Chapter 12 Goals, Executive Control, and Action
Phineas Gage

• Severe Frontal Lobe damage

The tamping iron was 3 feet 7 inches long and weighed 13 1/2 pounds. It was 1 1/4 inches in diameter at one end (not circumference as in the newspaper report) and tapered over a distance of about 1-foot to a diameter of 1/4 inch at the other. The tamping iron went in point first under his left cheek bone and completely out through the top of his head, landing about 25 to 30 yards behind him. Phineas was knocked over but may not have lost consciousness even though most of the front part of the left side of his brain was destroyed. Dr. John Martyn Harlow, the young physician of Cavendish, treated him with such success that he returned home to Lebanon, New Hampshire 10 weeks later.
Personality changes?
He was no longer Gage!

Gage as having been hard-working, responsible, and "a great favorite" with the men in his charge, his employers having regarded him as "the most efficient and capable foreman in their employ." But these same employers, after Gage's accident, "considered the change in his mind so marked that they could not give him his place again":

“The equilibrium or balance, so to speak, between his intellectual faculties and animal propensities, seems to have been destroyed. He is fitful, irreverent, indulging at times in the grossest profanity (which was not previously his custom), manifesting but little deference for his fellows, impatient of restraint or advice when it conflicts with his desires” In this regard his mind was radically changed, so decidedly that his friends and acquaintances said he was "no longer Gage." In this regard his mind was radically changed, so decidedly that his friends and acquaintances said he was "no longer Gage."
Phineas got better..

Went to San Francisco, Chile.. took great pics with his spike—probably made money selling his story.

The story got more complex involved him beating his wife and children and attacking people on the street.. he never had a wife or children.
Diseases Commonly Associated With Frontal Lobe Lesions

- Vascular disease
  - Common cause especially in elderly
  - ACA territory infarction (anterior cerebral arterial)
    - Damage to medial frontal area
  - MCA territory (middle cerebral arterial)
    - Dorsolateral frontal lobe
  - ACom aneurysm rupture
    - Personality change, emotional disturbance
Other Severe Frontal lobe Brain Damage: Psychiatry!

Sadly the other kind of severe brain damage to individuals were **Lobotomies**.

- But no accident. Developed 1860s in Austria and picked up again in the US by a psychiatrist named Walter Fisher—especially for Mental Hospitals.
- 1930s to 1950s 10,000s of Lobotomies performed.
- Mental Patients were “cured” by such procedures.
- Several outcomes; passivity, suicide, zombie-like; sometimes death.
  worked better with Manic Depression then Schz.
By late 50s Drugs appeared that had similar effects: Thorazine etc.. before Haldol, socalled anti-psychotics.
From the silent lobes to the organ of civilization: it took scientists many years to begin to appreciate the importance of the frontal lobes for cognition. Unlike the busy sensory processes that occur in the other lobes, the frontal lobe were not easily linked to any single, easily defined function and were known as ‘the silent lobes’.

The concept of executive control is intimately linked to the function of the frontal lobes, however not all functions of the frontal lobe fall under the domain of executive control, and not all executive control functions are subserved by the frontal lobes.
Prefrontal cortex can be divided into lateral (side), medial (midline), ventral (bottom), and dorsal (top) regions. The lateral division divides into dorsal and ventral halves separated by a major horizontal fold, the inferior lateral sulcus.
The prefrontal cortex has expanded over mammalian and primate evolution. A greatly enlarged prefrontal cortex is a distinctively human and primate feature.

According to Brodmann (1909), the prefrontal cortex accounts for 29% of total cortex in humans, 17% in the chimp, 11.5% in the macaque, and 3.5% in the cat.

While whales and dolphins have large brains, it is the parietal rather than frontal cortex that has expanded in these mammals.
Gross anatomy and connections

The prefrontal cortex is directly connected with every distinct functional unit of the brain.

