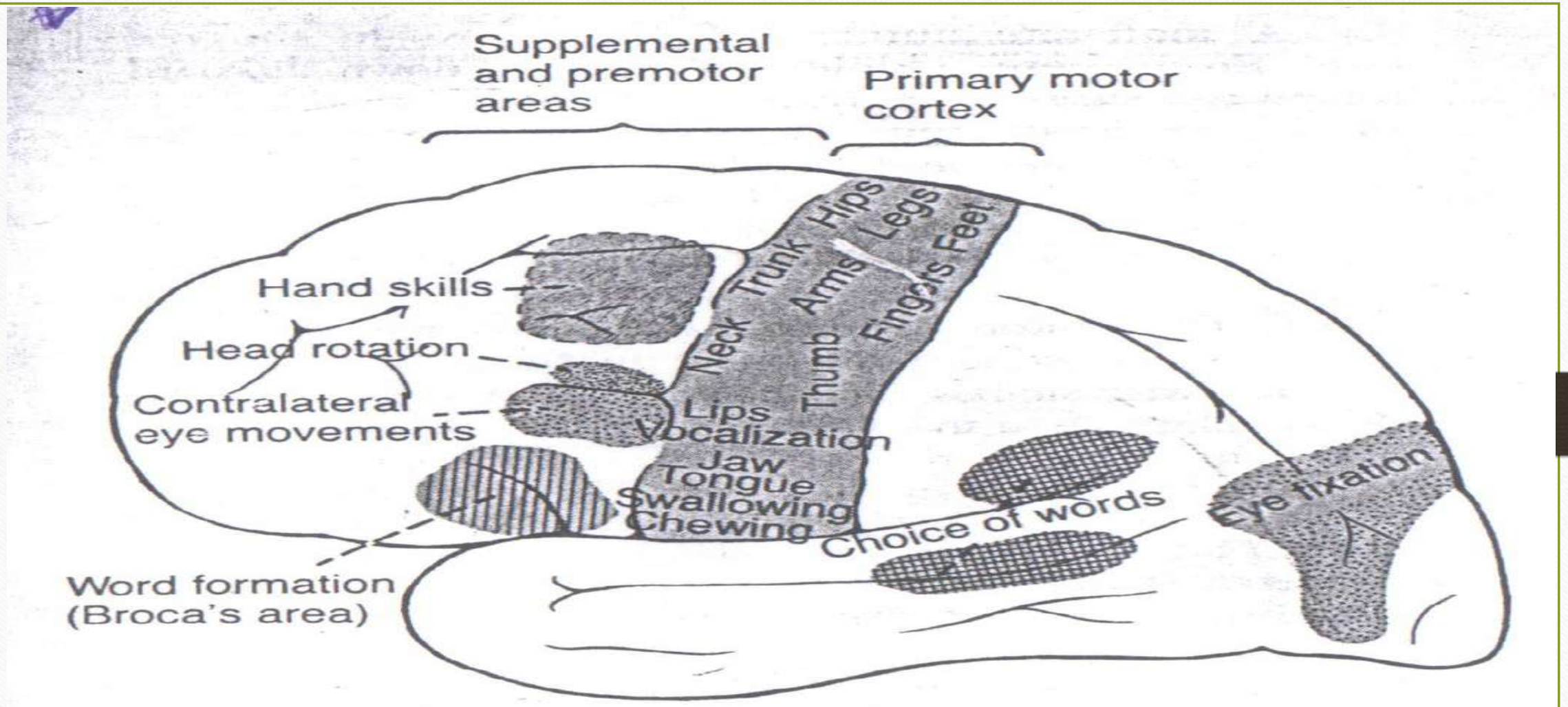
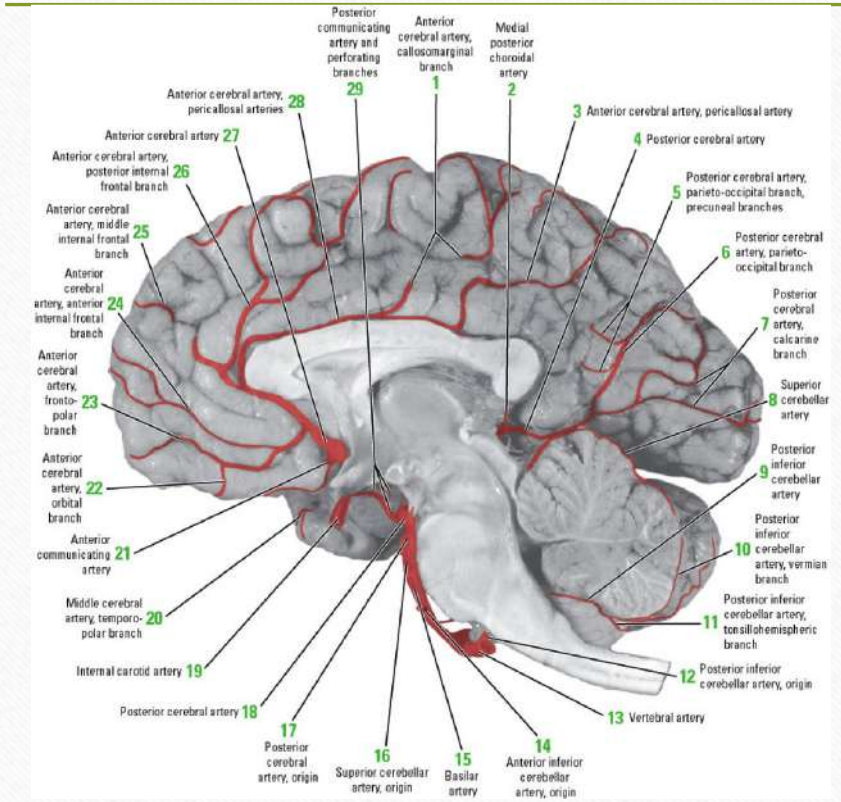
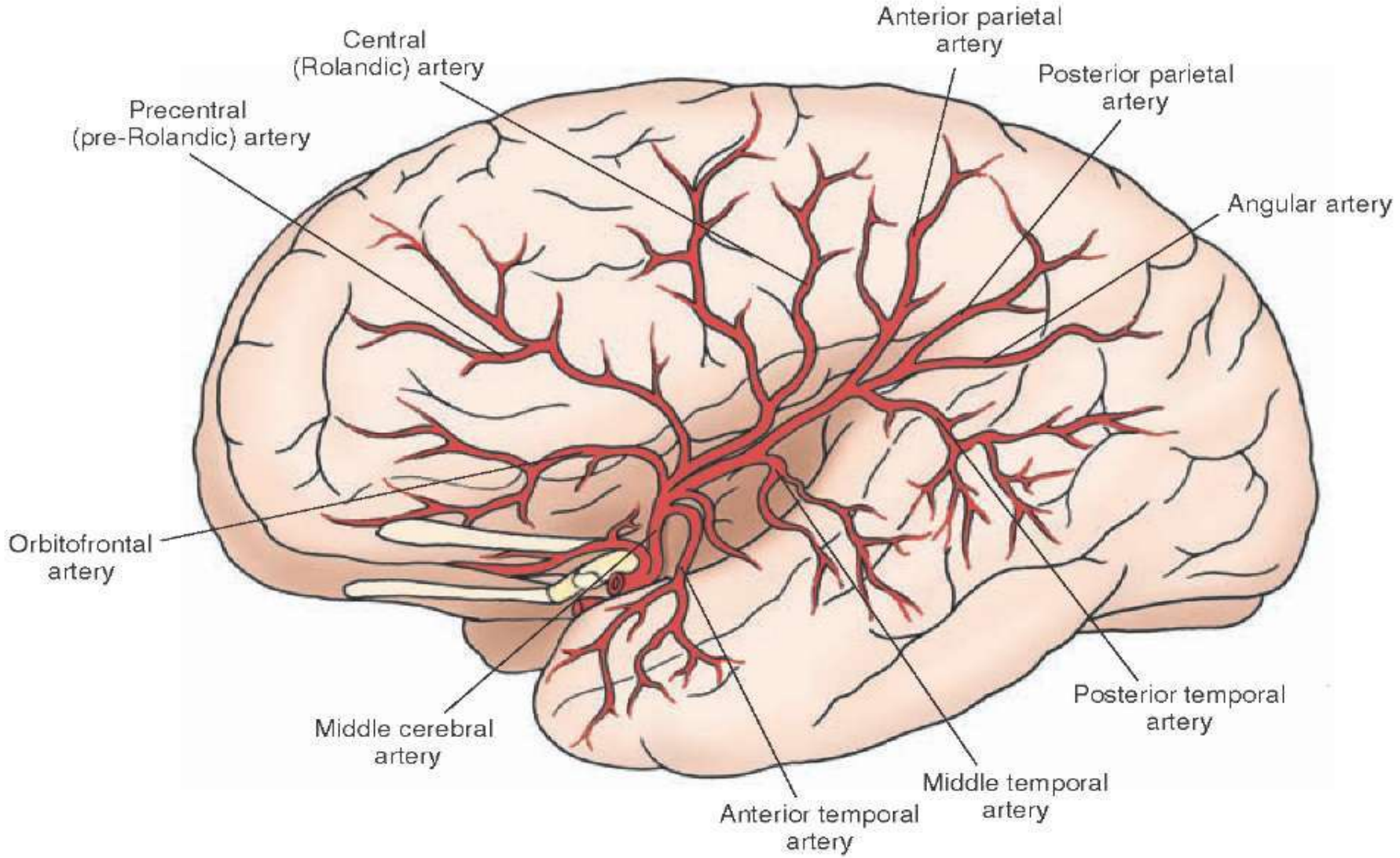


