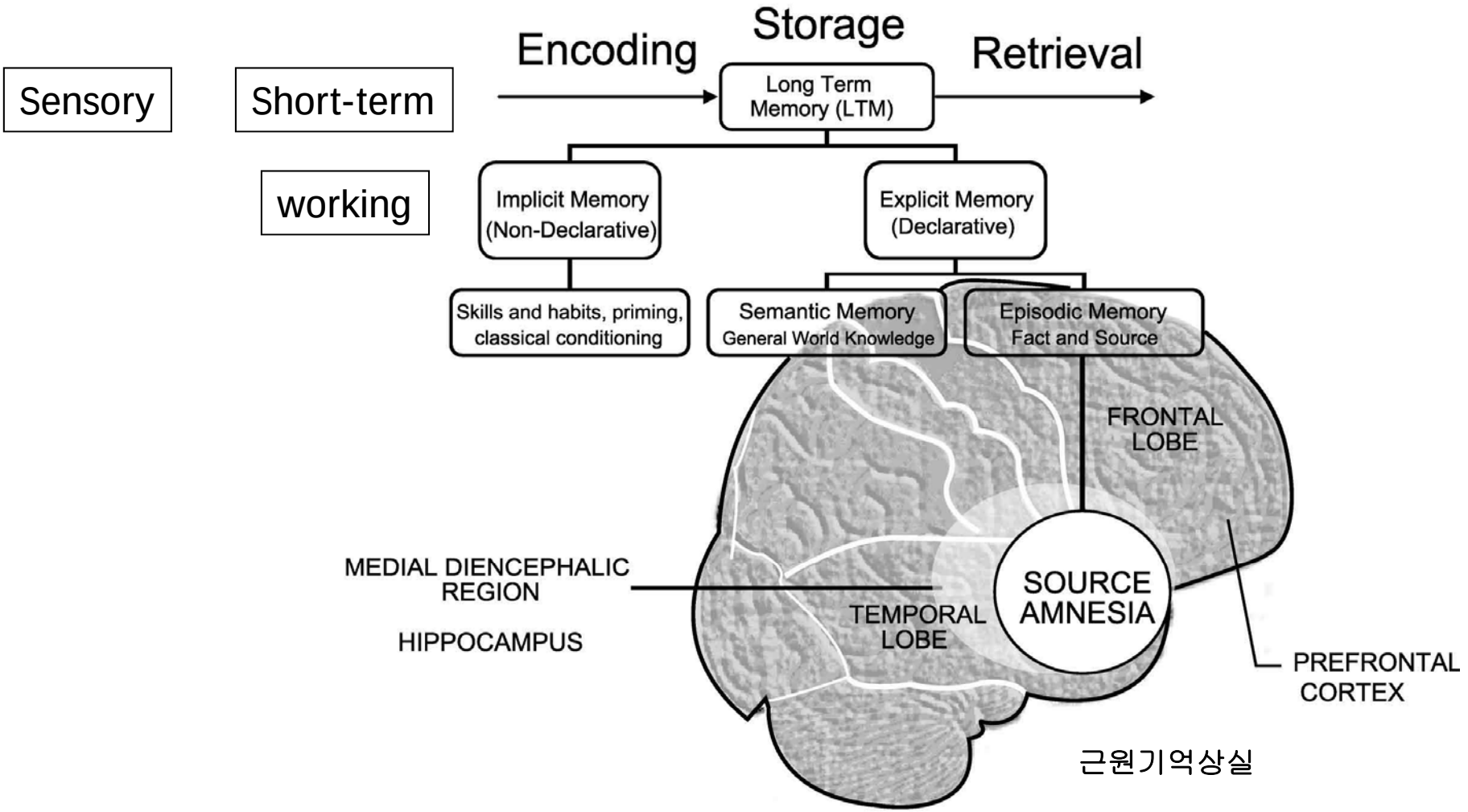
Chapter 5. Memory

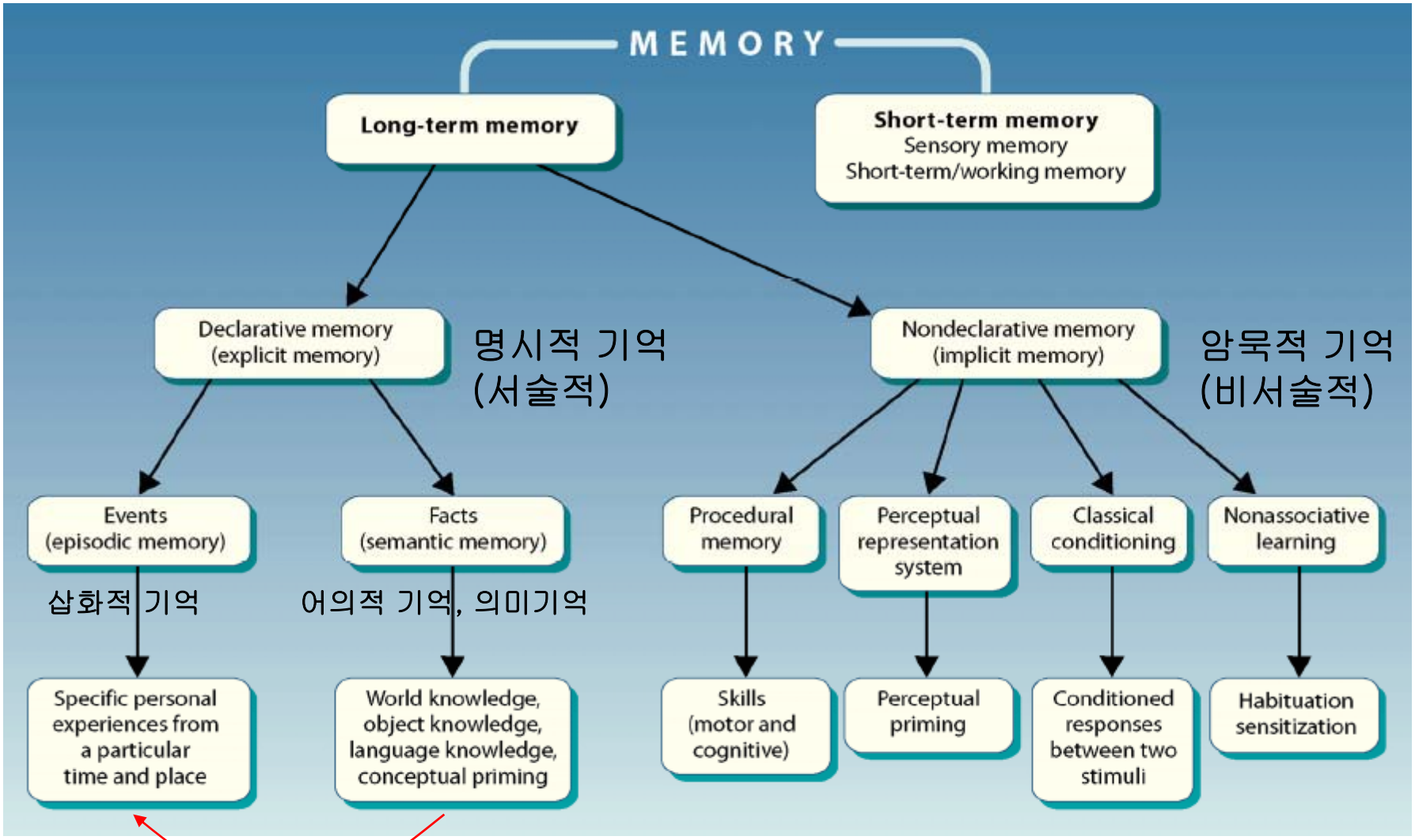
Learning is acquiring new knowledge, behaviors, skills, values, preferences or understanding, and may involve synthesizing different types of information. Memory is an organism's ability to store, retain, and recall information and experiences.