A schematic of prefrontal connectivity: the prefrontal lobes (inside the yellow box) have prolific connections throughout cortical and subcortical regions.
The functions of the frontal lobes defy a simple definition. They are not invested in any single ready-to-label function.

• Prefrontal cortex plays the central role in forming goals and objectives and then in devising a plan of action required to attain those goals.

• It selects the cognitive skills needed to implement the plans, coordinates those skills, and applies them in a correct order.

• Finally, the prefrontal cortex is responsible for evaluating our actions as success or failure relative to our intentions.
The massive connectivity of the frontal lobes is suggested by this tractograph (right panel) of the fiber tracts to Brodmann area 10 (left panel). The red and dark vertical fibers show only the ipsilateral (same hemisphere) connections. In addition to these fiber tracts, there are many connections between the two hemispheres traveling across the corpus callosum.
A precise definition of prefrontal cortex can be accomplished using Brodmann area maps -- which are based on the types of neurons and connections that are typically found within each area.

The prefrontal cortex is comprised of Brodmann areas 8, 9, 10, 11, 12, 13, 44, 45, 46, and 47.

A lateral view of the prefrontal cortex, showing Brodmann areas 8, 9, 10, 11, 44, 45, 46, and 47.
Closer Look at Frontal Lobes

How prefrontal cortex is defined

A precise definition of prefrontal cortex can be accomplished using Brodmann area maps -- which are based on the types of neurons and connections that are typically found within each area.

The prefrontal cortex is comprised of Brodmann areas 8, 9, 10, 11, 12, 13, 44, 45, 46, and 47.

A mid-sagittal view of the prefrontal cortex, showing Brodmann areas 8, 9, 10, 11, and 12.
Closer Look at Frontal Lobes

How prefrontal cortex is defined

Another method of outlining the prefrontal cortex is through its subcortical projections.

The dorsomedial thalamic nucleus is a point of convergence, the ‘summit’ of the integration occurring within the specific thalamic nuclei.
A Closer Look at Frontal Lobe Function

Traditional perspective on frontal lobe function: motor functions, actions, and plans

Two broad types of cognitive operations linked to the frontal lobe executive system:

1. An organism’s ability to guide its behavior by internal representations -- the formulation of plans and then guiding behavior according to those plans
A Closer Look at Frontal Lobe Function

Traditional perspective on frontal lobe function: motor functions, actions, and plans

Two broad types of cognitive operations linked to the frontal lobe executive system:

2. An organism’s ability not only to guide its behavior by internal representations, but also the capacity of ‘switching gears’ when something unexpected happens

A Closer Look at Frontal Lobe Function

Traditional perspective on frontal lobe function: motor functions, actions, and plans

Two broad types of cognitive operations linked to the frontal lobe executive system:

2. An organism’s ability not only to guide its behavior by internal representations, but also the capacity of ‘switching gears’ when something unexpected happens.
Ingvar (1985) coined the phrase ‘memories of the future’ referring to one of the most important functions of advanced organisms: making plans and then following the plans to guide behavior.

Unlike primitive organisms, humans are active, rather than reactive, beings. We are able to form goals, our visions of the future. Then we act according to our goals.

In order to guide our behavior in a sustained fashion, these mental images of the future must become the content of our memory: thus the ‘memories of the future’ are formed.
Another function currently being linked to the prefrontal cortex is an ability to deal with **cognitive novelty**.

The dark areas in this composite brain image show regions that control novel actions, but which lose activity when the identical actions becomes automatic with practice.

Working memory is closely linked to the critical role the frontal lobes play in the temporal organization of behavior and controlling the proper sequence in which various mental operations are enacted.

Since the selection of information required to solve the problem at hand is made in the frontal lobes, they must ‘know’, at least roughly, where in the brain the information is stored.

This suggests that all the cortical regions are somehow represented in the frontal lobes, an assertion first made by Hughlings-Jackson in 1884.
Frontal lobe dysfunction often reflects more than the direct damage to the frontal lobes themselves. The frontal lobes seem to be the bottleneck, the point of convergence of the effects of damage virtually anywhere in the brain.