Figure 55–3. Representation of the different muscles of the body in the motor cortex and location of other cortical areas responsible for specific types of motor movements.

Blood Supply



- Supero lateral surface
  Anterior & Middle cerebral artery
- Medial surface
  Anterior cerebral artery
- Inferior surface
  Anterior & middle cerebral artery


Anterior parietal artery
Central (Rolandic) artery
Posterior parietal artery
Precentral (pre-Rolandic) artery
Angular artery
Orbitofrontal artery
Posterior temporal artery
Middle cerebral artery
Middle temporal artery
Anterior temporal artery
B

FRONTAL LOBE FUNCTIONS

- Elemental Neurological Functions
  - Pyramidal motor functions
  - Control of continence
  - Olfaction
- Ocular Motor Functions
- Frontal Release Signs
- Sphincter Control

FRONTAL LOBE FUNCTIONS

- Speech and Language Functions
- Pre-frontally Mediated Skills and Syndromes
  - motivational behaviors
  - social competency
  - executive abilities

Elemental Neurological Functions

- Pyramidal motor functions - The pyramidal motor tract begins in the motor strip and projects through the internal capsule and peduncle to the basis pontis and the medullary decussations before descending to the anterior horn cells. The pyramidal motor system mediates fine finger and lip movements, as well as upper limb reach into the environment.
- Olfaction - The medial olfactory track projects into the septal region of the basal forebrain within the inferior medial frontal lobe
- Control of continence -Incontinence is caused by right or left sided lesions involving posterior part of sup frontal gyrus, anterior cingulate gyrus.

Ocular Motor Functions

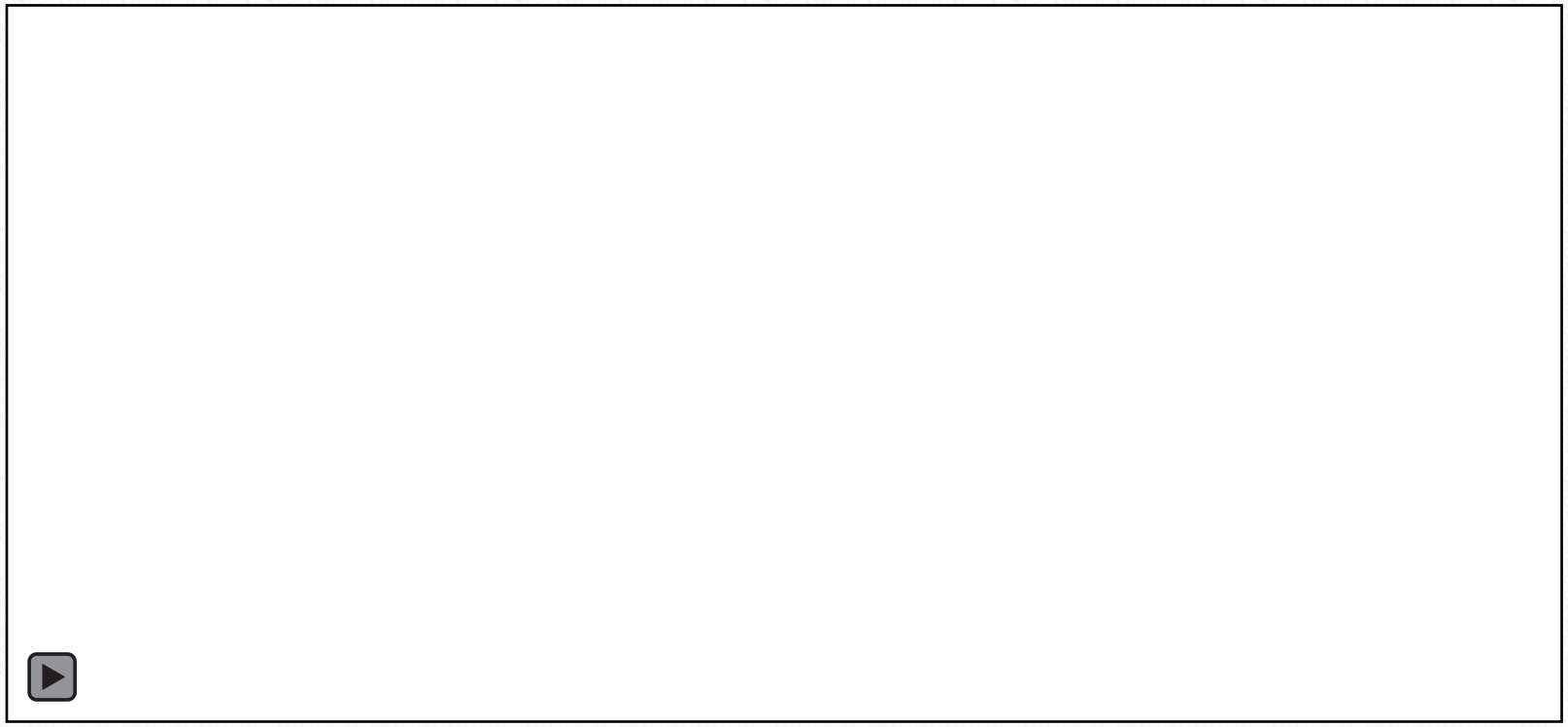
- Volitional eye movements are mediated by the frontal eye fields (Brodman's area 8) anterior to the motor strip.
- Saccadic eye movements depend on the integrity of this system.
- Supranuclear eye movement abnormalities reflecting an involvement of the frontal eye fields or disconnection of the fields from the ocular nuclei occur in progressive supranuclear palsy, Huntington's disease, and a variety of other neurological disorders.

Seizures produce ocular deviation away from the affected frontal eye field
Ocular eye deviation toward the affected side is characteristic of a postictal state or a focal lesion.