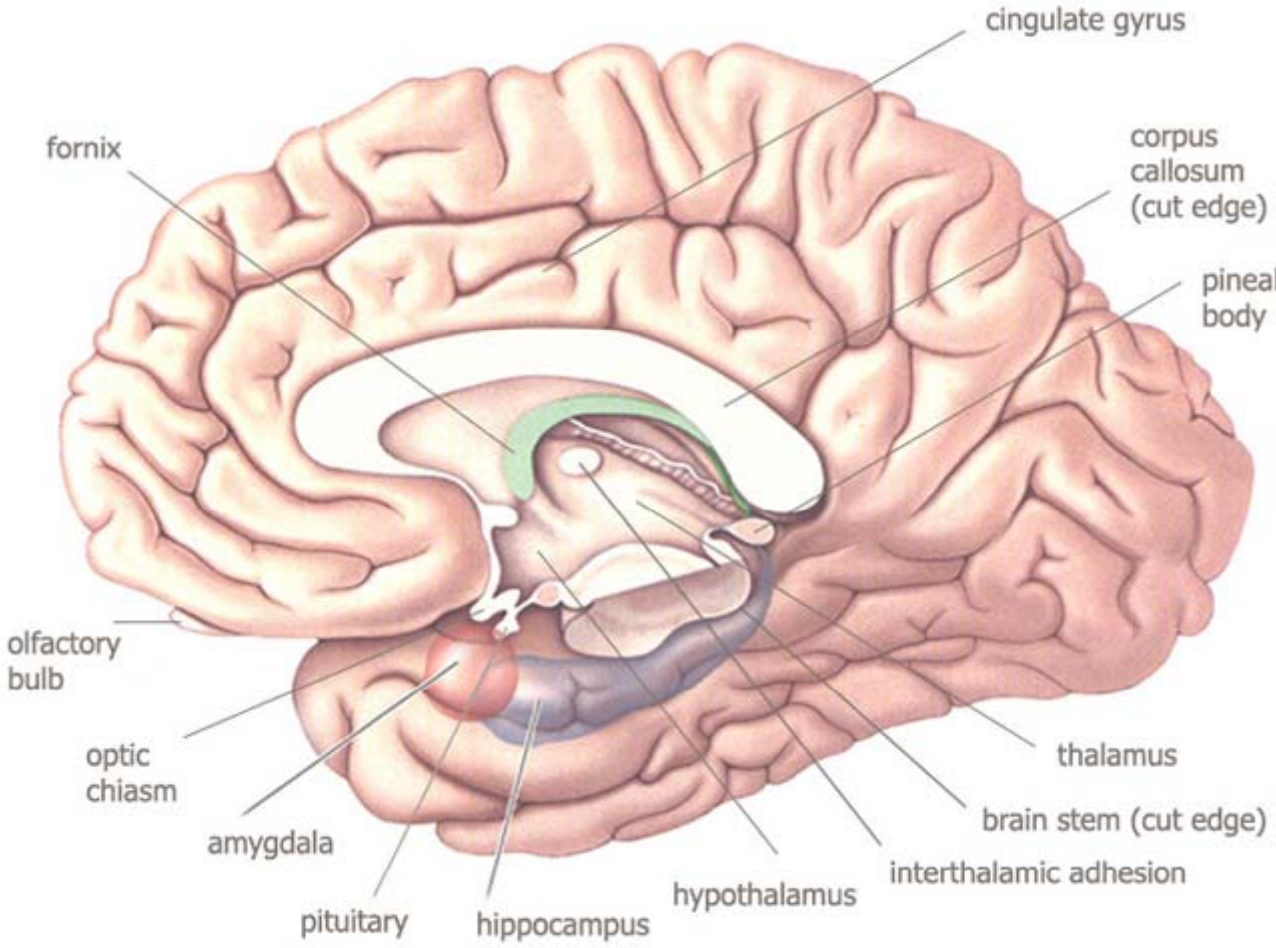
Circuitry in brain: partly genetic and mostly environmental
How it works?
The process of evolving a unique brain
The essence of the individual depends on experience and memory

Memory

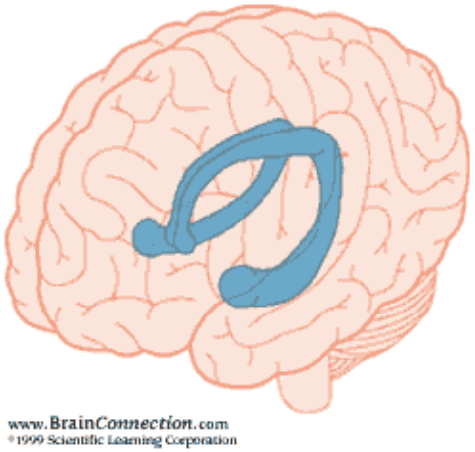
Sensory: just a second observation
Short-term (primary or active): cf. working memory
Long-term: implicit & explicit (semantic & episodic)



