



Introduction to Cognitive Neuroscience

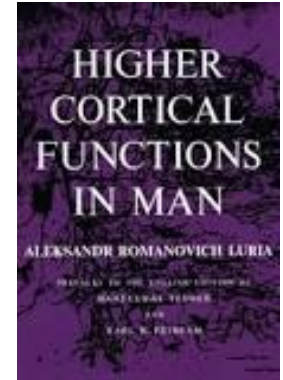
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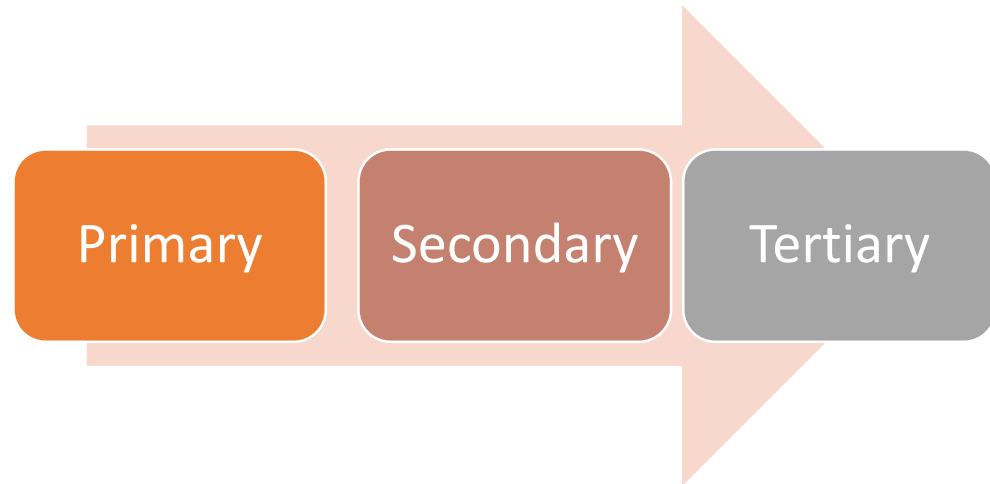
Higher Cortical Functions in Man



- Alexander Luria **1962** (Neurologists)
- Main idea comes from **lesion studies**
- Multiple specialized **subareas** that are connected **hierarchically**
- For sensory and motor cortex



1902-1977



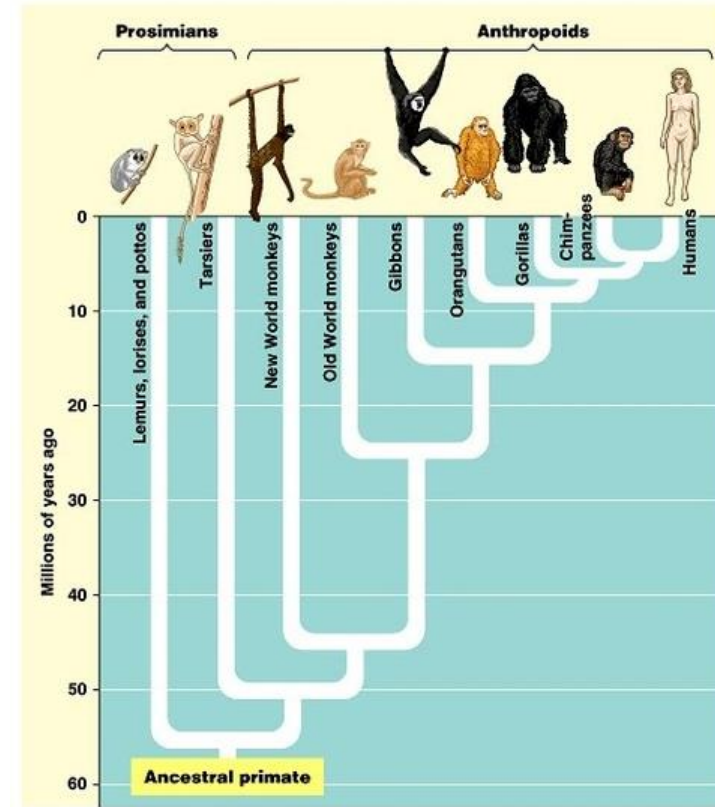
Functionally related areas of cortex lie close together



Closest living relatives aside from the apes;

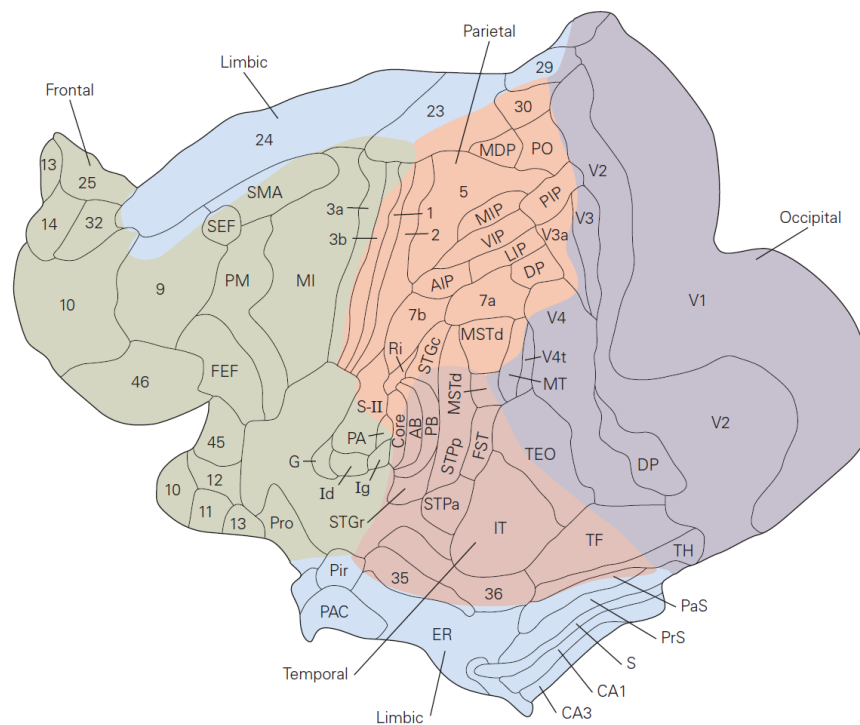
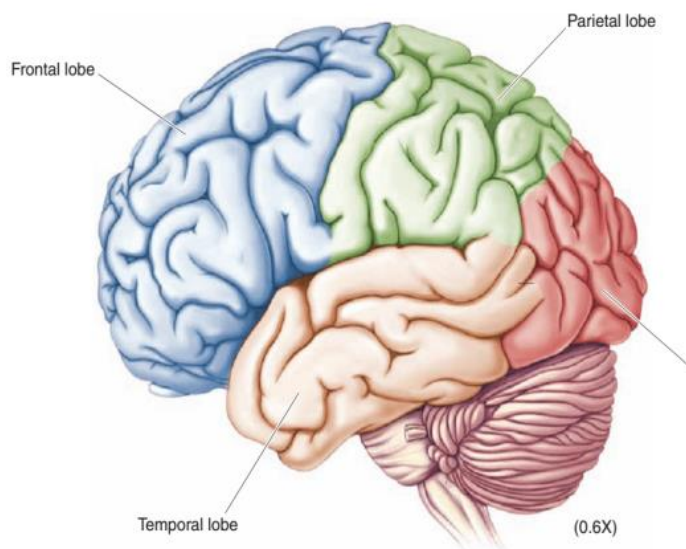
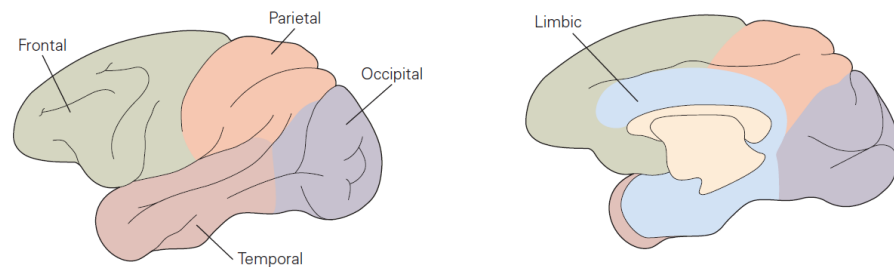