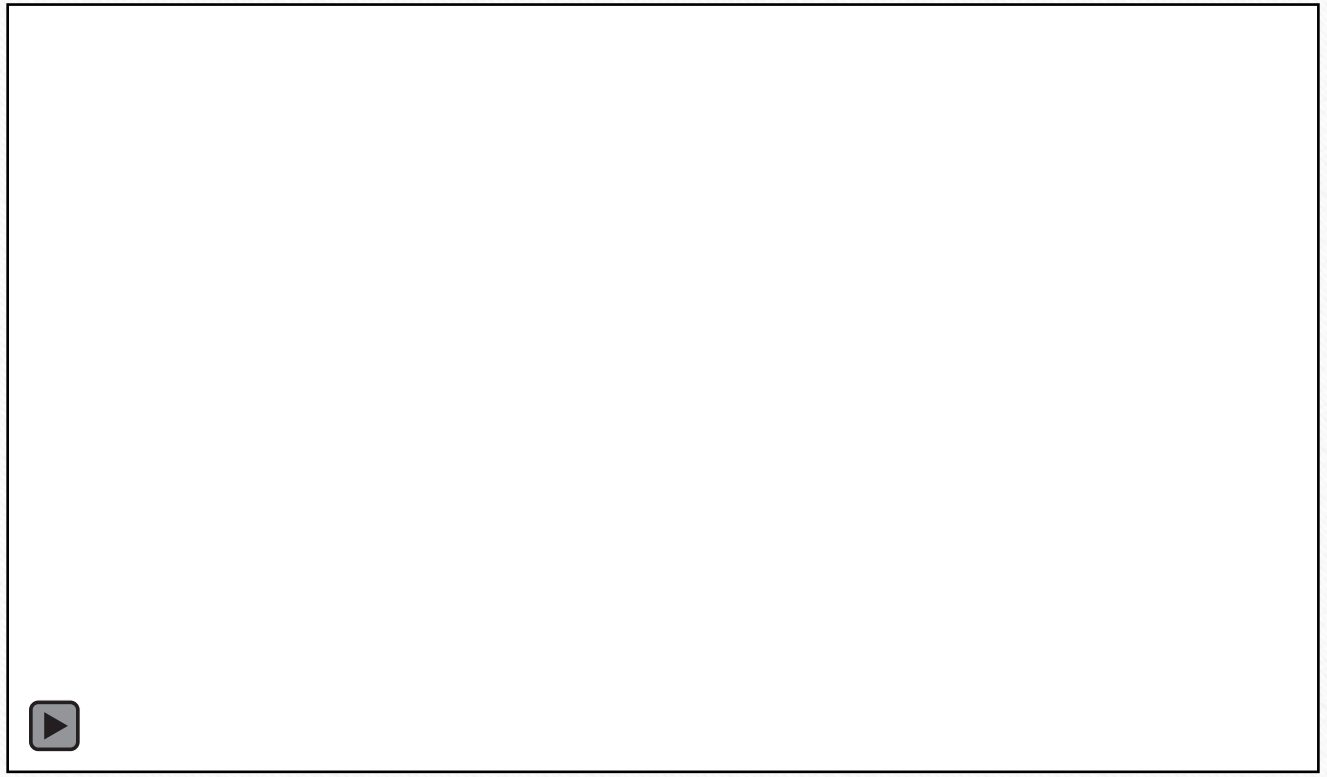
Frontal Release Signs

- Frontal release signs more properly called “primitive reflexes,” represent evolutionarily derived motor programs that facilitate the existence of the infant but are normally lost as frontal cortex matures and frontal function suppresses these more primitive motor programs.
- The Suck reflex
- The Grasp reflex
- The Extensor plantar
- The Palmomental reflex

Palmomental Reflex



Grasp reflex



Sphincter Control

- The urethral and anal sphincters are represented anatomically in the medial inferior frontal cortex, inferior to the leg area of the medial primary motor cortex.
- Involvement of this region through anterior cerebral artery stroke or degeneration results in loss of sphincter control and urinary or fecal incontinence.

Speech and Language Functions

- Speech and language functions are mediated by frontal lobe structures.
- A frontal dysarthria has been described with lesions anterior to the mouth area of the primary frontal cortex
- Aphemia is a syndrome is associated with small lesions confined to Broca's area of the left hemisphere
- Larger Broca's area lesions on left produce the syndrome of Broca's aphasia, with nonfluent verbal output, largely intact comprehension, and compromised repetition
- An executive aprosodia with impaired speech occurs with lesions of the right hemisphere in the location equivalent to Broca's area on the left
- More anterior lesions of the right hemisphere contribute to a language output syndrome of verbal dysdecorum, featuring lewd remarks, sarcasm, or inappropriate humor

Broca's Area

A Tendency to whisper instead of speaking aloud and dysarthria

	Broca's aphasia	Aphemia
Speaks	✗	✗
Write	✗	✓
Comprehends	✓	✓

Pre-frontally Mediated Skills and Syndromes

- The prefrontal cortex is parcellated into orbitofrontal, dorsolateral prefrontal, and medial frontal/anterior cingulate regions
- Dorders affecting
  - Medial frontal cortex produce an apathetic amotivational syndrome
  - Orbitofrontal cortex produce a disinhibited, impulse control disorder
  - Dorsolateral prefrontal cortex result in executive dysfunction

Executive Dysfunction

- Formulating goals with regard for long-term consequences
- Generating multiple response alternatives
- Choosing and initiating goal-directed behaviors
- Self-monitoring the adequacy and correctness of the behavior
- Correcting and modifying behaviors when conditions change
- Persisting in the face of distraction.