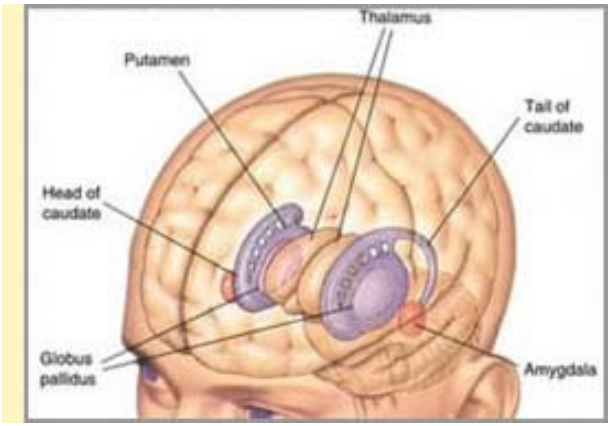

MEMORY
Long-term memory
Short-term memory
Sensory memory
Short-term/working memory
Declarative memory
(explicit memory)
명시적 기억
(서술적)
Nondeclarative memory
(implicit memory)
암묵적 기억
(비서술적)
Events
(episodic memory)
Facts
(semantic memory)
Procedural
memory
Perceptual
representation
system
Classical
conditioning
Nonassociative
learning
삽화적 기억
어의적 기억, 의미기억
Specific personal
experiences from
a particular
time and place
World knowledge,
object knowledge,
language knowledge,
conceptual priming
Skills
(motor and
cognitive)
Perceptual
priming
Conditioned
responses
between two
stimuli
Habituation
sensitization
시간과 장소



hippocampus



thalamus



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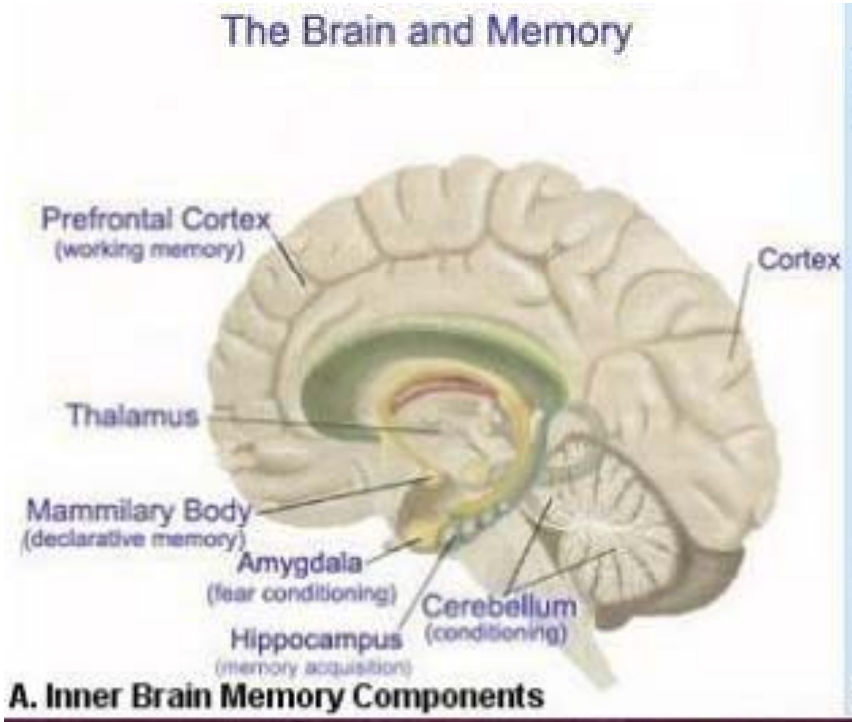
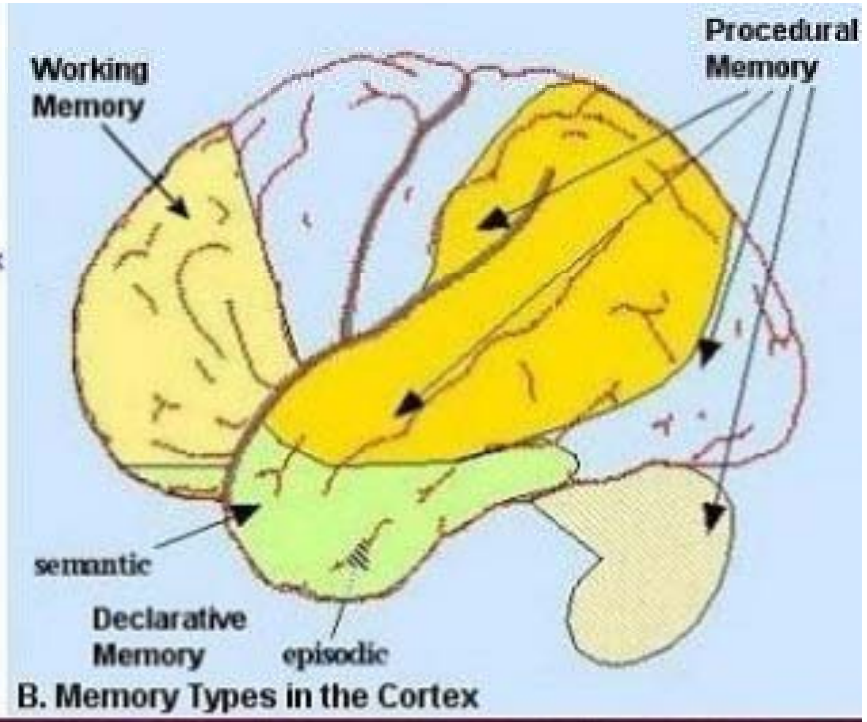
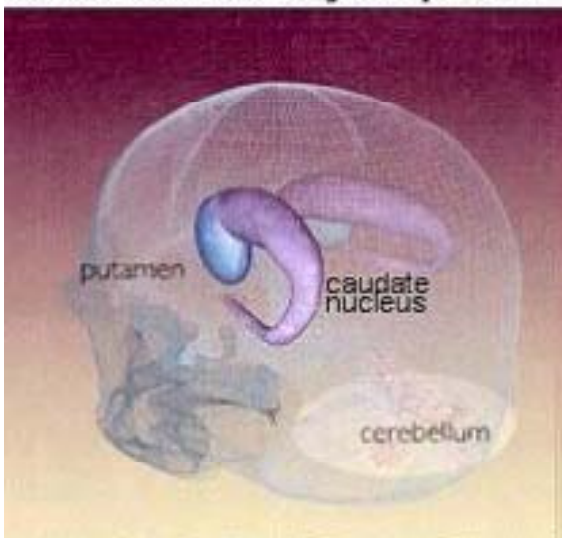


