Space Mapping

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Bibliography

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Neural Maps

- The body, and the outside world are represented in the brain by neural maps that replicate the layout of the body or world.

- In the visual cortex and superior colliculus the neurons that receive information from the visual world are laid out according to 'retinotopic' maps.

- The same is true for the sensory cortex and cerebellum.

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Neural Maps

- To understand space, it is important to realise that spatialization is a fundamental property of life.

- The genetic organisation of the body includes a hierarchy of maps of various shapes that coincide from the spinal cord to the cortex - the same basic organisation is found at different levels of the brain, which must simplify the registration of the maps.

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Neural Maps

- The brain uses space to encode sensory inputs.
- All sensory detectors operate within different frames of reference, and encode space according to a variety of geometries.
- In the visual cortex the neurons are arranged according to a directional map, but within this map the neurons are also arranged according to a pinwheel geometry to allow them to be highly sensitive and selective to orientation.

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Three Topological areas - 1) Cortex and thalamus
Neuronal Group Selection Theory

Three levels of connections - Primary and

secondary repertoires of connections

+ reciprocal re-entrant pathways.

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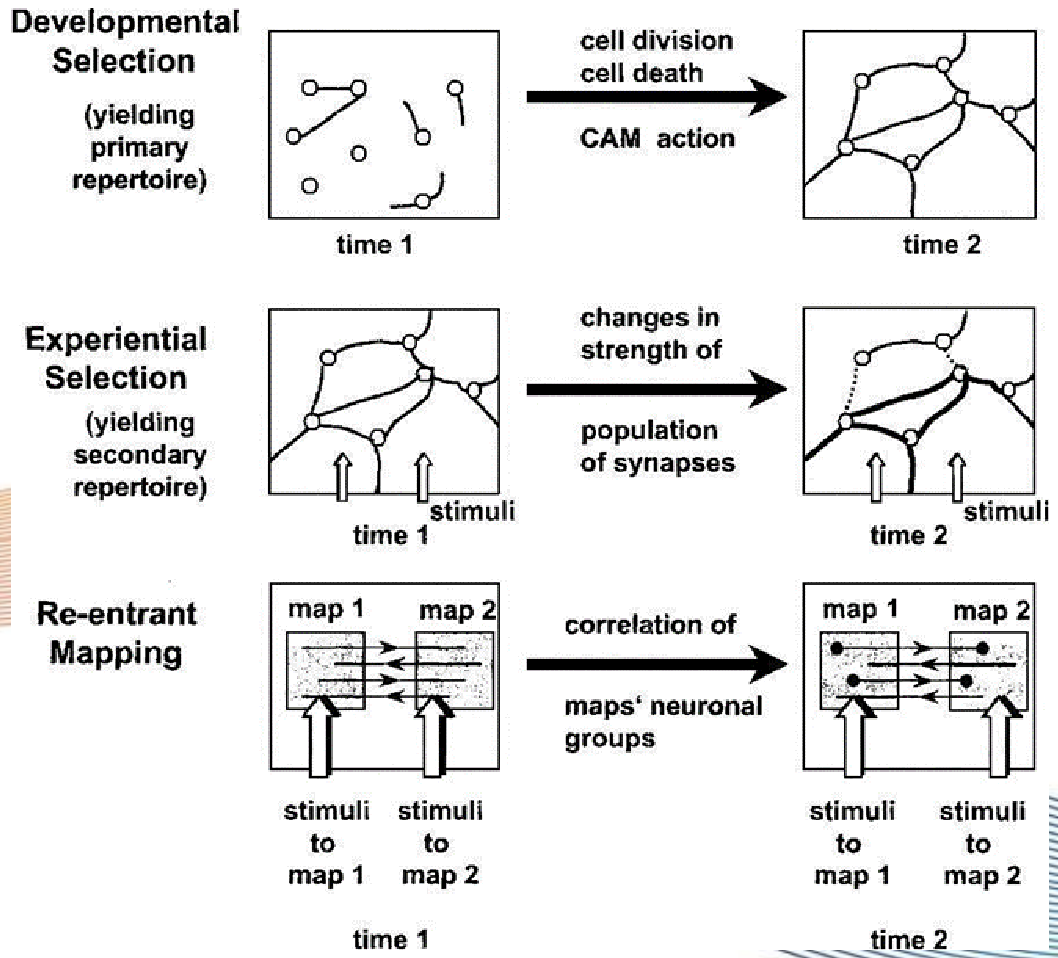
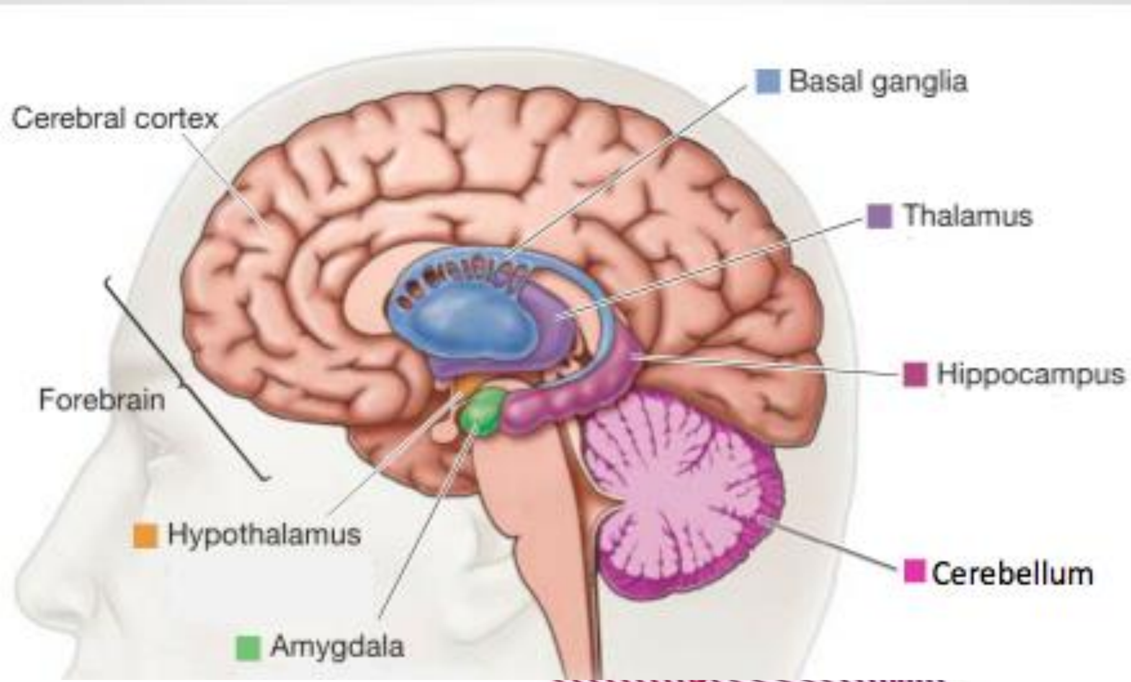


Three Topological areas - 2) Parallel, unidirectional chains

Sets of parallel, unidirectional chains, long loops that link the cortex to three appendages

- Cerebellum,
- Basal Ganglia,
- Hippocampus.