FRONTAL–SUBCORTICAL CIRCUITS

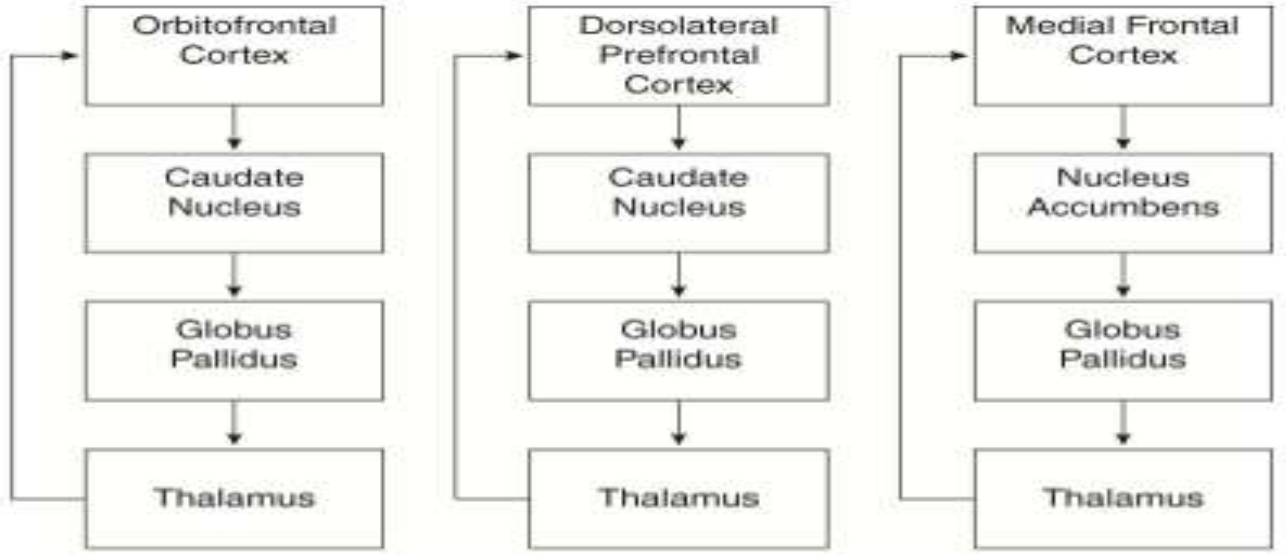
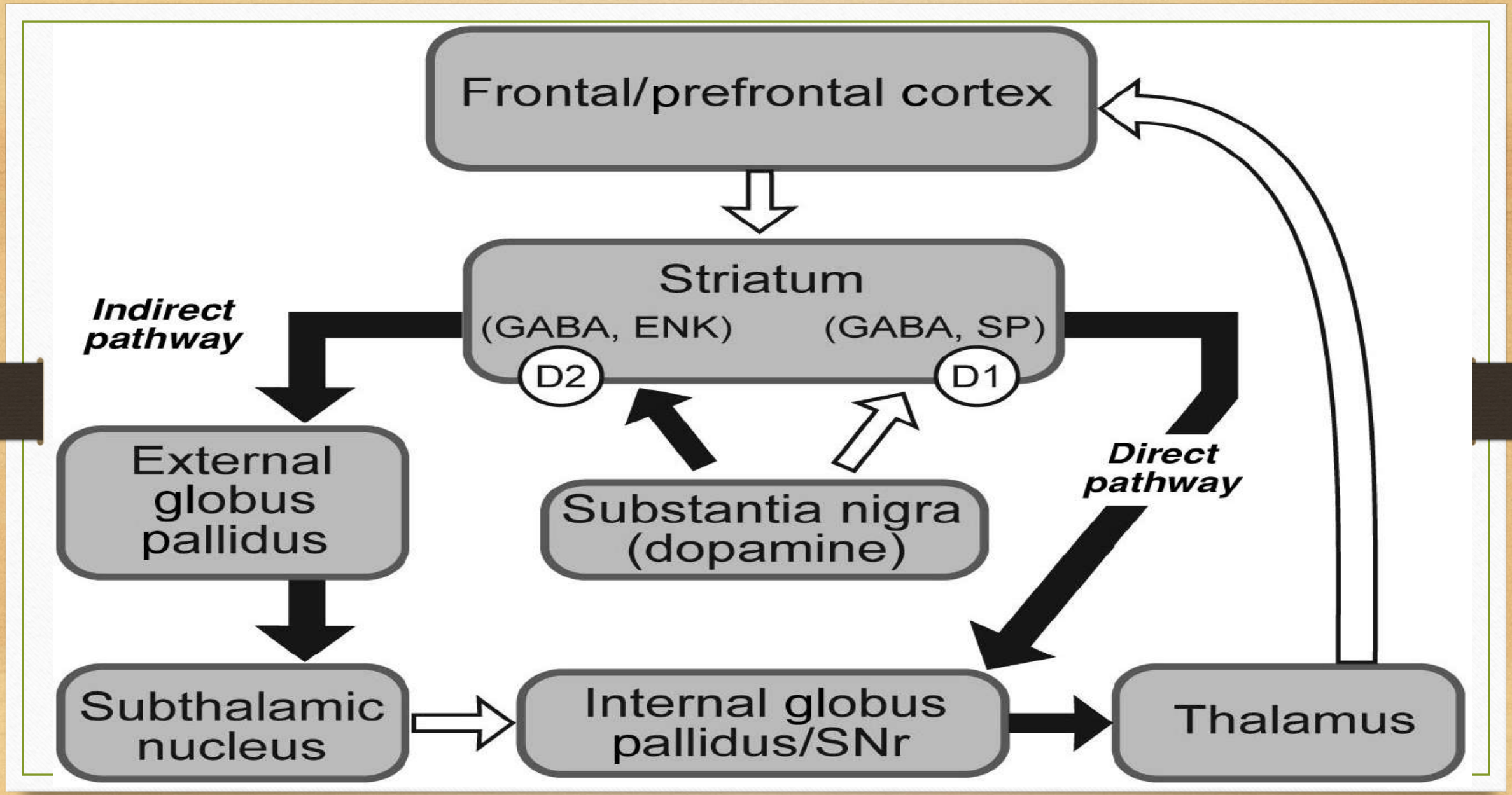
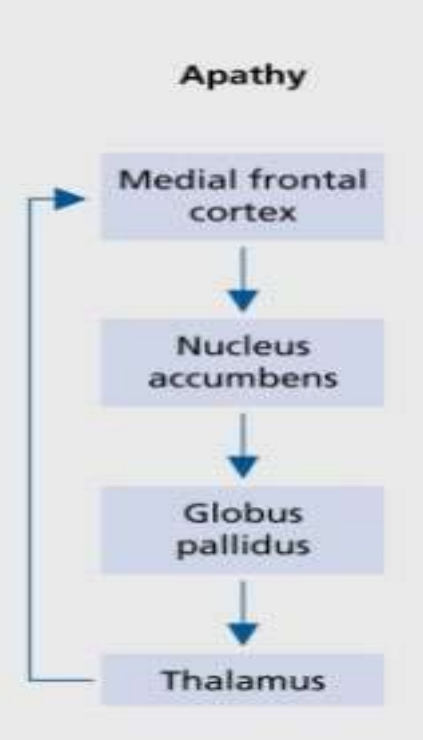


FIGURE 2.1. Principal anatomic structures of frontal–subcortical circuits.


Frontal/prefrontal cortex
Striatum
(GABA, ENK)
(GABA, SP)
D2
D1
Indirect pathway
Direct pathway
External globus pallidus
Substantia nigra (dopamine)
Subthalamic nucleus
Internal globus pallidus/SNr
Thalamus

MEDIAL FRONTAL CORTEX



The medial frontal cortex comprises the supplementary motor area and the anterior cingulate cortex

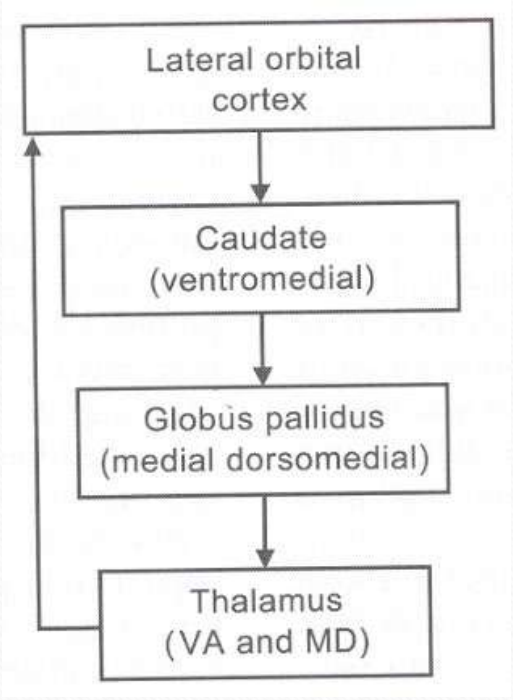
The anterior cingulate is intimately involved in Motivated behavior (apathetic state)

When Damaged :-
Akinetic Mutism (Neither walk nor speak)
Abulia (Absence of willpower or an inability to act decisively)
Impairment in Spontaneous Initiation of behavior

MEDIAL FRONTAL CORTEX

- *Motoric apathy* is manifested by diminished motor activity, reduced gesturing, and diminished verbal output.
- *Cognitive apathy* is manifested by decreased curiosity and altered interest in learning, deducing, and drawing logical conclusions.
- *Affective apathy* includes diminished vocal inflection and reduced facial expression of internal emotional states.
- *Emotional apathy* is evidenced by reduced social interest, diminished affection, and compromised enthusiasm.
- *Motivational apathy* includes reduced initiation and poor maintenance of implemented activities