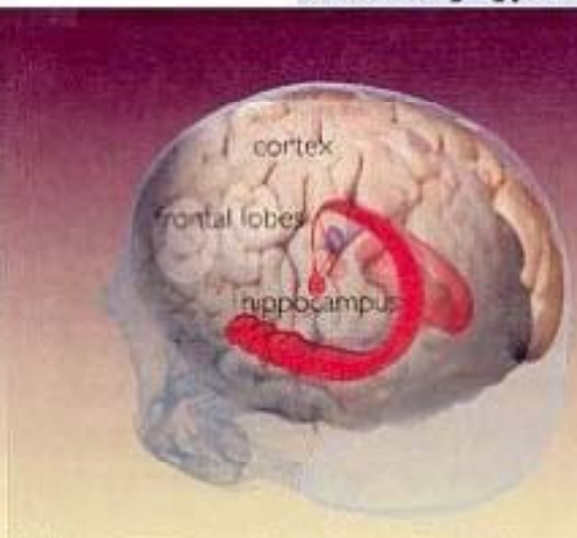
A. Inner Brain Memory Components



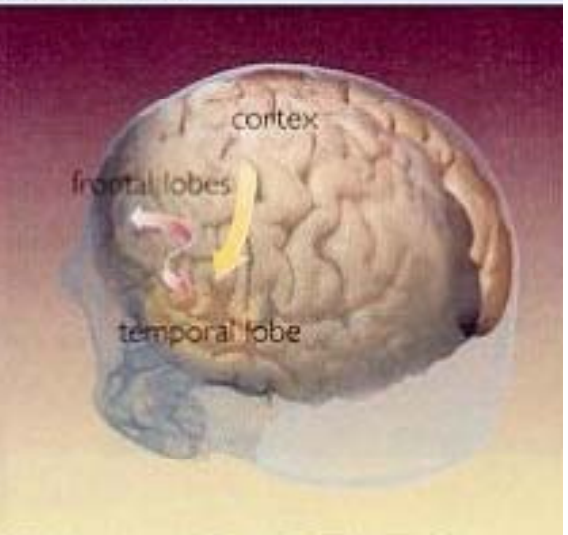
B. Memory Types in the Cortex



C. Procedural Memory Components

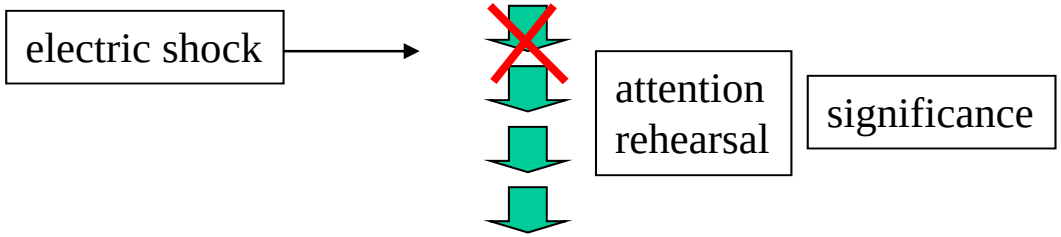


D. Episodic Memory Components



E. Semantic Memory Pathway

Short-term memory: transient, highly unstable, vulnerable process



Long-term memory: more permanent and dormant

H.M.

Brain surgery to control epilepsy: medial temporal lobe
Trapped in the present: remember events before operation (up to two years beforehand)
Amnesic: short-term memory is working but not lead to long-term memory

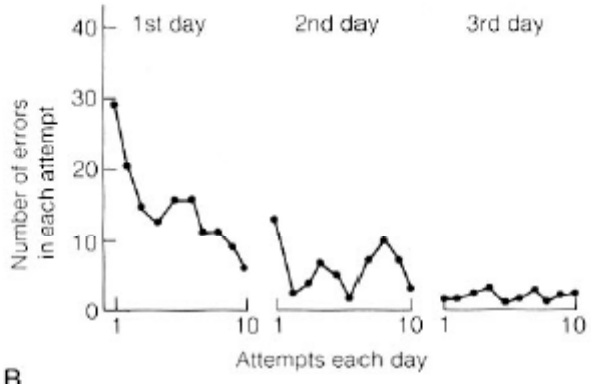
Implicit memory is working: mirror tracing task
Does not conscious of remembering the event of learning

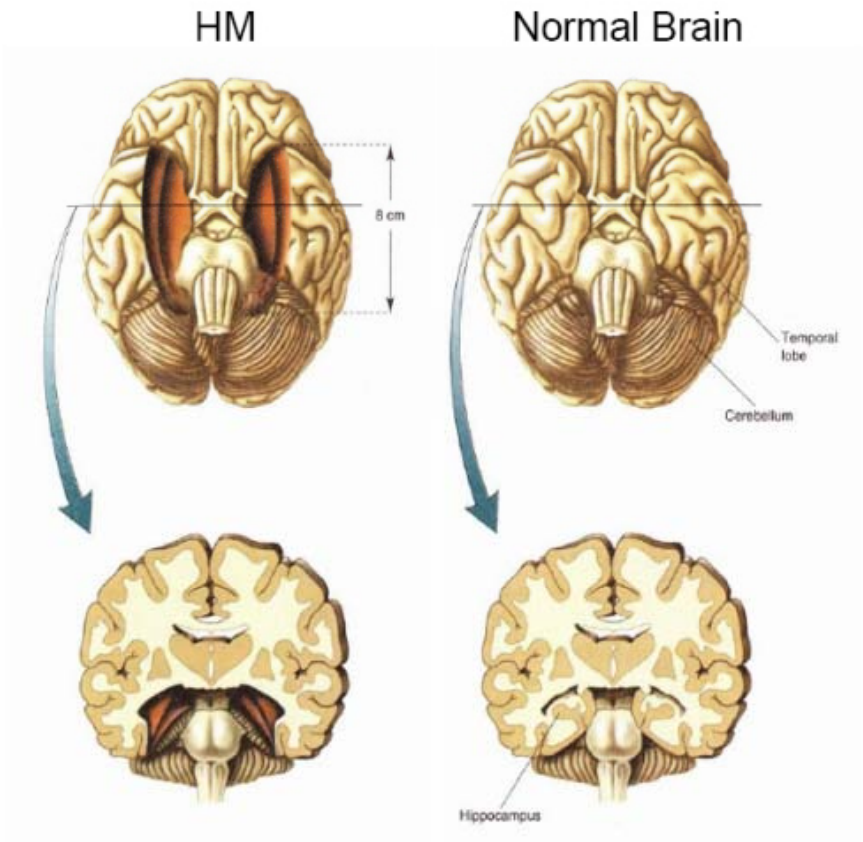
HM: Amnesic

- Mirror tracing task, Milner, 1965

HM: Amnesic

- improvement in H.M. for mirror tracing task
- no conscious recollection of previous training episodes