There is a reciprocal relationship between frontal and other brain injuries: damage to the frontal lobes produces wide ripple effects through the whole brain.
Chapter 12 Goals, Executive Control, and Action
Brain Trauma …
Frontal lobe syndromes
Damage to different parts of the frontal lobes produces distinct, clinically different syndromes. The most common are dorsolateral and orbitofrontal syndromes.
Frontal Lobe Pathology, Executive Impairment, and Social Implications of Frontal Lobe Dysfunction

Frontal lobe syndromes - Dorsolateral

Most common symptoms of dorsolateral syndrome are perseverative behavior, field-dependent behavior, and mental rigidity. These patients often typically have a flat affect: an emotionless voice and facial expression.

Perseverative behavior: a patient will have an inability to initiate behaviors. Once behaviors are initiated, the patient is equally unable to terminate or change the behavior.
Frontal lobe syndromes - Dorsolateral

Field-dependent behavior highlights the distractibility seen with frontal lobe injury. A patient will drink from an empty cup, put on a jacket belonging to someone else, or scribble with a pencil on the table surface, merely because the cup, jacket, and pencil are there, even though these actions make no sense.
Frontal lobe syndromes - Dorsolateral

Field-dependent behavior highlights the distractibility seen with frontal lobe injury. A patient will drink from an empty cup, put on a jacket belonging to someone else, or scribble with a pencil on the table surface, merely because the cup, jacket, and pencil are there, even though these actions make no sense.
Frontal lobe syndromes - Orbitofrontal

The orbitofrontal syndrome is in many ways the opposite of dorsolateral syndrome: the patients are behaviorally and emotionally disinhibited. Their affect is rarely neutral, constantly oscillating between euphoria and rage, with impulse control ranging from poor to non-existent.

Their ability to inhibit the urge for instant gratification is severely impaired: they do what they feel like doing, when they feel like doing it, without any concern for social taboos or legal prohibitions.
Frontal Lobe Syndromes
Integrative Functioning

- Emotional make-up and personality
- Abstraction and judgment
- Attention and memory
- Language
Frontal Lobe Syndromes

- Emotional make-up and personality
  - May be the only manifestation
  - Apathy / euphoria / labile mood
  - Decreased drive / poor impulse control
  - Abulia; akinetic mutism (apathy, slow to respond)
  - Pseudobulbar palsy; Opercular syndrome (lack of facial control)
- Best assessed with Hx from family / friends & observation
Frontal Lobe Syndromes

- Abstraction and judgment
  - Cognitive functions undisturbed
  - Concrete thinking
  - Diminished insight
  - Defect in planning / executive control
Frontal Lobe Syndromes

- Tests of abstraction and judgment
  - Interpret proverbs (e.g. “the golden hammer opens iron doors”, “a rolling stone gathers no moss”)
  - 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
Frontal Lobe Syndromes

Tests of attention and memory
- Alternative sequence (e.g. copying MNNMN)
- Luria’s ‘fist-edge-palm’ test (show 3X)
- Go/no-go:
  - “tap once if I tap twice, don’t tap if I tap once”
  - “tap for A”
- read 60 letters at 1/sec; N: < 2 errors
Frontal Lobe Syndromes

- Tests of attention and memory cont’
  - Digit span
    - “repeat 3-52; 3-52-8; 3-52-8-67..” N: >5
  - Visual grasp: “look away from stimulus”
  - Recency test
    - “recall sequence of stimuli / events”
  - Imitation (of examiner) / utilization (of objects presented)
Frontal Lobe Syndromes

- Language
  - Broca’s / non-fluent aphasia
  - Prefrontal/ transcortical motor aphasia
  - Language-motor dissociation
  - Akinetic mutism
Frontal Lobe Syndromes

- Language tests
  - 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”
Frontal Lobe Syndromes