ORBITOFRONTAL CORTEX



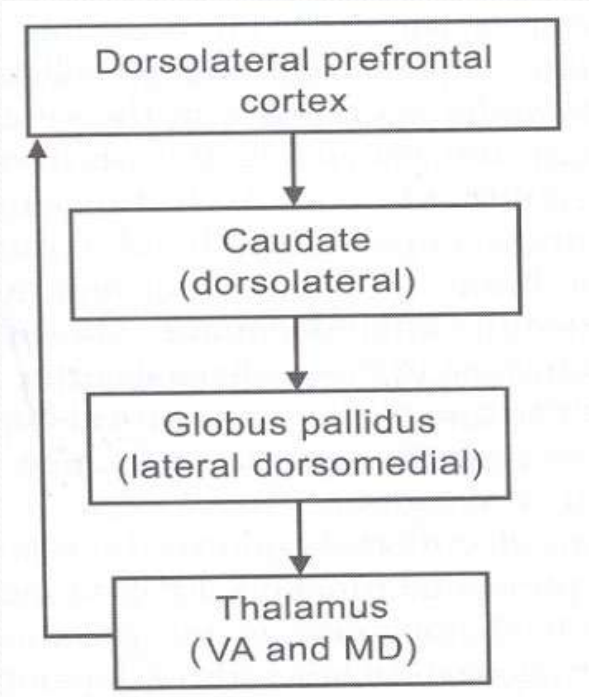
The orbitofrontal cortex, particularly the right- hemispheric orbitofrontal regions, mediates the rules of social convention.

- Socially disabled
- Manifesting interpersonal disinhibition
- Poor social judgment
- Impulsive decision making (Right or wrong)
- Lack of consideration for the impact of their behavior
- Absence of an appreciation for the effect of their behavior or comments on others
- Lack of empathy for others.

ORBITOFRONTAL CORTEX

- Orbitofrontal syndrome has been labeled a “pseudopsychopathic” disorder, linking it to the sociopathic or psychopathic behavior exhibited by individuals with character disorders who manifest a disregard for accepted social conventions
- Other behaviors that frequently co-occur with the orbitofrontal disinhibition syndrome include apathy, restlessness, stereotypes, indifference, euphoria, disinterestedness, cheerfulness, diminished attention, dependence or hyperdependence on stimuli in the physical environment, planning disorders, and impairment of emotional control.

DORSOLATERAL PREFRONTAL CORTEX



Critical For Executive Functions

The dorsolateral prefrontal cortex is responsible for :-

- Organizing a volitional response to environmental contingencies
- Recalling past events and planning current actions in a temporally informed manner
- Programming motor acts to follow volitional command
- Implementing programs to achieve the intended goal
- Monitoring the results of the action to determine the success of the intervention
- Adjusting or stopping the action depending on the outcome of the assessment.

FIGURE 2.2. Components of frontal executive function abnormalities and relevant assessments.

PREFRONTAL CORTEX

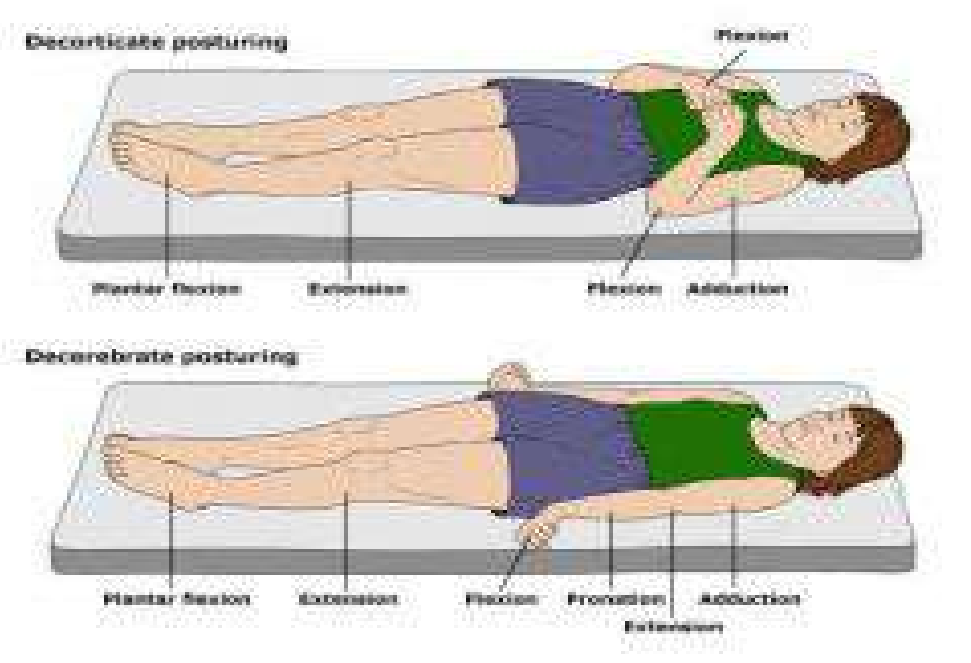
Ventrolateral prefrontal cortex

- Human personality
- Anticipation
- Planning
- Initiative
- Memory
- Control of decision making