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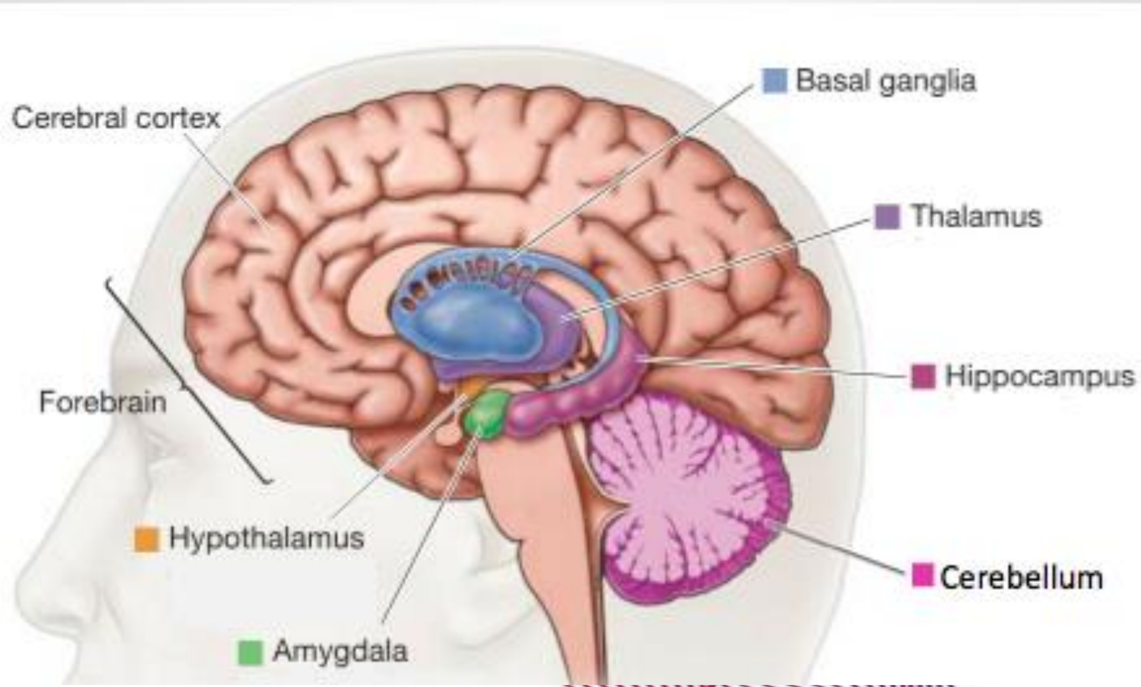
Cerebellum

Input

- cortical ,
- motor nuclei,
- vestibular nuclei.

Involved in

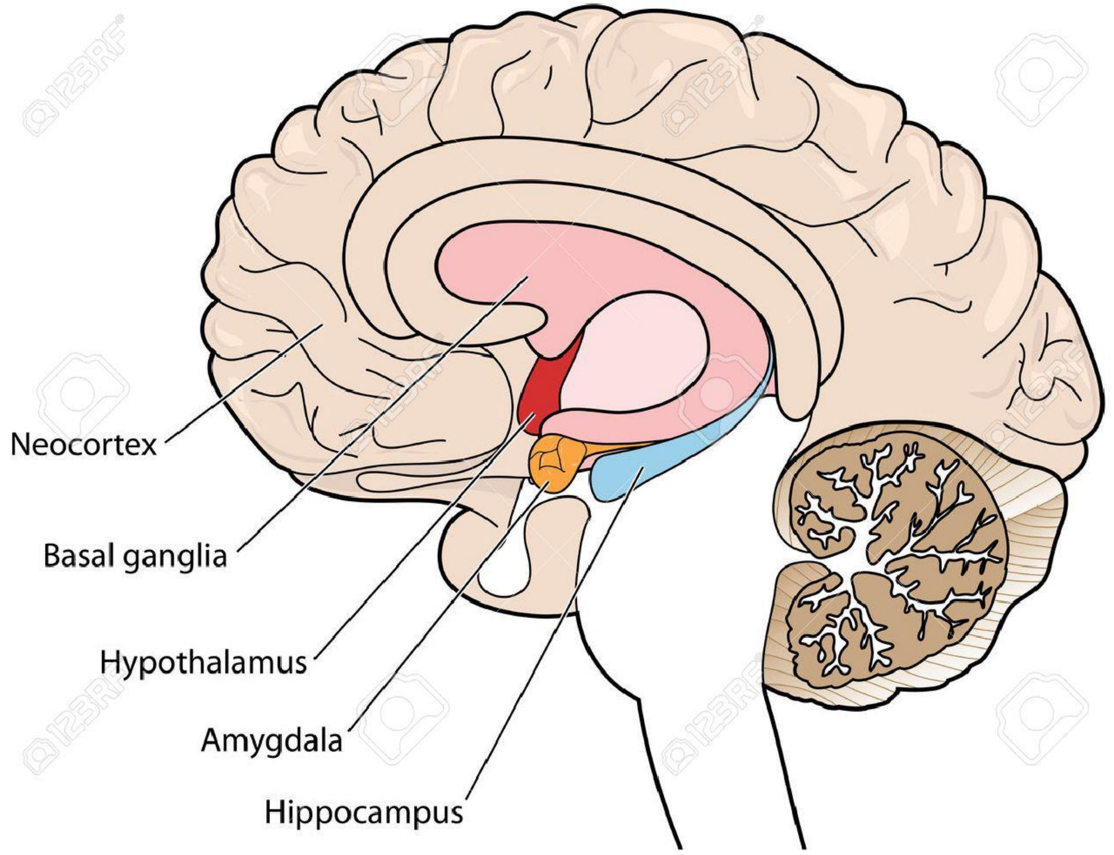
- co-ordination,
- synchrony of movements,
- motor learning,
- proprioception,
- fine control of saccades.