- Functional areas are **distinguished** by:
 - **Cellular** structure,
 - **Connectivity**
 - **Physiological** response properties of **neurons**
- We try to **design** experiment for finding **selectivity of neurons and their connection**
- We use **macaque** (macaca)
- **Anatomically similar** cells could have different functions

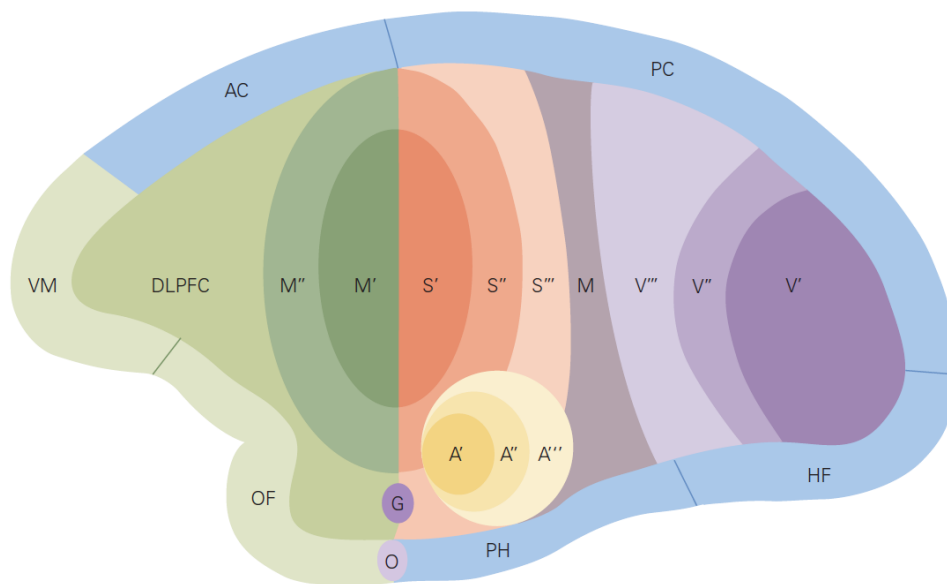


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The cerebral cortex of the macaque monkey.



The cerebral cortex is divided into discrete functional categories.



Category	Subcategory	Key	Figure 18-1
Visual	Primary	V'	V1
	Secondary	V''	V2, V3, V3a, PIP, PO, MT, V4
	Tertiary	V'''	MDP, LIP, 7a, MSTd, MSTl, FST, IT
Somatosensory	Primary	S'	3a, 3b
	Secondary	S''	1, 2, S-II
	Tertiary	S'''	5, MIP, AIP, 7b, Ri, Id, Ig
Auditory	Primary	A'	Core
	Secondary	A''	AB, PA
	Tertiary	A'''	PB, STGc, STGr
Multimodal		M	VIP, STPp, STPa
Gustatory		G	G
Olfactory		O	Pir, PAC
Motor	Primary	M'	M1
	Secondary	M''	PM, SMA, FEF, SEF, 24
Dorsolateral prefrontal	Dorsal		9, 10, 14
	Dorsolateral	DLPFC	46
	Ventral convexity		45
Orbital-ventromedial prefrontal	Orbital	OF	11, 12, 13, Pro
	Ventromedial	VM	25, 32
Limbic	Anterior cingulate	AC	24
	Posterior cingulate	PC	23, 29, 30
	Hippocampal	HF	CA1, CA3, S, PrS, PaS
	Parahippocampal	PH	ER, TF, TH, 35, 36

Sensory Information Is Processed in the Cortex in Serial Pathways



- The properties of **primary** sensory area
 - Input from **thalamus**
 - **Small** receptive field and **somatotopic** map (**retina, cochlea, or skin**)
 - **Injury** cause a small contralateral disability
 - **Connection are limited** and to the **near** area
- The properties of **higher order** area
 - **Little** input from thalamus
 - **Large** receptive fields
 - Injuries lead to **perception abnormalities** not stimuli detection
 - **Long** distance (limbic and prefrontal) connection
- e.g. **Visual** areas receptive field
- Not pure **feed forward**, but there is **feed back** (how to read specific details)

Association area

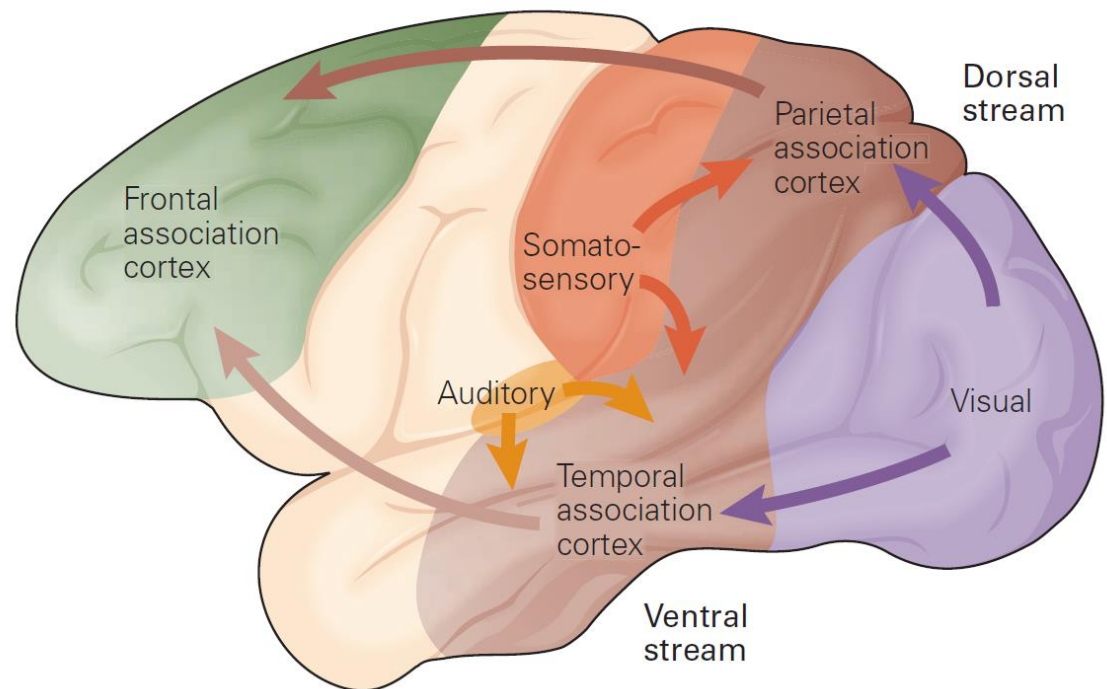
- The sensory hierarchy lead to **complex** area
- Cognition depends **upon our learning** which of the myriad stimuli impinging on our senses are **associated with** one another
- **Injury** to association could not explain by sensory or motor **alone**
 - **Parietal** association area: **sensory guidance, motor behavior, spatial awareness**
 - **Temporal** association: **recognition and storage of semantic (factual) knowledge**
 - **Frontal** association: **organized behavior and working memory**
 - **Limbic** association: **emotion and episodic (autobiographical) memory**
- **Heavy** input-output **connection** and with each other



Santiago Ramon y Cajal
Spanish pathologist
1852-1934

Parallel pathways in each sensory modality lead to **dorsal and ventral** association areas

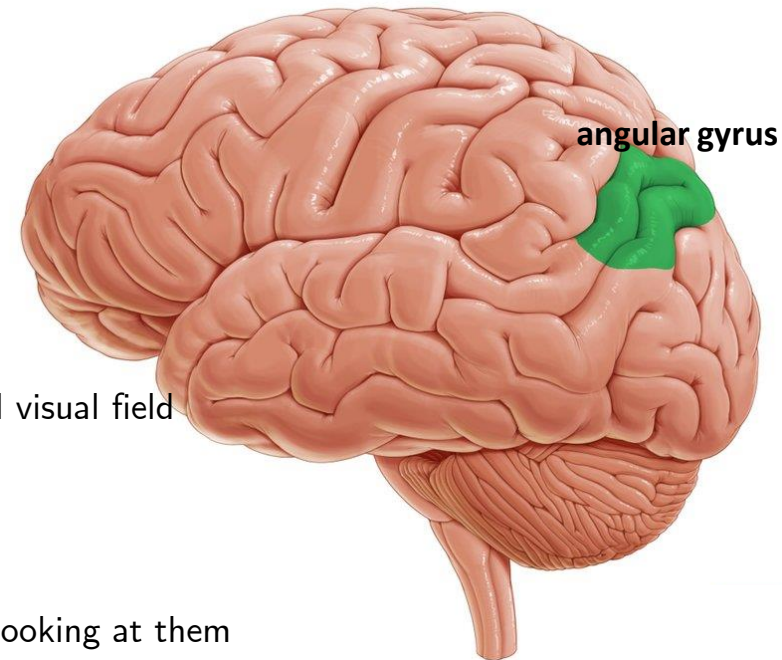
- **Dorsal** for **spatial** and motor information
- **Ventral** (temporal) for **recognition**



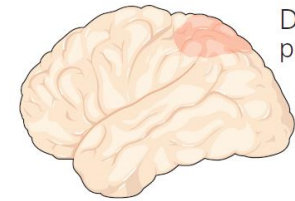
The dorsal and ventral systems of the cerebral cortex.