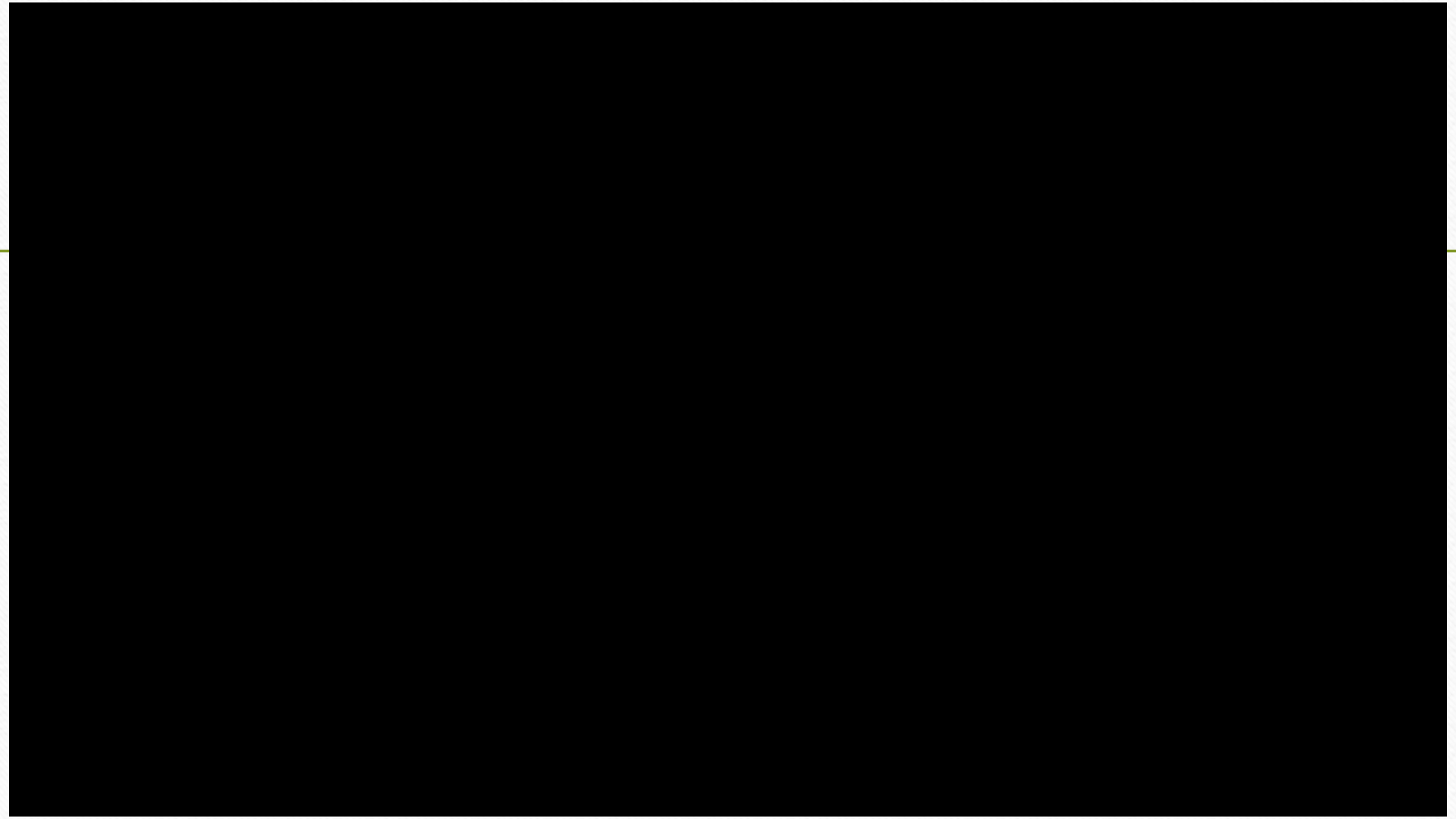
Dorsolateral prefrontal cortex

- Control behavior
- Long term memory formation
- Preparation &execution of act

FRONTAL LOBES AND GAIT



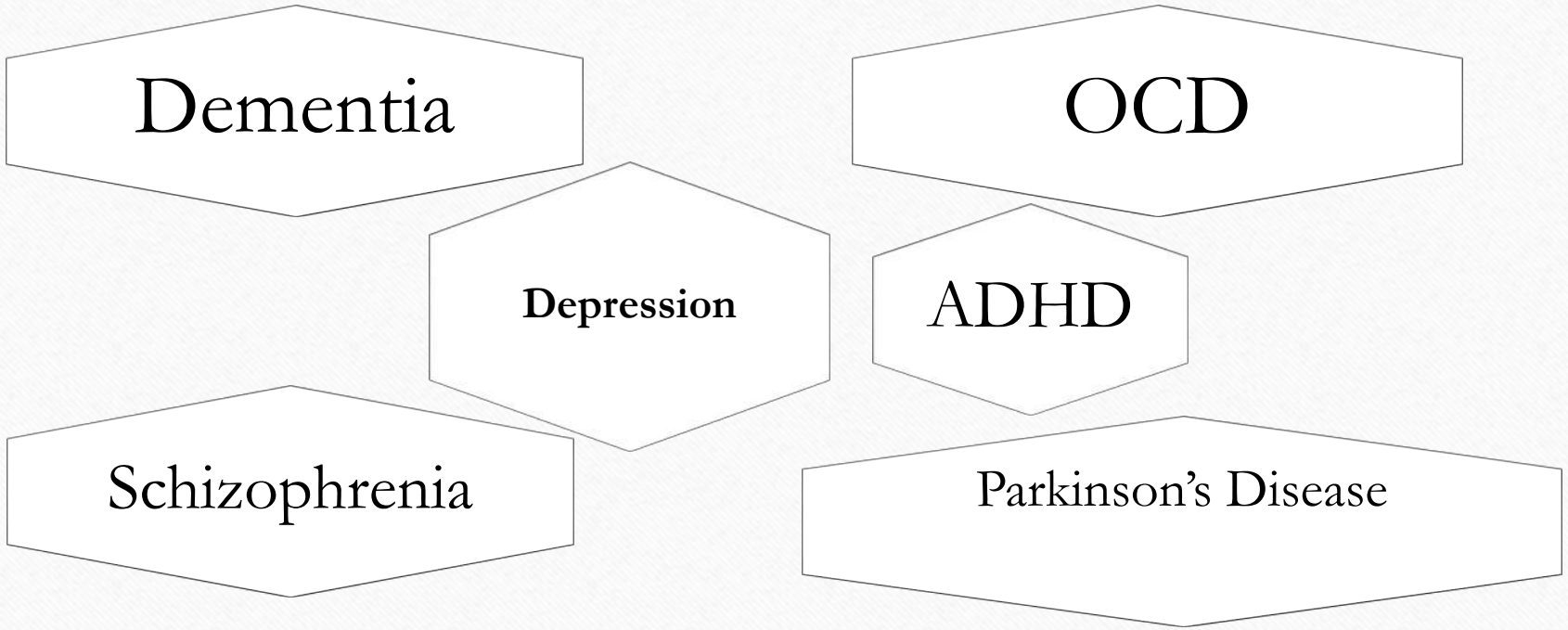
- The steps are shortened to a shuffle and balance is precarious
- Astasia-abasia
- Magnetic gait: where one or both feet appear to be stuck to the ground as the body moves forward.
- Cerebral paraplegia in flexion; the affected individual lies curled up in bed, unable even to turn over.



FRONTAL LOBE AND SEIZURES

- Lesion in post frontal zone – Adversive seizures
- Focus in opercular region - Gustatory aura and masticatory and smacking movements of lips and tongue
- Lesion at frontal-diencephalic region – altered consciousness
- Supplementary motor cortex –fencer's posture.
- Cingulate seizures-complex motor gestural automatisms, mood changes & autonomic signs

Psychiatric Importance



Frontotemporal Dementia and Related Disorders

- Frontotemporal lobar degeneration (FTLD) is a neurodegenerative disease that selectively attacks the frontal and anterior temporal regions
- Genetics remain the only known risk factor for FTLD
- In contrast to AD, in which memory loss is usually the first symptom, the initial symptoms of FTLD often involve changes in personality, behavior, affective symptoms, and language function .

Frontotemporal Dementia and Related Disorders

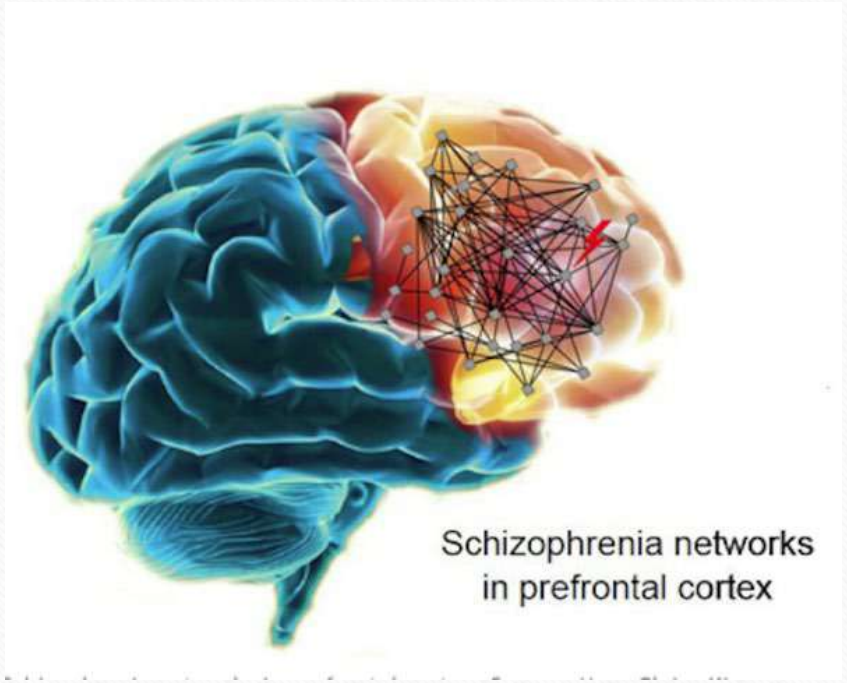
- Memory
- Language and aphasia
- Orientation
- Agnosia
- Activities of daily living
- Apraxia
- Social, community, and intellectual function
- Executive Functioning
- Problem-solving abilities
- Judgement

Parkinson's Disease with and without Dementia and Lewy Body Dementia

Impaired memory components	
Frontal related	Basal ganglia related
1. Verbal and spatial working memory	1. Procedural learning
2. Random generation	
3. Word-list acquisition and recall	
4. Visuospatial acquisition and recall	
5. Trial-and-error learning	
6. Recency discrimination and temporal ordering	