Basal ganglia

- Large nuclei receiving input from all over the cortex, go through a series of synaptic connections and return to the thalamus and cortex.

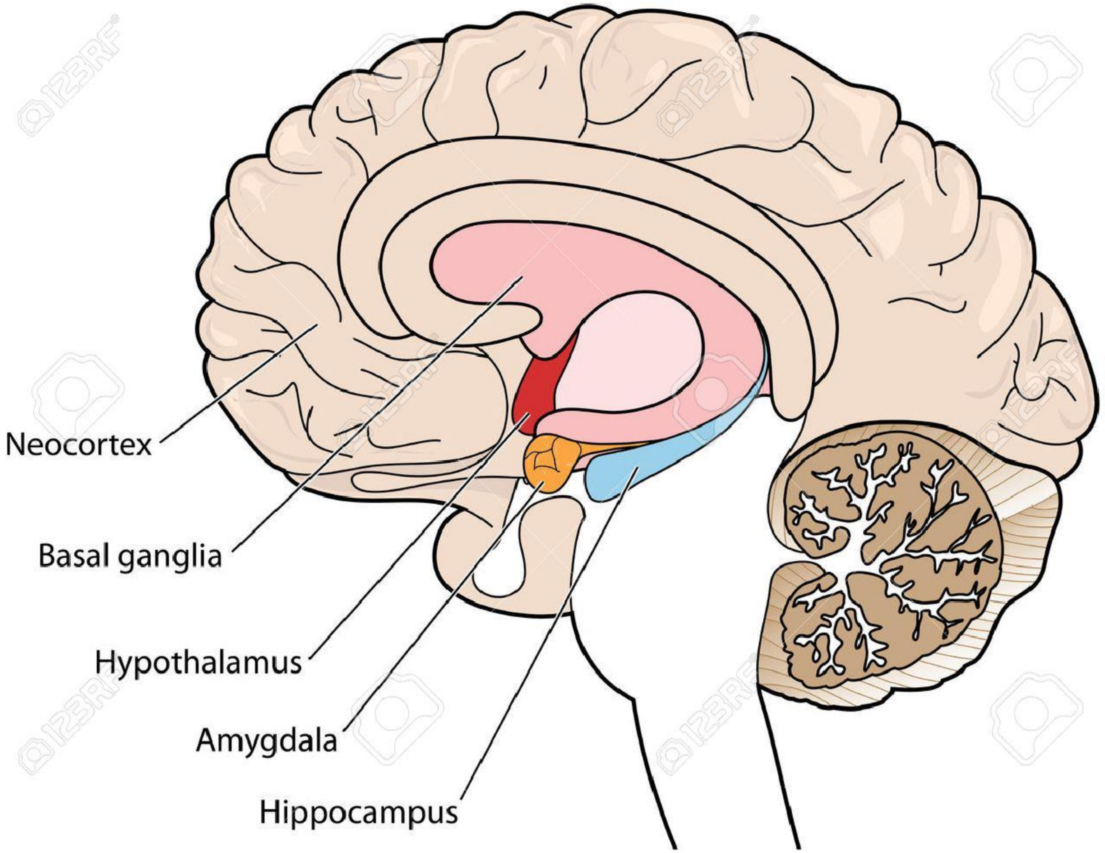
- Involved in the planning and execution of complex motor and cognitive acts.
- Co-ordinates interactions among cortical areas.