HM
Normal Brain
8 cm
Temporal lobe
Cerebellum
Hippocampus

Memory: processing & consolidation

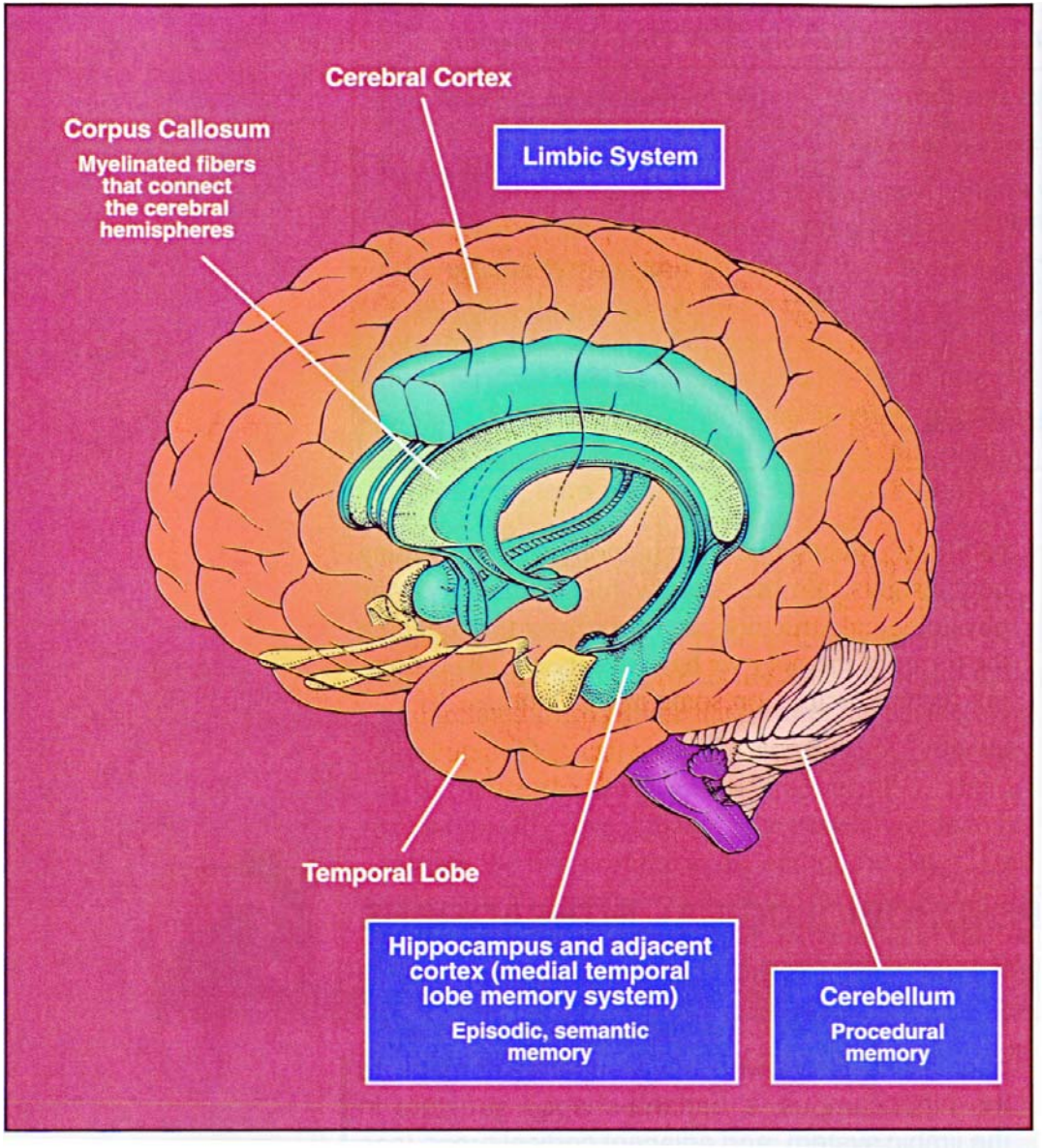
Medial temporal lobe (hippocampus)