The dorsal visual pathway carries spatial information and leads to parietal association cortex

- Two subdivisions of **parietal** cortex:
 - **Dorsal**: **motor** function; close to somatosensory
 - **Ventral**: **spatial** function; close to visual cortex
- **Impairments**
 - **Asomatognosia**:
 - Disorder of body awareness,
 - Ideomotor apraxia: disorder in voluntary hand gesture
 - **Optic ataxia**: disorder in reaching objects in peripheral visual field
 - **Hemispatial neglect**
 - Neglect
 - Constructional apraxia: disability to arrange things by looking at them
 - **Disorder in abstract spatial thinking**
 - Acalculia: position of digits and numbering
 - Injury to the left **angular gyrus**:
 - Disorder to reading and writing and spelling (spatial thinking about letters)



Optic ataxia



Dorsomedial parietal cortex

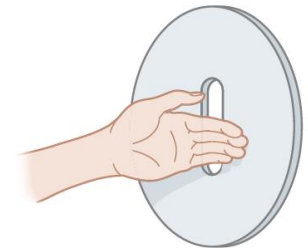
Inaccurate preshaping of grasp

Normal

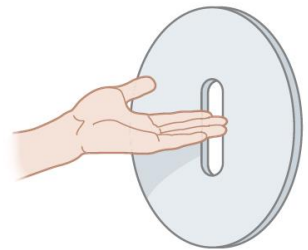
Impaired



Misdirected reach



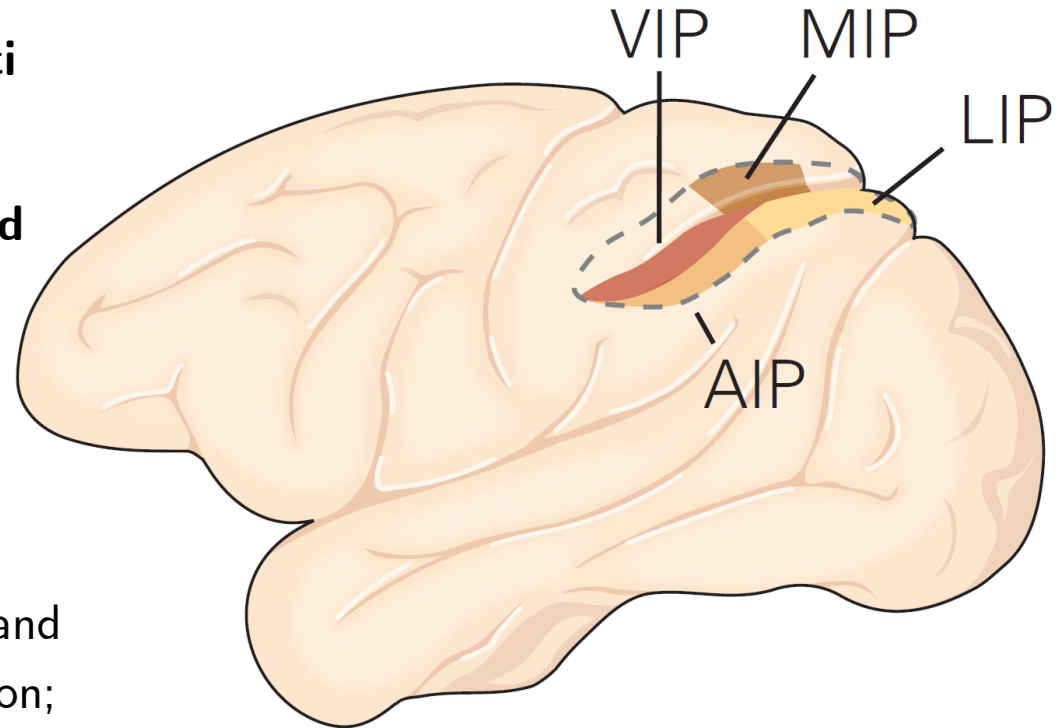
Misorientation of hand



Patients with damage to the **dorsomedial parietal** cortex have difficulty with visually guided **grasping** and reaching

Studies of parietal in monkey

- **Four** areas in intraparietal sulcus:
 - lateral, ventral, medial, and anterior
- Response to **attention** and **multi sensory**
- **Anticipating, remembering and planning**
- **VIP**: **head centered** spatial information for mouth and eye movement
- **MIP**: stored both **body center** and **retinal center spatial** information; visually guided reaching
- **AIP**: **object centered** and **hand** centered spatial information



Disorders of copying and drawing



Copying

Model



Patient's copy

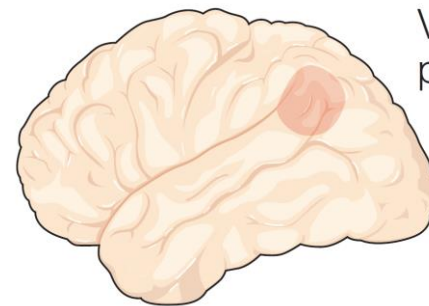
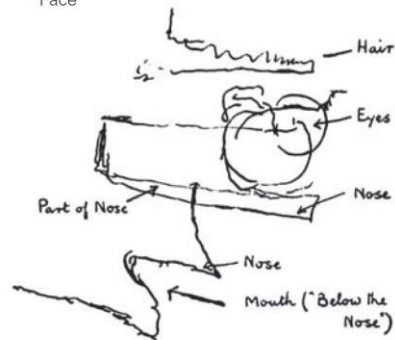


Free drawing

Bicycle



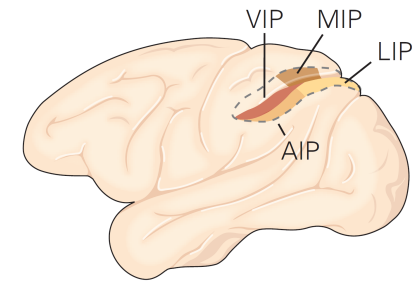
Face



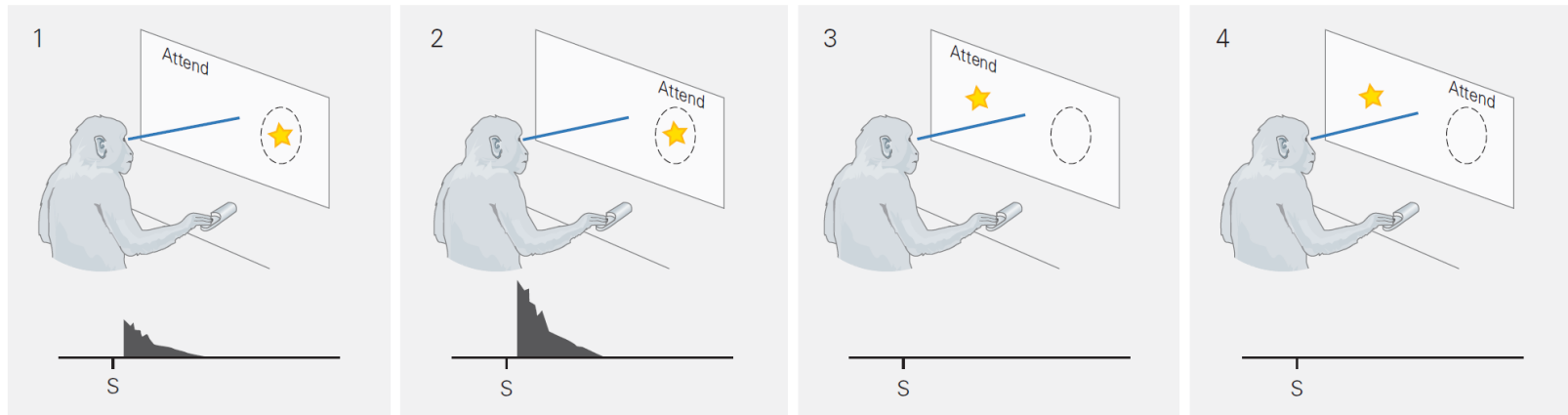
Ventrolateral
parietal cortex

Inability to perceive the **spatial relations** of the parts of an object

Neurons are selective for the location of objects in the visual field **relative to particular parts of the body**