- **Formal Tests**
  - Wisconsin Card Sorting Test
    • abstract thinking and set shifting; L>R
  - Trail Making
    • visuo-motor track, conceptualization, set shift
  - Stroop Color & Word Test
    • attention, shift sets; L>R
  - Tower of London Test
    • planning
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.”
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”
Stroop Color and Word Tests

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

“Please read this as fast as you can”
Tower of London Tests

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”
Diseases Commonly Associated With Frontal Lobe Lesions

- Traumatic brain injury
  - Gunshot wound
  - Closed head injury
    - Widespread stretching and shearing of fibers throughout
    - Frontal lobe more vulnerable
  - Contusions and intracerebral hematomas
Diseases Commonly Associated with Frontal Lobe Lesions

- Frontal Lobe seizures
  - Usually secondary to trauma
  - Difficult to diagnose: can be odd (laughter, crying, verbal automatism, complex gestures)
Diseases Commonly Associated With Frontal Lobe Lesions

- **Tumors**
  - Gliomas, meningiomas
  - Subfrontal and olfactory groove meningiomas: profound personality changes and dementia

- **Multiple Sclerosis**
  - Frontal lobes 2\(^{nd}\) highest number of plaques
  - Euphoric/depressed mood, Memory problems, cognitive and behavioral effects
Diseases Commonly Associated With Frontal Lobe Lesions

- Degenerative diseases
  - Pick’s disease
  - Huntington’s disease

- Infectious diseases
  - Neurosyphilis
  - Herpes simplex encephalitis
Diseases Commonly Associated with Frontal Lobe Lesions

- Psychiatric Illness – proposed associations
  - Depression
  - Schizophrenia
  - OCD
  - PTSD
  - ADHD
Frontal Lobe Syndromes – Summary

• Personality and emotional changes
• Reflect prefrontal lesions
• Role of Dopamine and Norepinephrine
• Trauma > vascular, tumors
Functional Frontal Lobe Anatomy

- Five ‘frontal subcortical circuits’
  (Cummings, ‘93)

1. Motor
2. Oculomotor
3. Dorsolateral prefrontal
4. Lateral orbitofrontal
5. Anterior cingulate
Functional Frontal Lobe Anatomy

• ‘Frontal subcortical circuits’
Frontal subcortical Circuits:
1. Motor Circuit

- Supplementary Motor & Premotor: planning, initiation & storage of motor programs; fine-tuning of movements
- Motor: final station for execution of the movement according to the design
Frontal subcortical Circuits: 2. Oculomotor Circuit

- Voluntary scanning eye movement
- Independent of visual stimuli
Frontal subcortical Circuits: 3. Dorsolateral Prefrontal Circuit

- Executive functions: motor planning, deciding which stimuli to attend to, shifting cognitive sets
- Attention span and working memory
Frontal subcortical Circuits:
4. Lateral Orbitofrontal Circuit

- Emotional life and personality structure
- Arousal, motivation, affect
- Orbitofrontal cortex: consciousness
Frontal subcortical Circuits: 5. Anterior Cingulate Circuit

- Abulia, akinetic mutism (slow to action, language problems)
Frontal Lobe Pathology, Executive Impairment, and Social Implications of Frontal Lobe Dysfunction

Other clinical conditions associated with frontal lobe damage

It is not necessary to have focal damage to the frontal lobes themselves to have prefrontal dysfunction.

The frontal lobes are particularly vulnerable in numerous non-focal disorders such as schizophrenia, Tourette’s syndrome, and Attention deficit (hyperactivity) disorder (AD(H)D).
Frontal Lobe Pathology, Executive Impairment, and Social Implications of Frontal Lobe Dysfunction

Other clinical conditions associated with frontal lobe damage

Attentional functions might may be influenced by the frontal lobes as well as an ‘attentional loop’ combining frontal, brainstem, and posterior cortex.

Breakdown anywhere along this loop may interfere with attention, thus producing a form of attention deficit disorder. Thus, any damage to the prefrontal cortex or its pathways may result in attentional impairment.