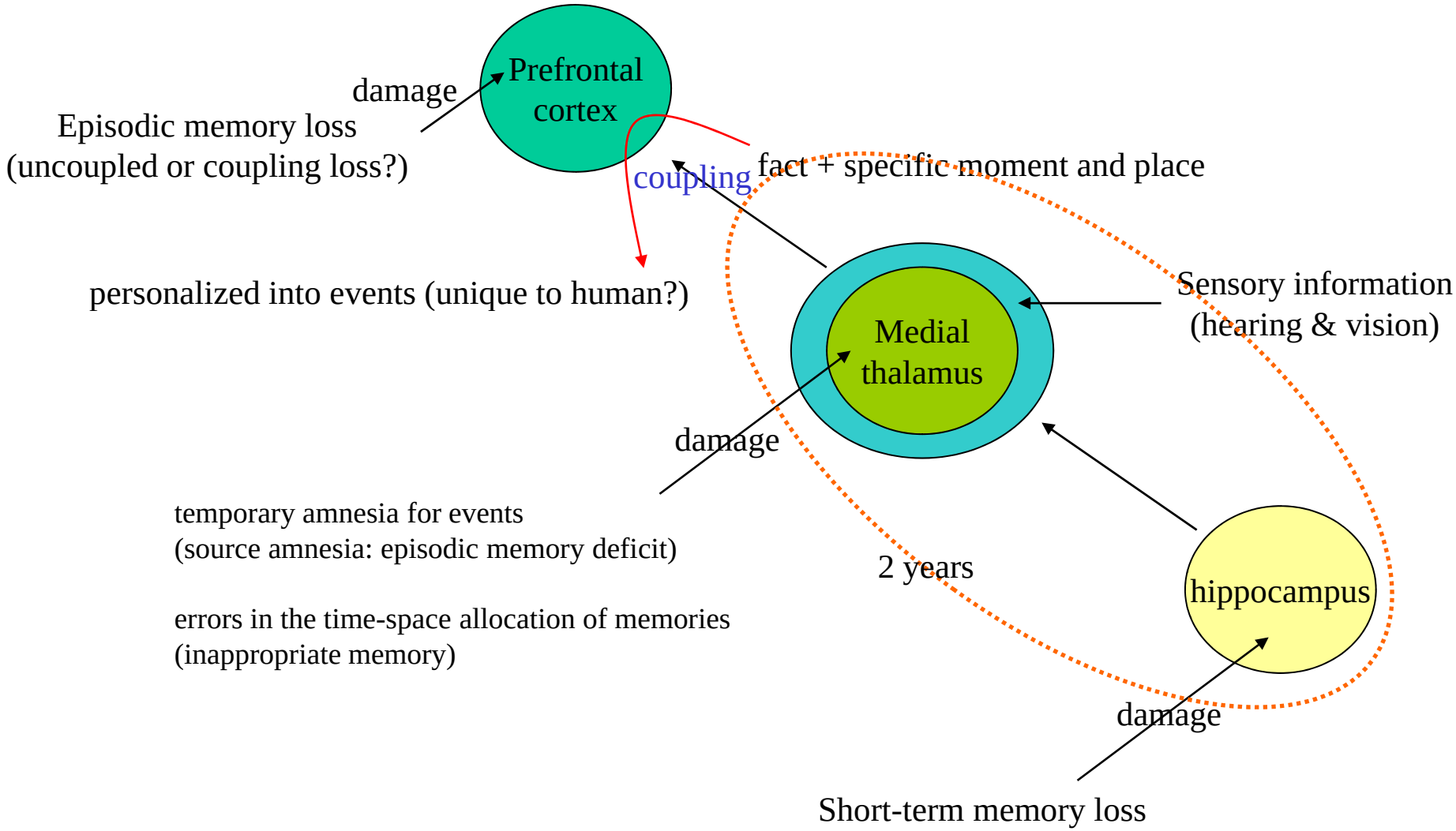
↓

Medial thalamus

↓

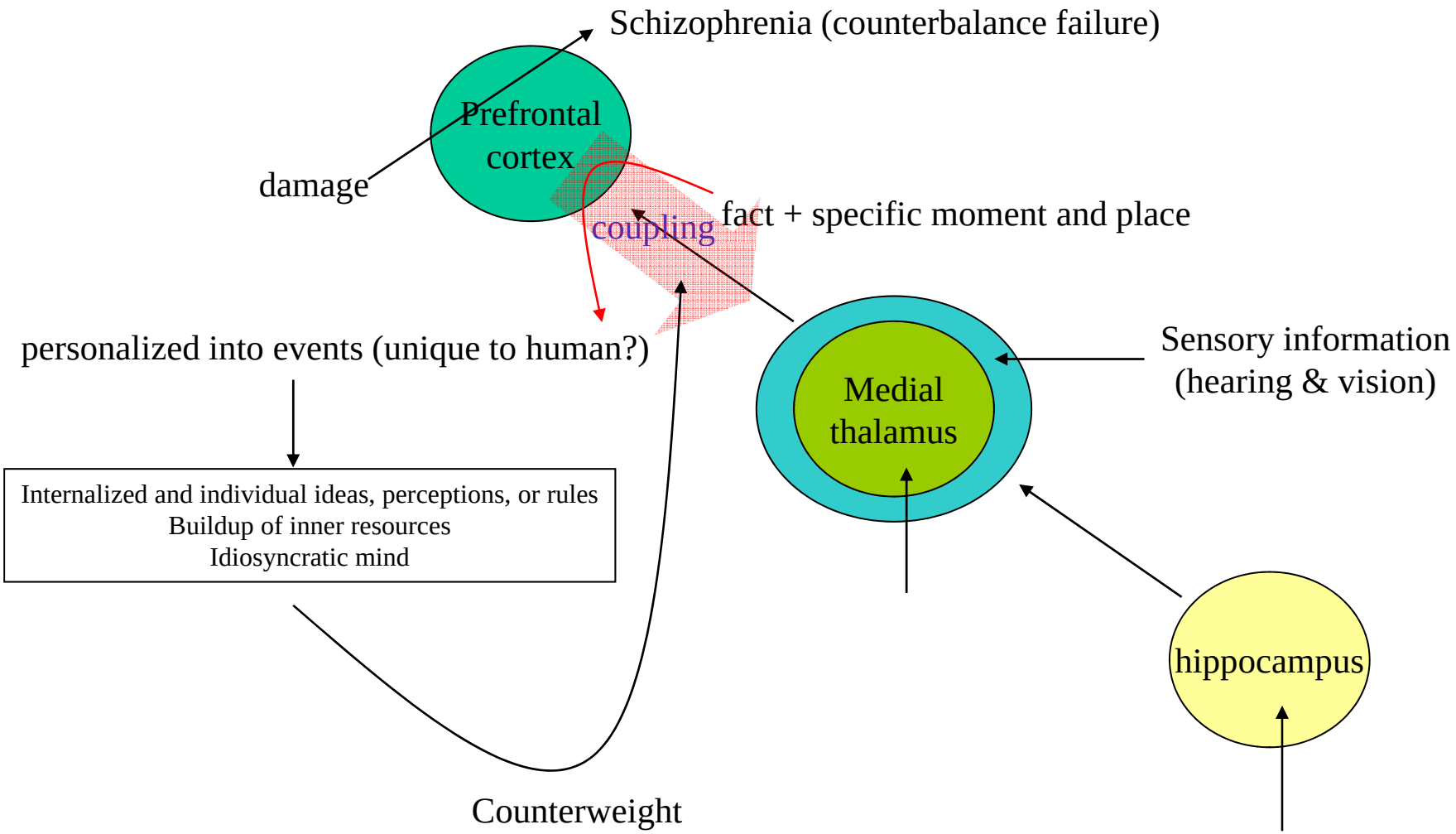
Cortex





Events: unique & personal
Facts: generic & free of time and space frames of reference

Schizophrenia: counterbalance failure?