A Lateral intraparietal area



Receptive field characteristics

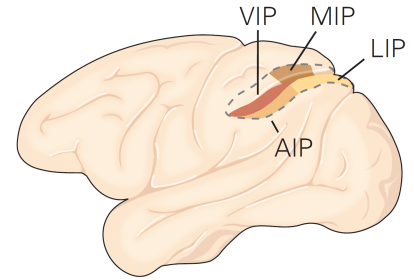
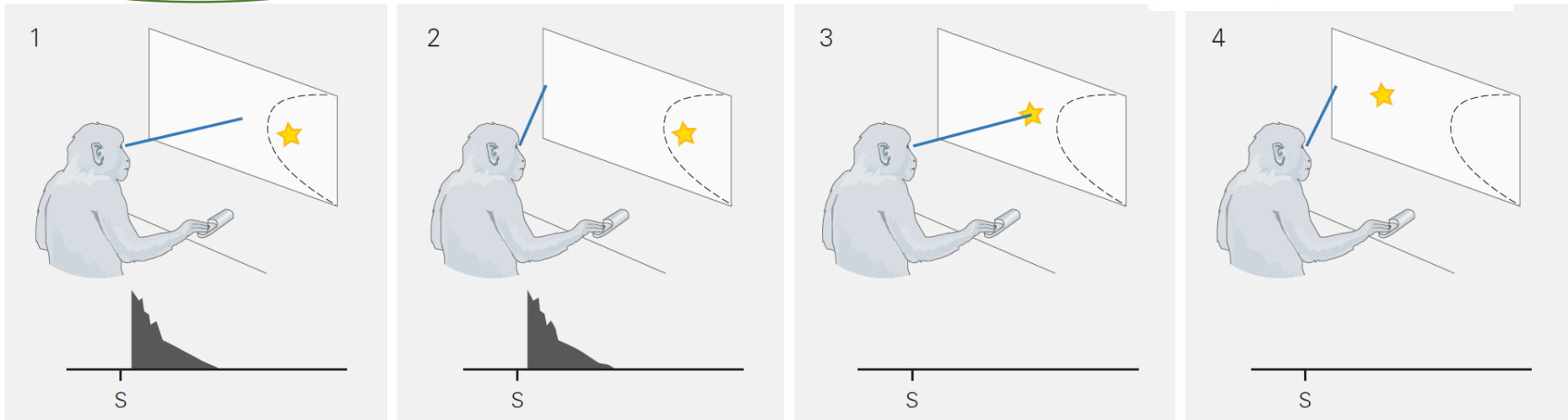
Retina-centered, attention sensitive

The strength of the visual response depends on whether the monkey is **paying attention** to the stimulus.

Head-centered

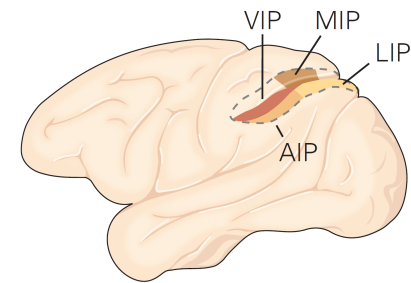


B Ventral intraparietal area

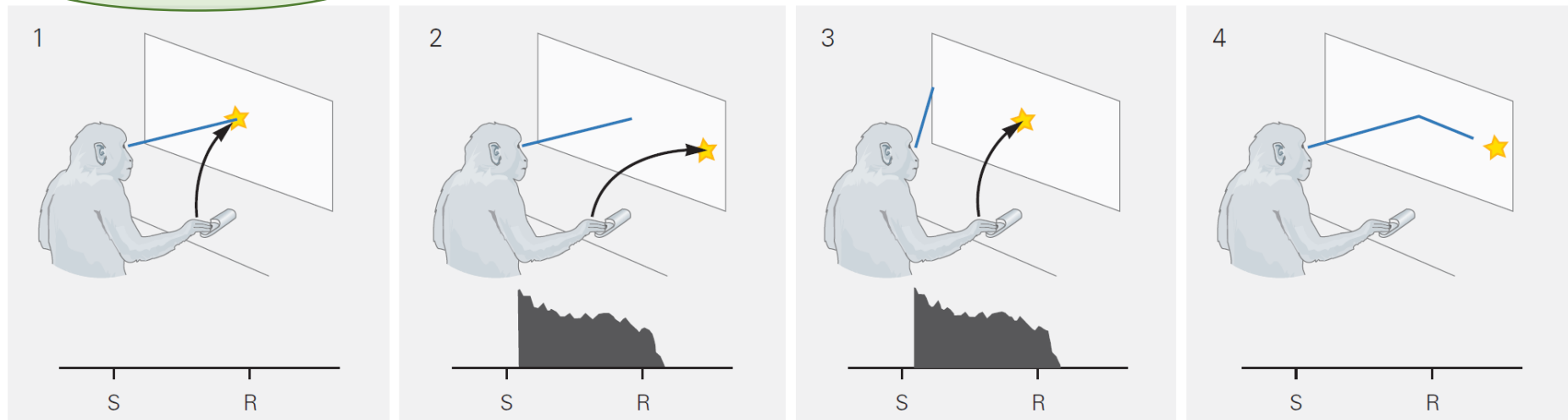


- Keeping the head in a fixed position while the monkey is instructed to shift its gaze to various locations.
- This neuron fires when a light appears to the right of the midline of the head

Retina-centered direction of reach; preparation to reach

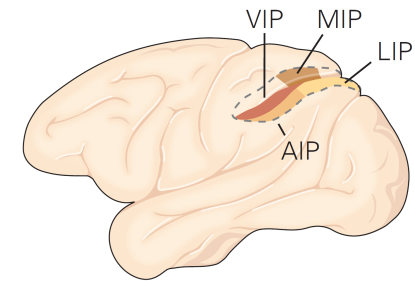


C Medial intraparietal area

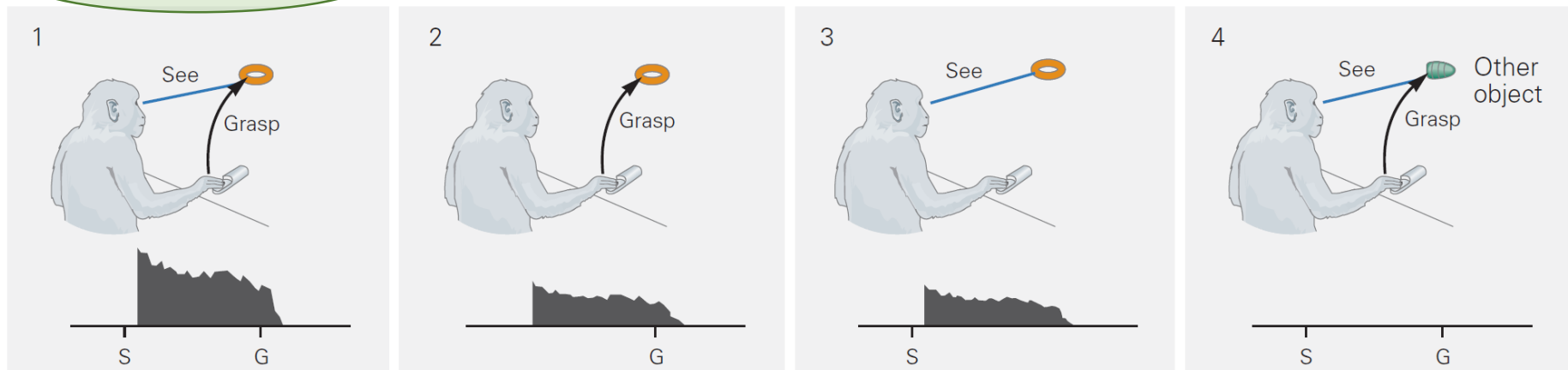


- Neurons fire when the monkey **is preparing to reach** for a visual target and are **selective for the retina-centered** direction of the reach.