Hippocampus

- Input from many cortical areas, dealt with in synaptic steps then returned to the same cortical areas.

- Consolidating short term memory into long term memory in the cortex.
- Neural basis of spatial memory.



Encoding

- Hippocampus stores spatial cues in allocentric co-ordinates ie in geometrical space independent of the person, rather than the egocentric coordinates of the vestibular system.

- In the vestibular nuclei information about bodily self-motion is encoded in combination with visual and proprioceptive cues and is affected by the direction of gaze - exclusively egocentric.

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Encoding

- At the level of the parietal cortex movements of the head are situated in the more general context of movements of the body and body schema.
- It is only at the level of the hippocampus that movement of the body is situated in allocentric space.

- The brain labels its perceptions according to its intentions and goals, and the hippocampus plays a significant part in this.

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Encoding

- The hippocampus detects and memorises simultaneous sensory messages, and is critical in associating together simultaneous perceptual cues.

- This is a configurational memory of events and the temporal sequence in which these events occurred.

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Three Topological areas - 3) Noradrenergic locus coeruleus

Distributes a hair net of fibres all over the brain to release noradrenaline.

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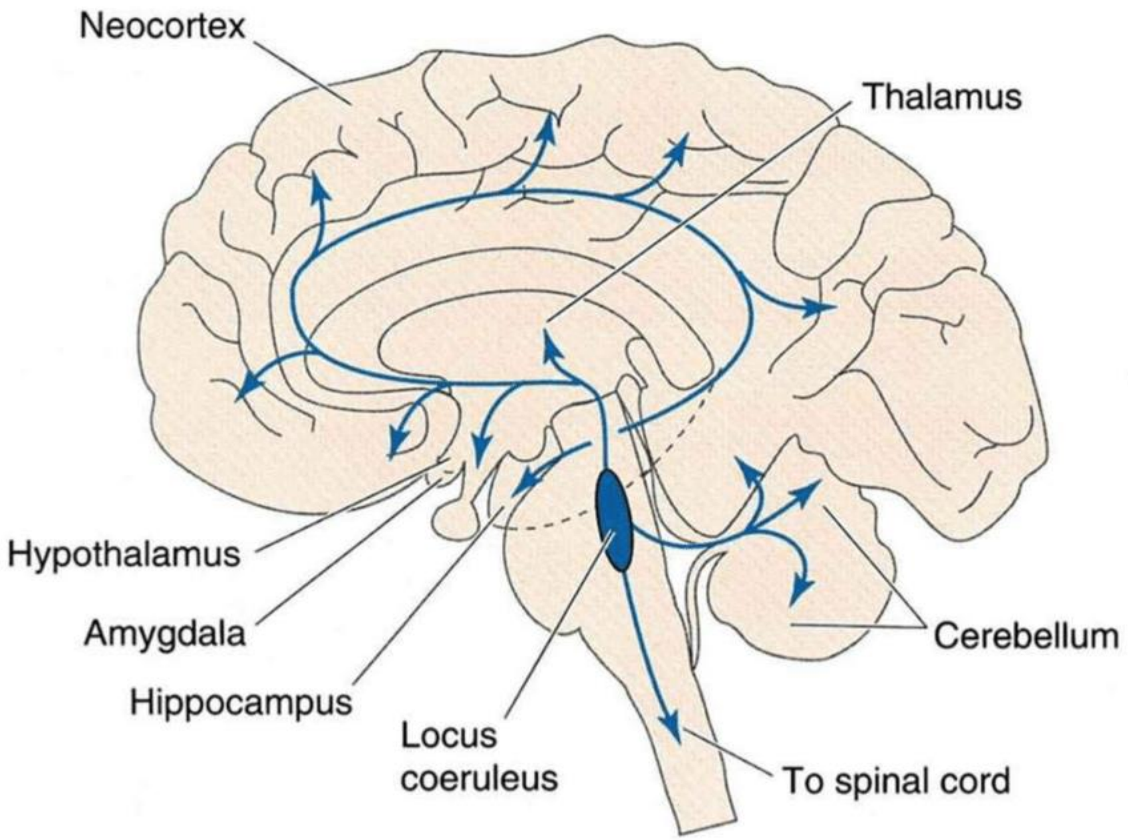
- Part of the Reticular Activating System, so involved in the regulation of arousal and autonomic activity.
- Part of homeostatic control.