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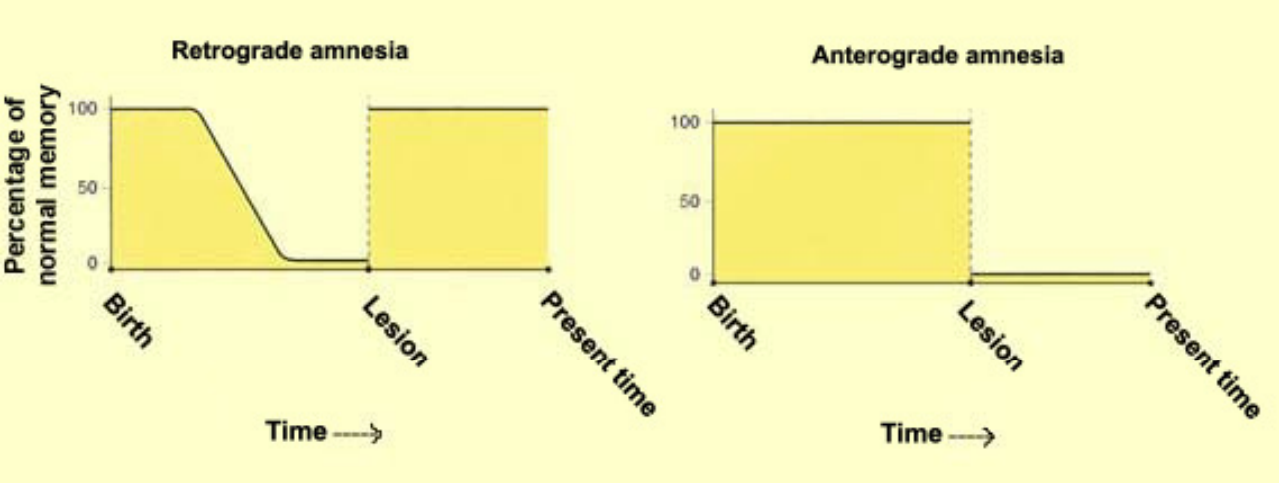
Amnesia

Anterograde amnesia (진행성 기억상실): everything that happened since his surgery

Retrograde amnesia (역행성 기억상실): damage in large brain area

loss of memory for everything that happened before being taken into the hospital, and even before the onset of the illness



Amnesia

- Types:
  - Retrograde: cannot remember old memories
  - Anterograde: cannot form new episodic memories
- Retrograde amnesia is more rare
- Sources
  - Blow to head, Concussion
  - Korsakoff syndrome (severe vit. B1 deficiency)
  - Alzheimer's
  - Damage to hippocampus, thalamic structures
  - ECT (electroconvulsive shock therapy)
  - Midazolam: artifically induced amnesia

Anterograde Amnesia

- Inability to acquire new information (think of "memento")
- Does not affect short-term memory
- Does not affect general knowledge from the past
- But, it is difficult to learn new facts
- Affects memory regardless of modality (visual, auditory, tactile, etc). Spares skilled performance
- Hyper-specific memory for those skills that are learned after onset – learning is expressed only in context in which it was encoded

Retrograde amnesia

- Temporal extent can vary:
  - ECT: months or weeks
  - Korsakoff's, Alzheimer's: years
- Temporal gradient:
  - early memories are better remembered than memories before trauma
  - New memories continue to undergo neurological change: memory consolidation
- Retrograde amnesia often becomes less severe over time
  - Most remote memories are likely to return first
- Does not affect overlearned information (e.g. skills)

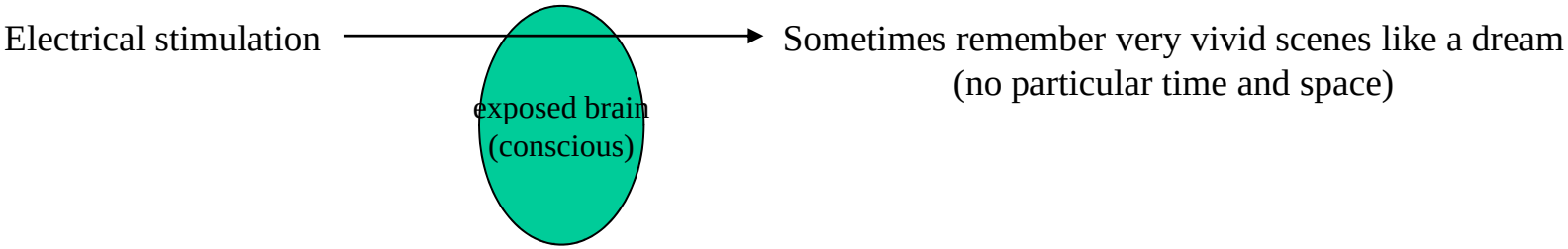
How memory is stored in brain?

Karl Lashley

Removal of rat cortex area: the more the worse
The entire cortex plays an important role in the storage of memory

Penfield experiment (1881-1976)

No fixed area for a particular memory
Stimulation of different places led to same memory and the vice versa
Probably activated the same circuit



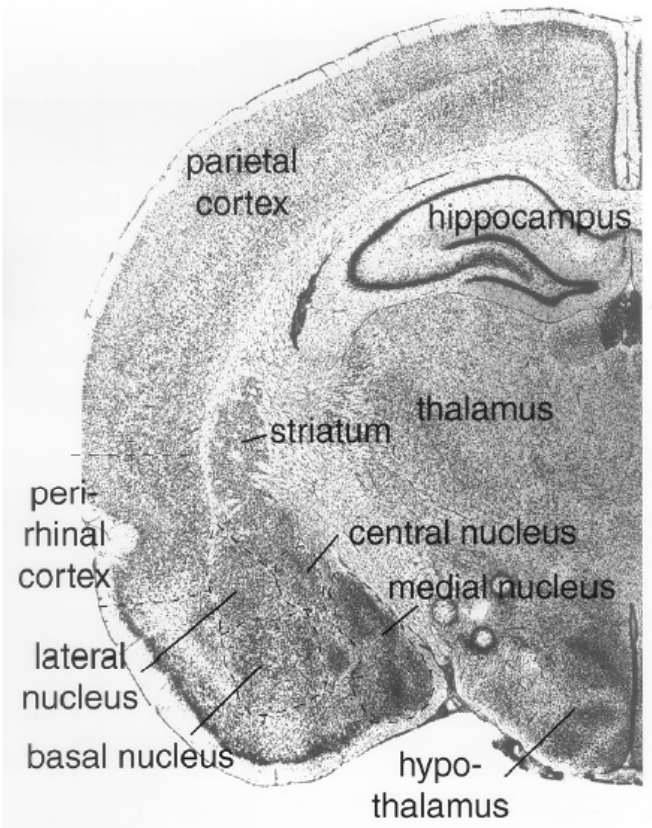
Stephen Rose

The memory would be distributed by different levels of circuitry
No single cell or exclusively committed group of cells

Memory function is distributed

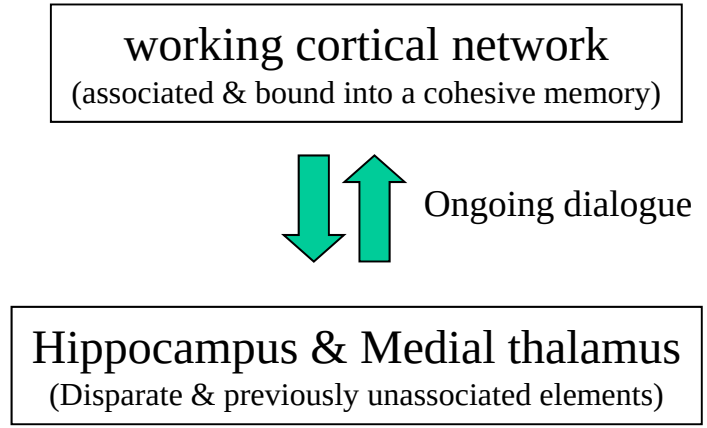
Molecules and Genes for Memory

- Memory function is distributed
- Memories are stored in the connections between neurons: synapse
- Synaptic physiology: rules for plasticity, special channels, molecules and genes.