Retina-centered, object-specific viewing, grasping



Anterior intraparietal area



Neurons fire when the monkey is looking at or preparing to grasp an object and are selective for objects of particular shapes

The ventral visual pathway processes information about **form** and leads to **temporal** association cortex



- Receive information about, **vision, sound, and touch**
- Visual **object agnosia**: **cant recognize but could depict** (vs. **Parietal**)
- **Prosopagnosia**
- **Auditory agnosia**
- **Wernicke aphasia**:
 - Disorder in understanding **spoken** language (damage to the superior temporal gyrus of the left hemisphere) also make problem for speak production
- **Semantic dementia**:
 - Loss of detailed knowledge about things
- **IT neurons** are **shape** selective and independent of location
- **IT neurons** are **invariance** to identity preserving translations
- **Population** of response are important, **because each cell response to wide range of stimuli**

Injury to a **medioventral** region of temporal cortex results in visual object agnosia.



Test image

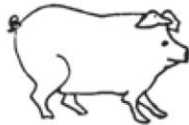


Patient's copy



Patient's description

I still don't know.



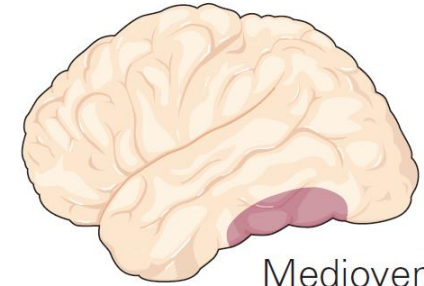
Could be a a dog or any other animal.



Could be a beach stump.

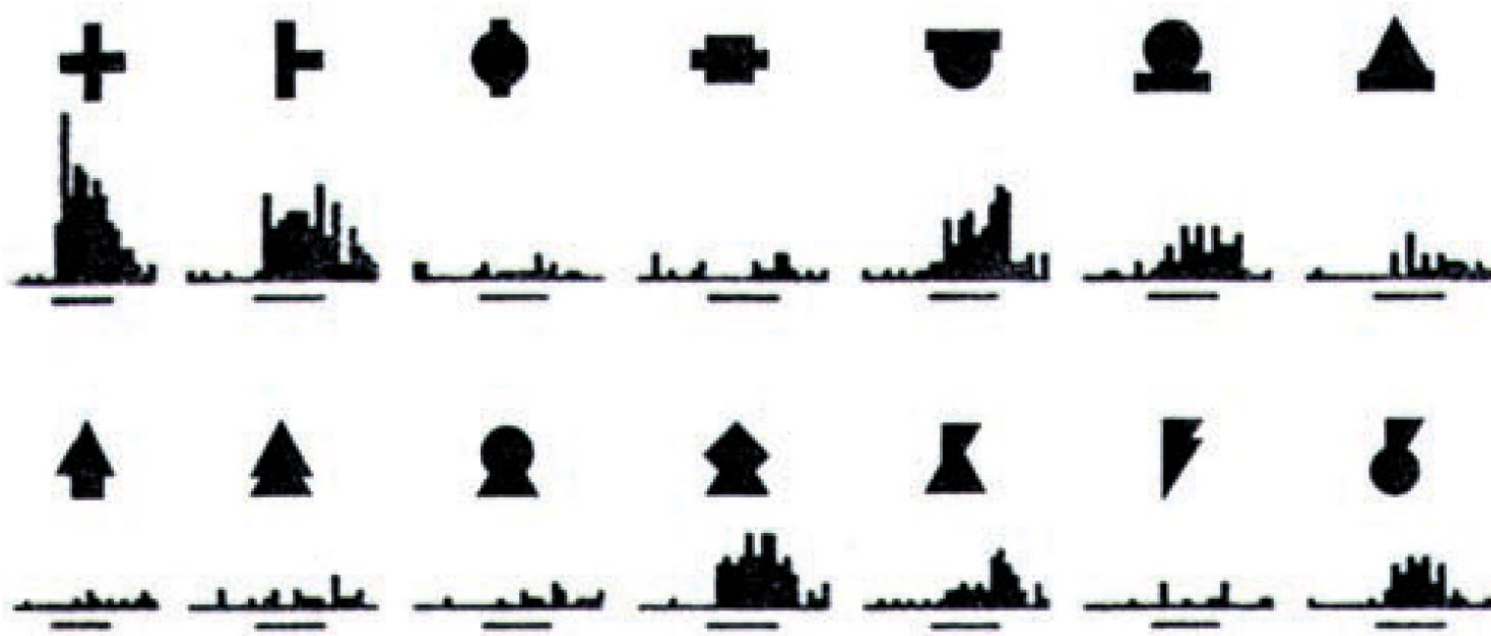
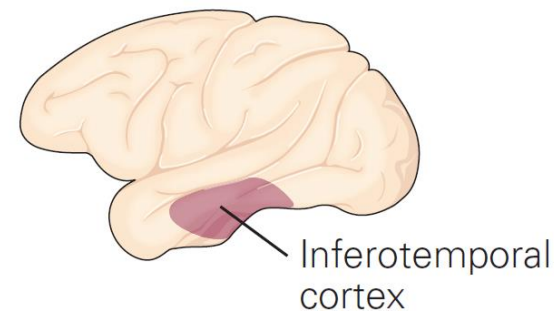


A wagon or a car of some kind. The larger vehicle is being pulled by the smaller one.



Medioventral
temporal cortex

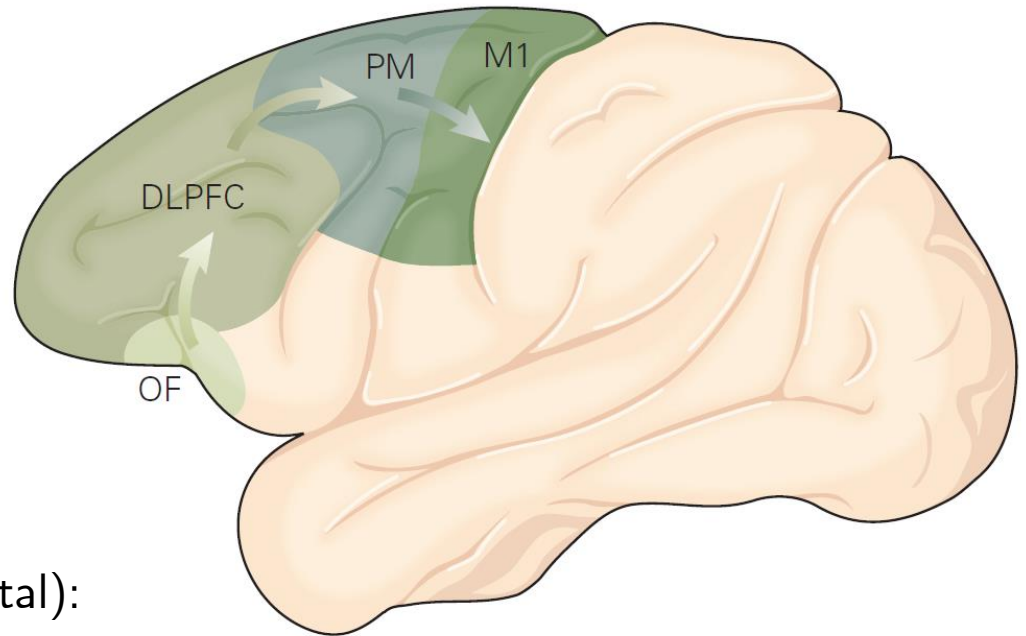
Neurons in the **inferotemporal** cortex of the monkey respond selectively to particular shapes