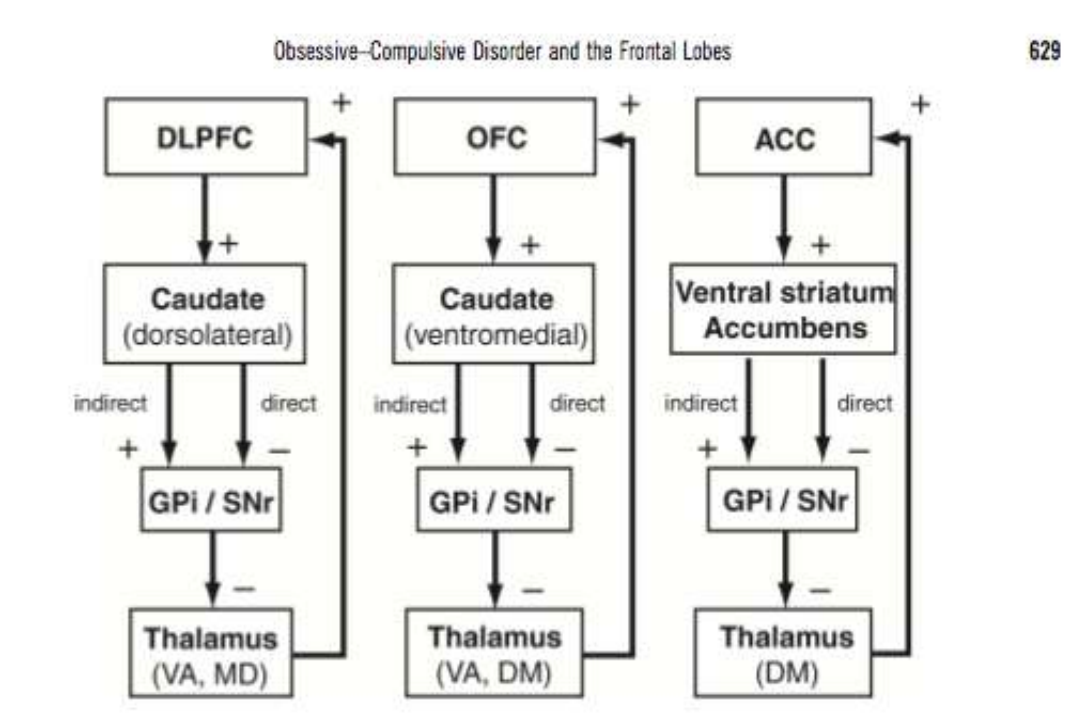
- Several cognitive changes have been regularly reported in nondemented patients with PD
- Planning disorders, more related to frontal lobe function, may also make a significant contribution In Parkinson's Disease
- Frontal-Related Memory Disorders

Schizophrenia



- Reduced NMDA glutamate receptors causing cognitive symptoms
- Responsible for negative symptoms
- Anatomical abnormality of prefrontal cortex
- MRI & PET shows functional difference in brain activity in frontal lobe, hippocampus, temporal lobe
- Pet shows less frontal activity during working memory related to neurocognitive defects

OCD



- Altered function in neuro circuit
- Increased blood flow & metabolism in frontal lobe
- Compulsive hoarding or pathological hoarding or disposophobia is the excessive acquisition of possessions, even if the items are worthless, hazardous, or unsanitary.
- Damage to Right medial prefrontal cortex cause Hoarding

Mood Disorders

- Mood Disorders are associated with frontal lobe/frontal circuit dysfunction.
- Left hemispherical lesion to Frontal /basal ganglia will Lead to Depression
- Right hemispherical lesion to thalamic, diencephalic, orbitofrontal, caudate Will Lead to Mania
- MRI: Small caudate nucleus & frontal lobe
- SPECT: Decreased blood flow to frontal cortex

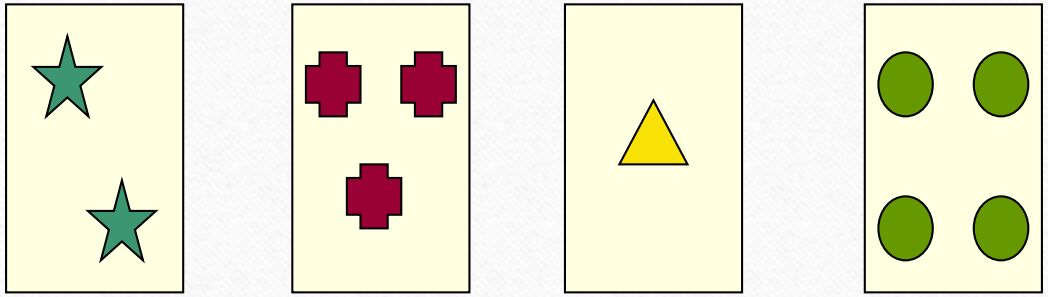
ADHD

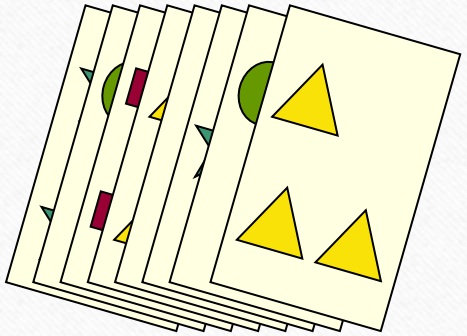
- General reduction of brain volume ,but proportionally great reduction of left prefrontal cortex
- Recent research shows following four connected fronto-striatal regions play a role in ADHD- Lateral prefrontal cortex ,Anterior cingulate, Caudate, Putamen
- Delayed development of frontal cortex, temporal lobe & fast maturity of motor cortex seen
- This contributes slow behavioral control & advanced motor development leads to fidgetiness, that is characteristic of ADHD
- PET shows low perfusion and metabolism of frontal area.

Tests - Prefrontal Lobe Function

- Wisconsin Card Sort
- Word fluency
- Trail Making Part B
- Color and word page of Stroop Color and Word Test
- Temporal orientation test
- Verbal associative learning
- Porteus Maze Test