Global Mapping

- The cerebral cortex is not sufficient to bear the burden of perceptual categorisation and control of movements. The burden is carried out by global mapping.

- A global mapping relates an animal's movement and changing sensory input to the action of the cerebellum, basal ganglia and hippocampus as they connect to the cerebral cortex.

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Global Mapping

A global mapping is a dynamic structure linking the first two topological areas of the brain, containing multiple re-entrant local maps (motor and sensory) that interact with non-mapped areas eg brain stem, basal ganglia, hippocampus and parts of the cerebellum.

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Global Mapping

- The activity of a global mapping reflects the fact that perception generally depends on, and leads to, action.

- When the head is moved to follow a target the motor and sensory portions of a global mapping continually readjust.

- The dynamic structure of a global mapping is maintained, refreshed and altered by continual motor activity and rehearsal.

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Global Mapping

- Synaptic changes over a large part of the global mapping provide the basis for memory - it is a process of continual recategorization and involves continual motor activity leading to the ability to repeat a performance.

- The contribution of global mappings to memory also carries the major burden of unconscious performance in the brain.

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Movement and Posture

- Perceptual categorization during infancy depends on more than just broad intersensory input; it requires, from the onset, the capacity to move and change postures.

- Postural control is seriously impaired if one of the sensory cues is modified or disabled because this disrupts the coordinate sensorimotor transformations that must occur across the whole body involving rotational and translational movements.

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Movement and Posture

- This is a dynamic system that is capable of carrying out feature detection and correlation simultaneously.
- The system undergoes continuous alteration by the sampling of different sensory sheets, and its input-output correlations are changed by motion or behaviour.

- Subcortical structures that include the hippocampus, cerebellum, and basal ganglia play an important role in sequencing events and switching output in accord with alteration in posture.

Dalton T. and Bergenn V. Early Experience, the Brain and Consciousness

What is happening at the superior colliculus?

- A great many animals do not have a visual cortex as developed as that of primates and humans.
- In all animals the image of the external world is projected onto an internal map, called the tectum, or, in humans, the superior colliculus.

- It is in this structure that the animal constructs a response to the appearance of a moving visual target at the periphery of its visual field.

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Superior Colliculus

Consists of multiple layers containing maps of visual and oculomotor space.