Goal-directed motor behavior is controlled in the frontal lobe



- M1:
 - **Total detail** map of body
- PM:
 - **Coarse** map;
 - Combination of movement and its sequence;
 - **Mirror** neurons
- DLPFC: **cognitive** aspect
- OF: (orbital-ventromedial prefrontal):
emotional aspect



Prefrontal cortex is important for the executive control of behavior



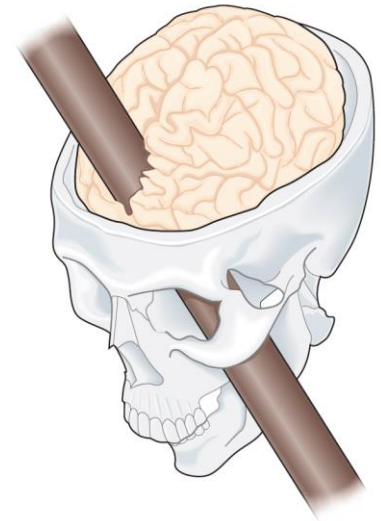
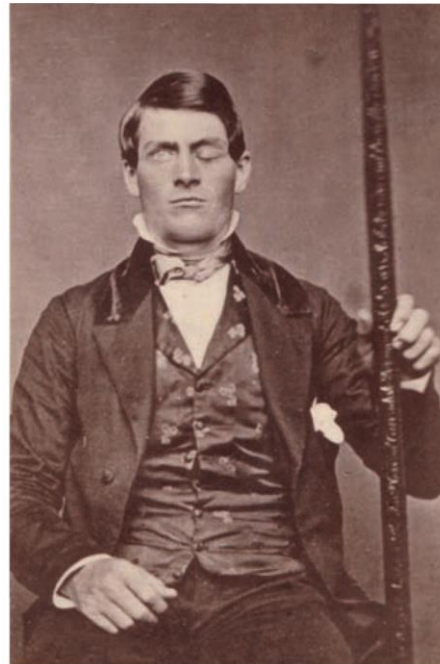
- Patient with damage confined to prefrontal cortex:
 - **Normal** perception and motor behavior
 - Perform normally on tests of **intelligence**
 - **Emotional** state is abnormal
 - Behavior is **disorganized**
- **Phineas Gage,**
 - Formerly “a **shrewd**, **smart** business man, very **energetic** and persistent in pursuing all his plans,”
 - Gage seemed transformed into another person altogether, “**pertinaciously** obstinate, yet **capricious and vacillating**, devising many plans of future operation, which are no sooner arranged than they are abandoned in turn for others appearing more feasible.”

Dependence of personality on prefrontal cortex



- Formerly he was:
 - Flatness
 - Shallowness
 - Indifference
- Gage seemed transformed into another person:
 - **Loss** of religious feeling
 - **Loss** of appreciation of literature or music
 - Feeling of others
 - **Indifference** to financial consequence

Phineas Gage



Effect on depression



- Charles Jacobsen: **chimpanzees** with prefrontal lesions no longer became **upset**
- **Prefrontal lobotomy** as a last-resort treatment for uncontrollable behavioral problems in patients with mental illness
- **Cognitive deficit:**
 - Injury to dorsolateral prefrontal
- **Emotional abnormalities:**
 - Orbital-ventromedial injury

Dorsolateral prefrontal cortex contributes to cognitive control of behavior

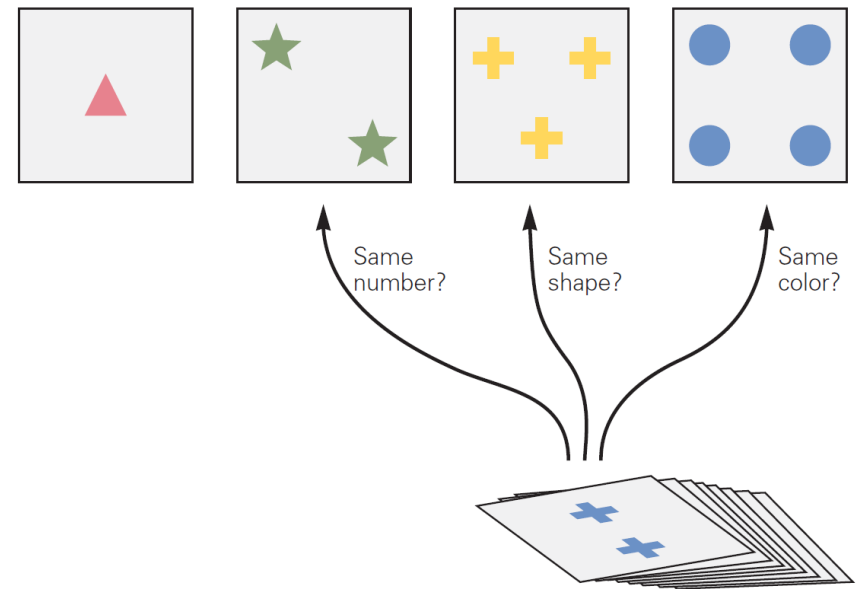
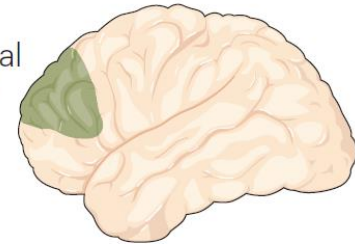


- **Fail** in **shopping expedition** with specific instruction
- Damage is the **wisconsin card** sort test
- Test of **verbal fluency**
 - They **could not finish task**; write down as many five-letter words as possible beginning with the letter “R”
 - *“My brain becomes a blank. I completely run out of words. I can’t think any more.”*
- Animal study:
 - Jacobsen: poorly in delayed-response tasks
 - **Ocular** delayed-response task (**MGS**)
 - Neuron in DLPFC , code **the specific target location** (right or left)
 - Related to **movement planning** or **working memory** (ability to hold information in mind)
 - Both depend on the ability to retain information over time.

Wisconsin card sort test

- Subject should learn by **trial and error** on of the rules
- The rules change **intermittently**
- Healthy subjects rapidly **adjust** their strategy
- The patients with prefrontal damage typically **continue to use the old** strategy long after it has ceased to be effective
 - **Perseverative** errors
 - **Capricious** errors (abandon successful rule unnecessary)

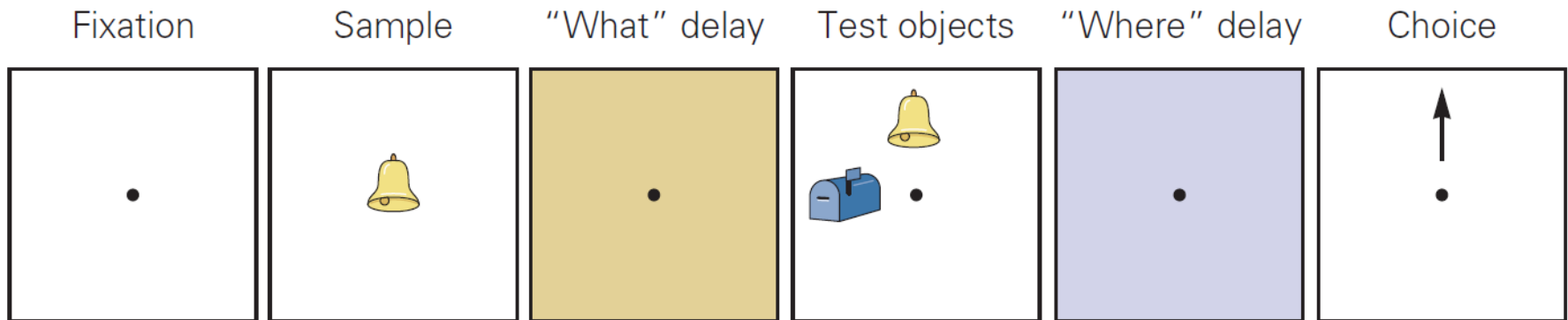
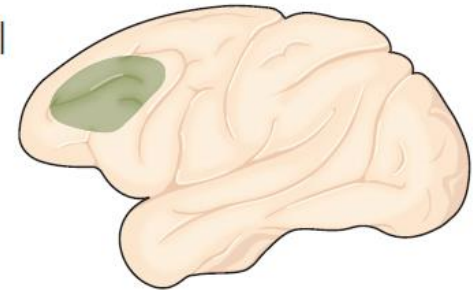
Dorsolateral prefrontal cortex