Tests - Prefrontal Lobe Function

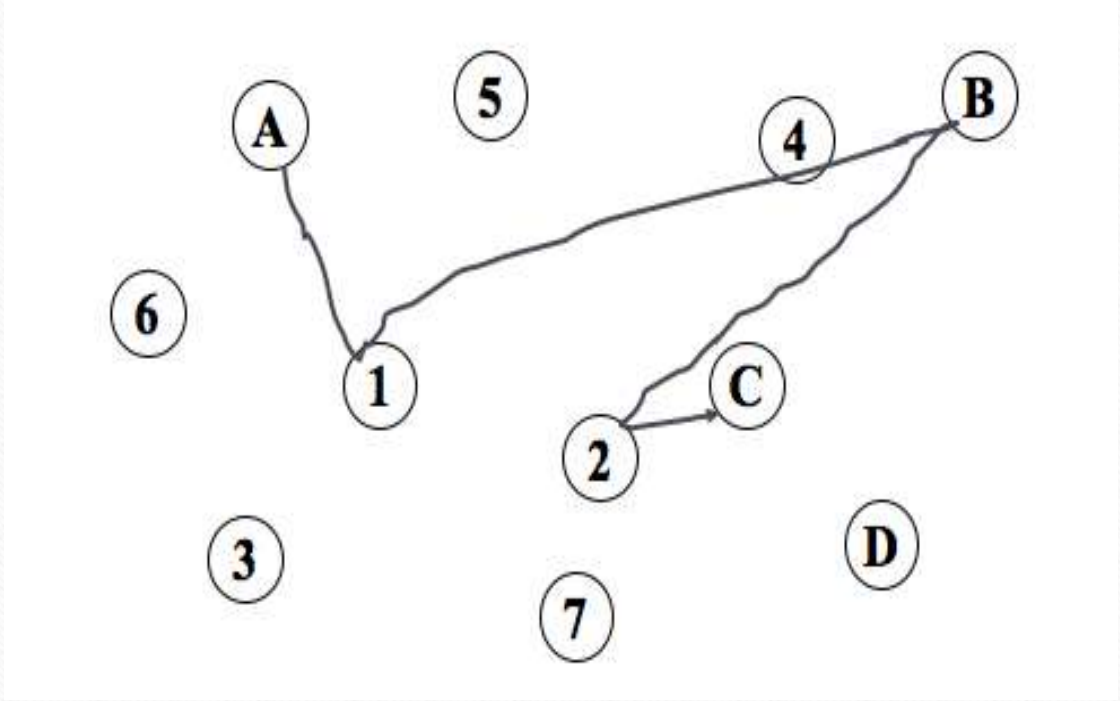




Wisconsin Card Sorting Test

"Please sort the 60 cards under the 4 samples.
I won't tell you the rule, but I will announce every mistake.
The rule will change after 10 correct placements."

Tests - Prefrontal Lobe Function



Trail Making Test

Various levels of difficulty:
1. “Please connect the letters in alphabetical order as fast as you can.”
2. “Repeat, as in ‘1’ but alternate with numbers in increasing order”

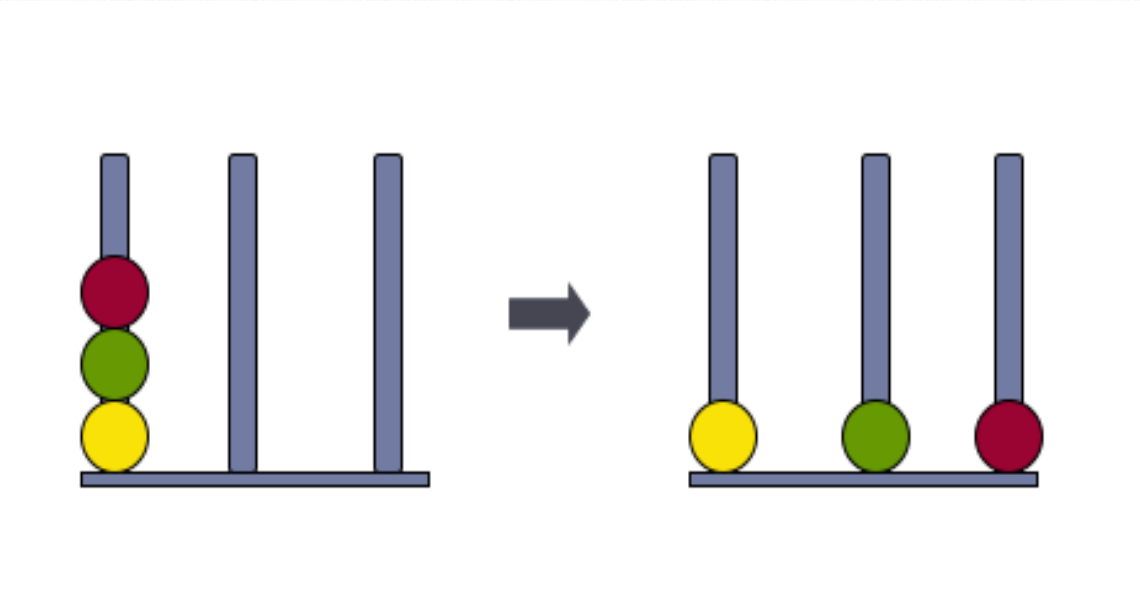
Tests - Prefrontal Lobe Function

RED BLUE ORANGE
YELLOW GREEN RED
PURPLE RED GREEN
YELLOW BLUE. RED
YELLOW ORANGE
RED GREEN BLUE
GREEN PURPLE RED

Stroop Color and Word Tests

"Please read this as fast as you can"

Tests - Prefrontal Lobe Function

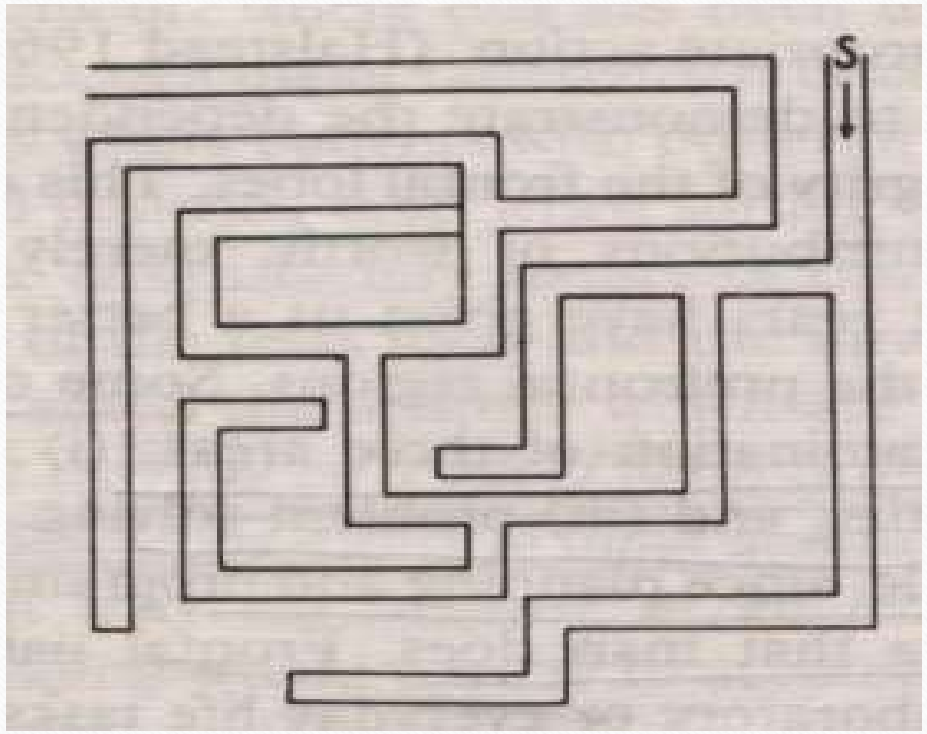


Tower of London Tests

For Planning

Various levels of difficulty:
e.g. “Please rearrange the balls on the pegs, so that each peg has
one ball only. Use as few movements as possible”

Tests - Prefrontal Lobe Function



Porteus Maze Test

Tests - Prefrontal Lobe Function

Tests of attention and memory

- Alternative sequence (e.g. copying MNMN)
- Luria's 'fist-edge-palm' test (show 3X)
- Go/no-go:
  - "tap once if I tap twice, don't tap if I tap once"
- Digit span
  - "repeat 3-52; 3-52-8; 3-52-8-67.." N: >5
- Recency test
  - "Recall sequence of stimuli / events"

Tests - Prefrontal Lobe Function

Tests for Language

- Thurstone / word fluency test
  - ("recite as many words beginning with 'F' in 1 min as you can, then with 'A', 'S'"); N: >15
- Repetition (Broca's vs transcortical)
  - "Ball"
  - "Methodist"
  - "Methodist episcopal"
  - "No if's end's or but's"
  - "Around the rugged rock the ragged rascal ran

Tests - Prefrontal Lobe Function

Tests of abstraction and judgment

- Interpret proverbs (e.g.“the golden hammer opens iron doors”)
- Explain why conceptually linked words are the same (e.g. coat & skirt)
- Plan & structure a sequential set of activities (“how would you bake a cake?”)
- Insight / reaction to own illness

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THANK YOU
FOR LISTENING!