- The upper, superficial layers receive a direct projection from the retina,
- The lower, intermediate and deep layers receive a separate cortical projection as well as being connected to the saccadic generation centres.
- The upper and deeper layers do not connect neurally.

Findlay J. and Gilchrist I. Active Vision

Superior Colliculus

- The cells in the upper and intermediate layers have visual receptive fields whose locations are laid out topologically.
- In the deeper layers electrical stimulation generates a saccadic eye movement dependent on the location of the stimulation.
- Some cells have both visual and oculomotor responsiveness.

- Stimulation of a location in the deeper layers results in a saccade to precisely the region of space which is represented in the visual map at the same collicular location.

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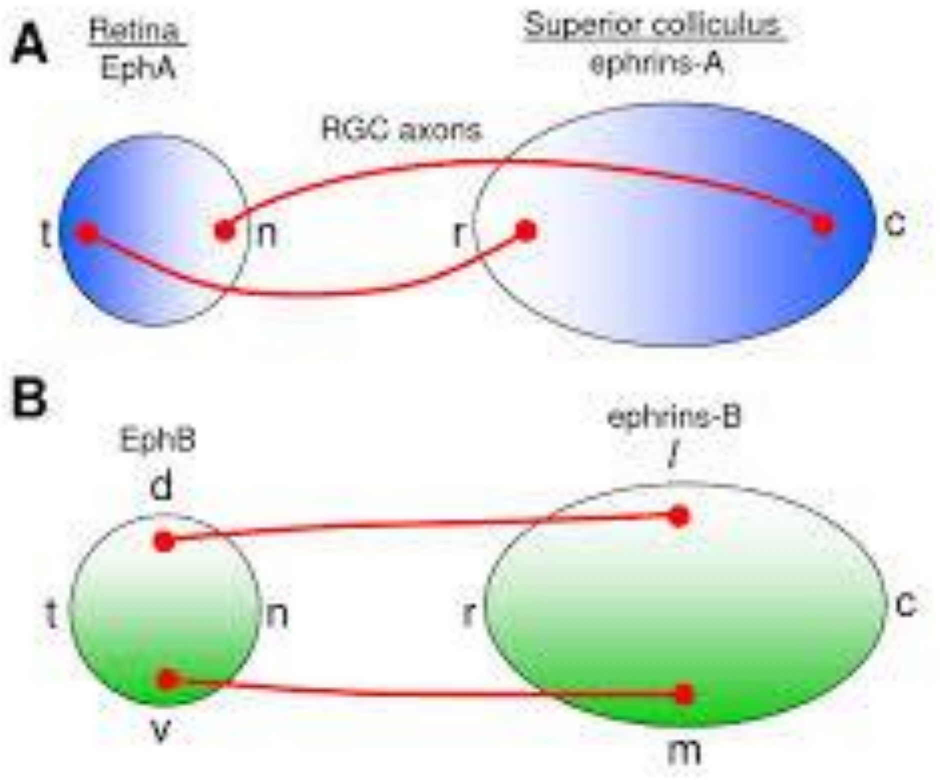
Superior Colliculus

- The superior colliculus enables the animal to rapidly orient the eyes, the head, and the body itself toward the object that is approaching and, in an anticipatory way, to capture or avoid it.
- This map loses the simplicity of the spherical geometry of retinal projection; it is not spherical anymore.