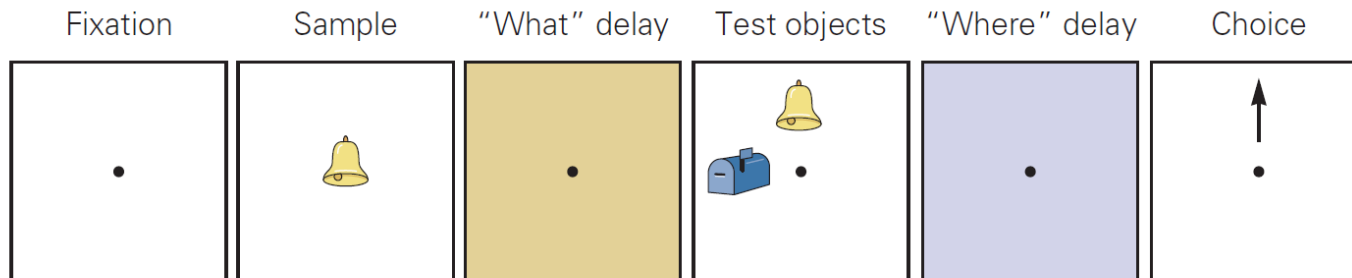


Neurons in the dorsolateral prefrontal cortex of a monkey are involved in holding information in working memory

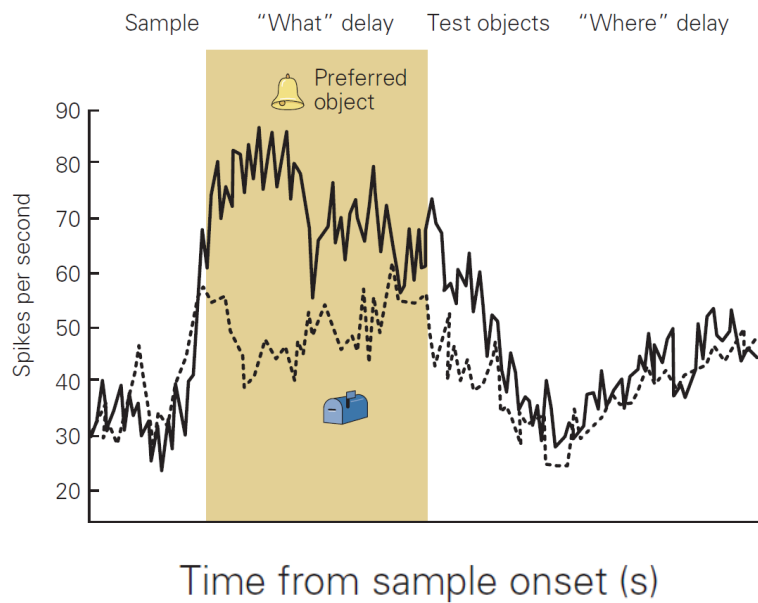


Dorsolateral
prefrontal
cortex

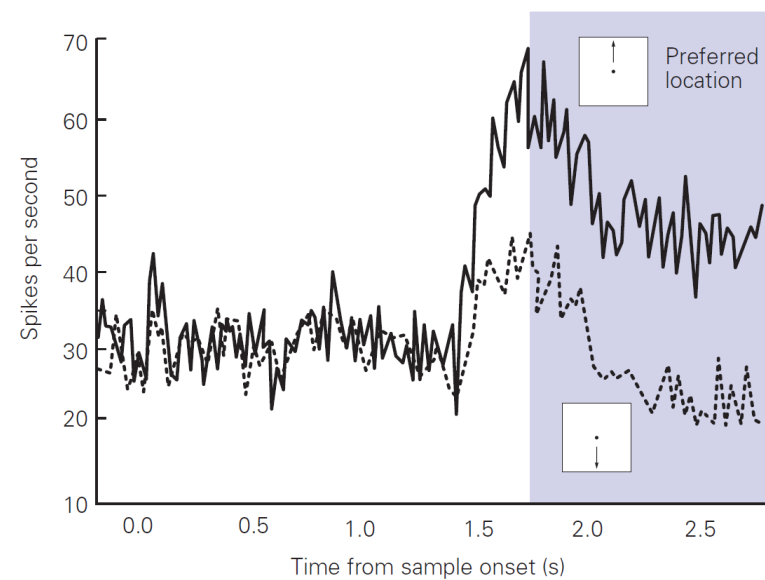




Object-selective neuron

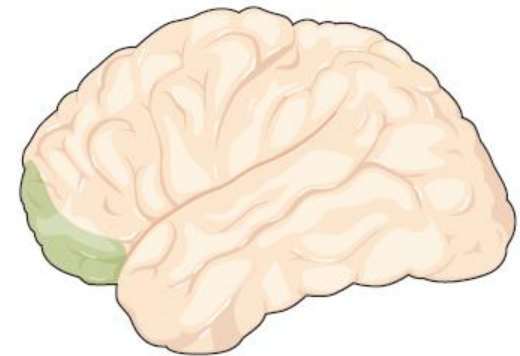


Location-selective neuron



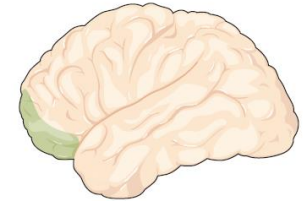
Orbital-ventromedial prefrontal cortex contributes to emotional control of behavior

- Plays a critical role in **goal-directed behavior** because of
- Connection:
 - **Subcortical** structure; **hypothalamus and amygdala**:
 - Mediate **homeostatic** drive states
 - **Fear, aggression, and mating**
 - Access to information about **various drives**
 - **Sensory** system
 - **Project** to DLPFC
- **Injury** to the orbital ventromedial prefrontal cortex:
 - Impaired **decision making**
 - Failed in **gambling task**
 - No **aversive emotional** response; no **skin conductance** response before selecting a **bad card**
- Orbitofrontal cortex activity reflects the **value of anticipated rewards**.



Orbital-ventromedial
prefrontal cortex

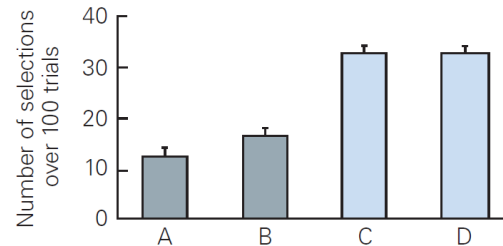
Injury to the orbital-ventromedial prefrontal cortex impairs **anticipation** of the consequences of decisions.



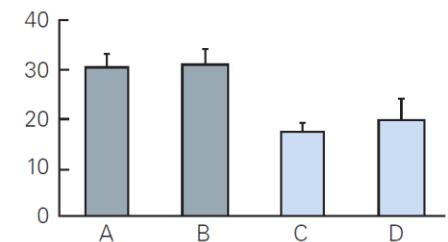
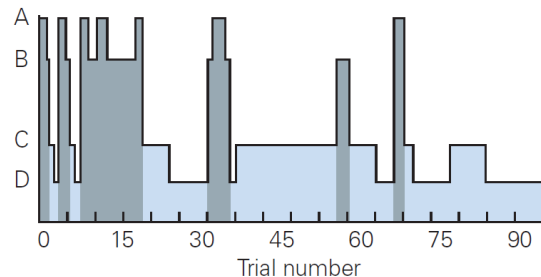
Orbital-ventromedial prefrontal cortex

Gambling task

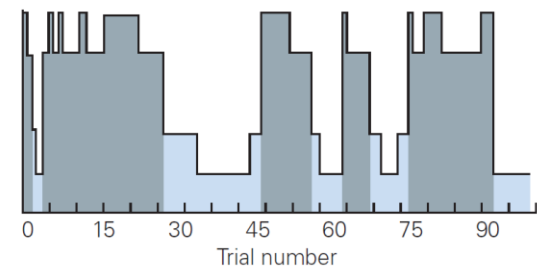
	A	B	C	D
Reward	+\$100	+\$100	+\$50	+\$50
Penalty	-\$250	-\$1250	-\$50	-\$250
Probability of penalty	0.5	0.1	0.5	0.1
Average return	-\$25	-\$25	+\$25	+\$25



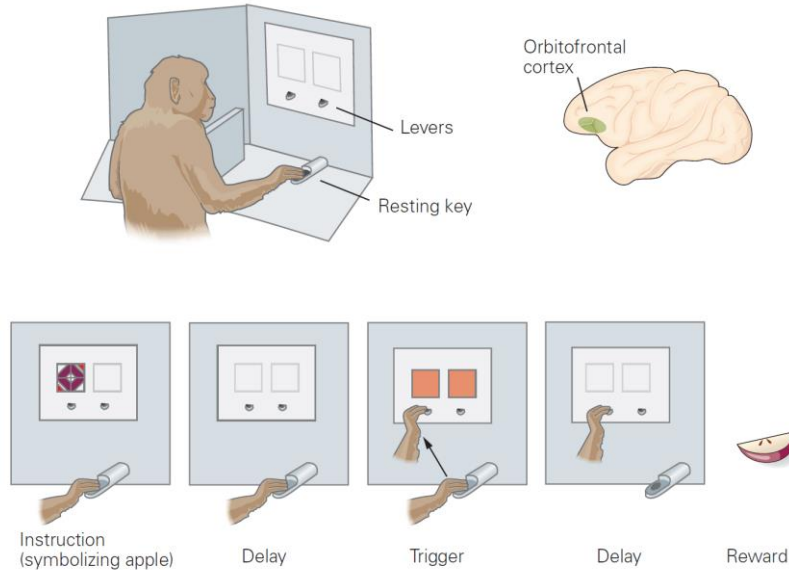
Typical normal subject



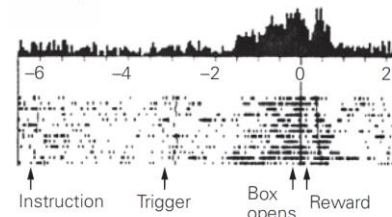
Typical subject with prefrontal damage



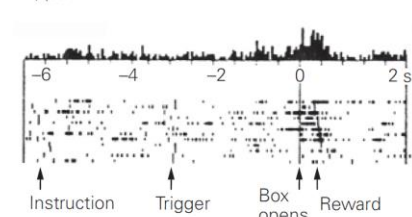
Neurons in the orbitofrontal cortex of a monkey signal the **subjective value** of an expected reward



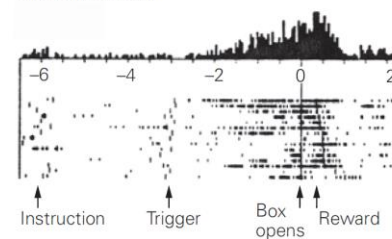
Possible rewards: raisin and apple
Raisin (preferred)



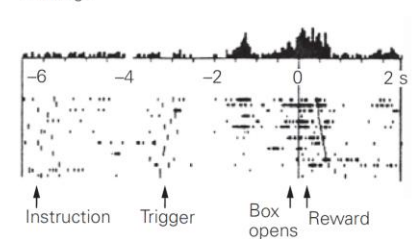
Apple



Possible rewards: apple and cabbage
Apple (preferred)



Cabbage



Limbic association cortex is a gateway to the hippocampal memory system

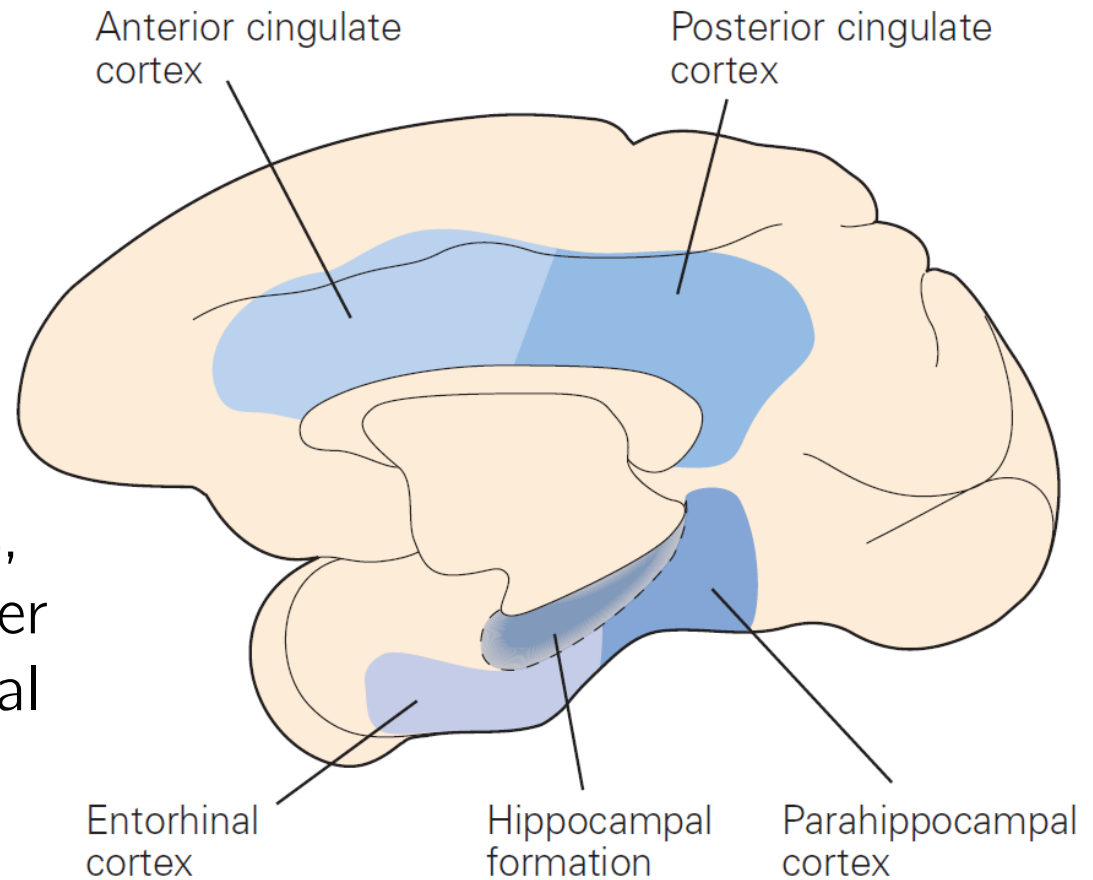


- Cortex at the **edge of the cortical surface** forms a ring
- Classic view:
 - **Limbic + amygdala + hypothalamus** make a unitary system for **homeostatic** and **instinctual** drives
 - Classic description certainly applies to the **orbital and ventromedial prefrontal** areas
- Hippocampus:
 - **It does not concern emotion.**
 - **Episodic memory:** ability to remember past **events**
 - **Long-term** memories and is critical for memory **consolidation**
 - Injury to this area: **anterograde amnesia**; unable to form new memories but retain old memories.
 - **First stored memories** temporarily, through long term plasticity and **transform to neocortex** by inducing a **replay** in parietal, temporal, and frontal association cortex of **activity patterns elicited by recent events**. → **Memories stored in the cortex** and are not dependent on the hippocampus

Limbic association cortex



Except for **hippocampus**,
The functions of the other
limbic areas on the medial
surface are not well
understood.



Overall view



- Unimodal vs. Association area where cognitive process occurs
- Parallel dorsal and ventral subdivision of each modality process aspect of **spatial** behavior and stimulus **identification** respectively
 - **Spatial information** in dorsal → parietal association cortex
 - **Feature information** in ventral stream → temporal association cortex
- **Parietal** neurons are responsible for spatial attribute of both objects and actions
- The functions of **temporal** cortex include recognizing things and storing knowledge about them.
- The **frontal**:
 - DLPFC: storing intention (distractibility, working memory and plans of actions)
 - OVMPFC: represent emotional value of objects
- **Limbic**: main role in long-term episodic memory