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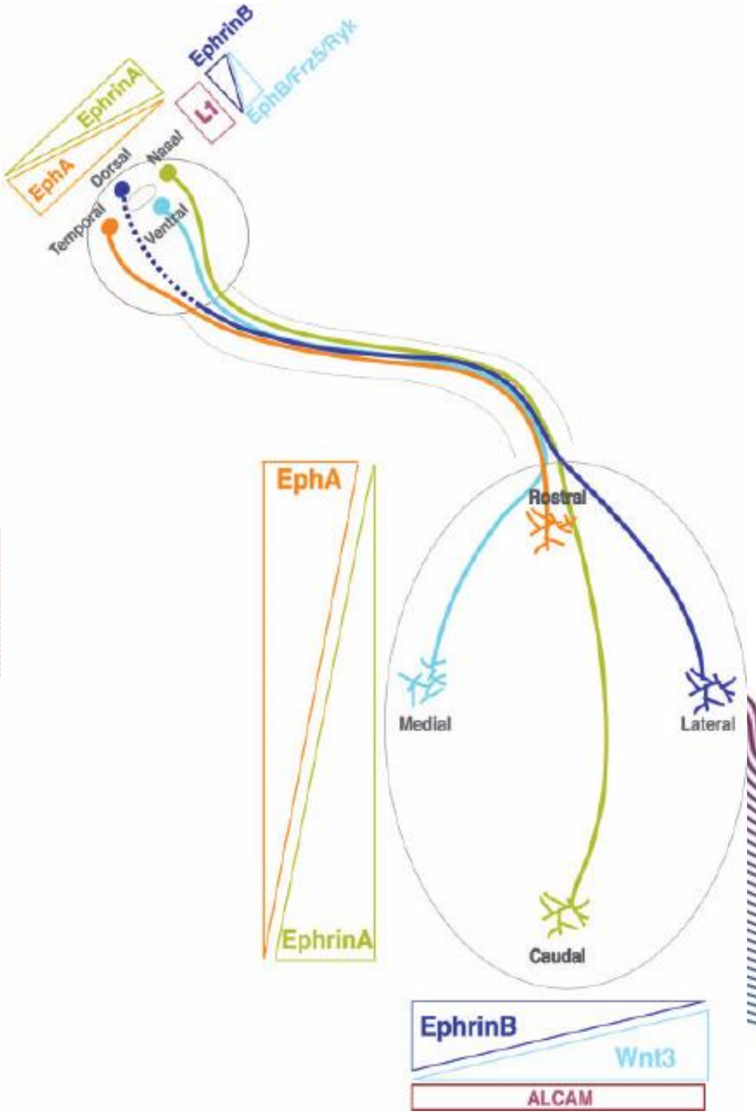
Superior Colliculus

- The visual world is represented in the SC according to complex logarithmic mapping.
- This deformation makes it possible to optimize sensorimotor transformations.
- This map results in a combination of properties that facilitate control of saccades.



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Superior Colliculus

- By transforming the geometry in the SC the brain resolves a difficult problem in a very elegant way.

- It matches a sensory space with a motor command in a complex muscle space.

The arrangement of the neurons in the collicular map varies with the animal species, probably to accommodate the repertoires of behaviours.

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Pursuit and Saccadic Eye Movements

Several interrelated brain regions are involved in the detection of peripheral, visual stimuli that are particularly sensitive to motion.

(i) The superior colliculus (SC) controls reflexive eye saccades;

(ii) An anterior system in the frontal cortex bypasses the SC and facilitates planned saccades to targets;

(iii) A third system involving the middle temporal and parietal areas of the cortex controls smooth pursuit;

(iv) A fourth system sets up an inhibitory pathway to the SC from cortical areas through the basal ganglia.

These systems do not go online all at once.

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Importance of Space Mapping

- The brain 'creates worlds' based on the body in action in the world by virtue of the flexibility and multiplicity of it's mechanisms for manipulating space.

- The diversity of maps, frames of reference and modes of spatial encoding is fundamental to our capacity for mathematics, reasoning and thinking.

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Importance of Space Mapping

- Complex;
- Elegant;
- Based in posture and movement;
- The dynamic structure of a global mapping is maintained, refreshed and altered by continual motor activity and rehearsal;
- So, sensory input and action and both continuous and recursive, with continual modification as the action takes place;

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- So, sensory input and action and both continuous and recursive, with continual modification as the action takes place;
- The visual process in action.