Consolidation of memory in the cortex: association

Highly transient and dissociable phase of short-term memory
Short-term memory lasts at most for half an hour



Implicit memory (암묵적 기억)

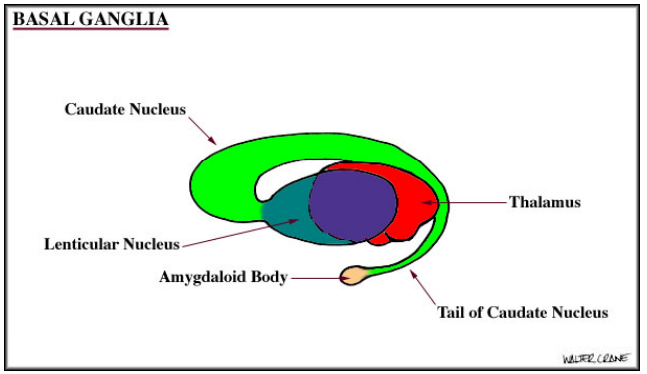
Habit & Skill

Basal ganglia: a sequence of movement

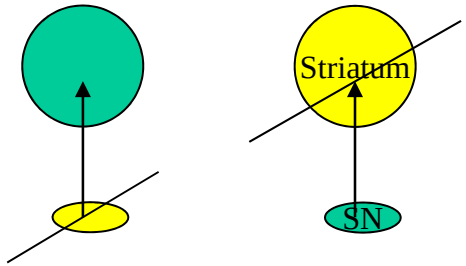
Cerebellum: conditioning involving movement

No direct reciprocal connection to cortex

Without attention & conscious effect: probably an autonomous circuit

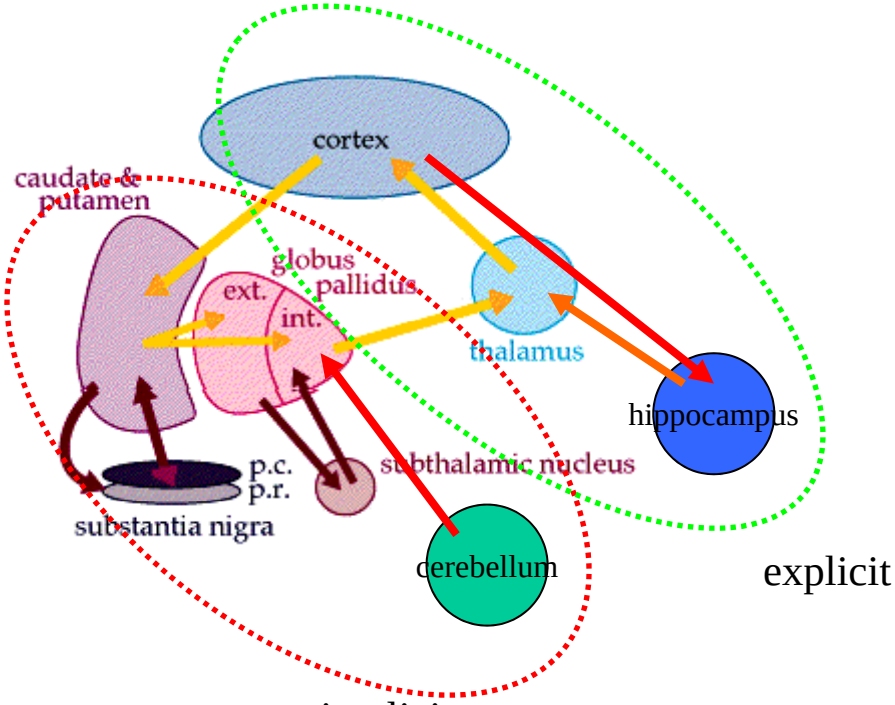


Parkinson's Huntington's



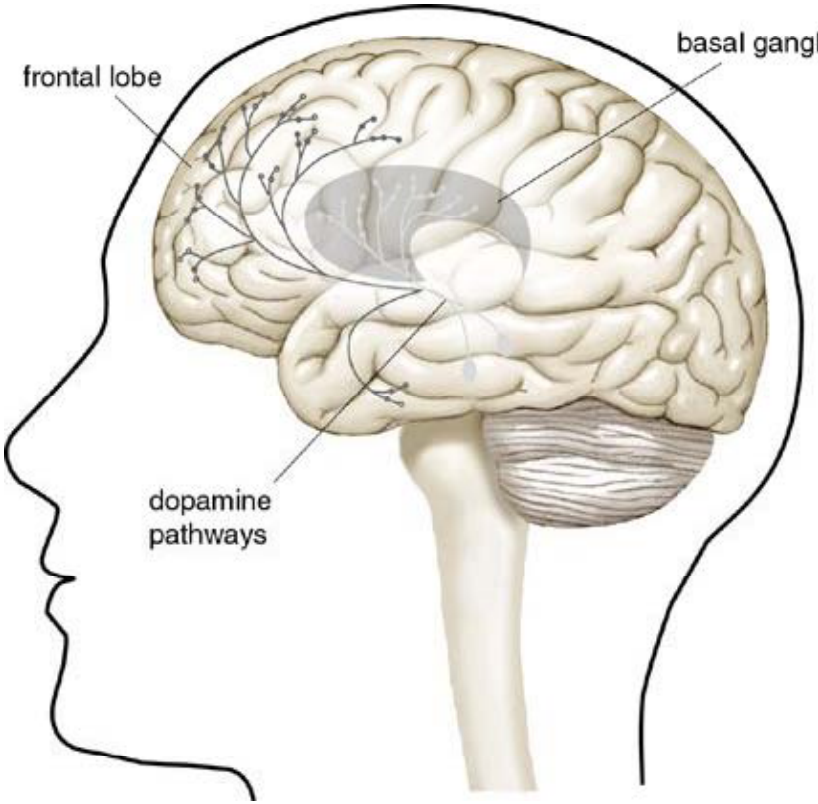
No dialogue
One side reaction

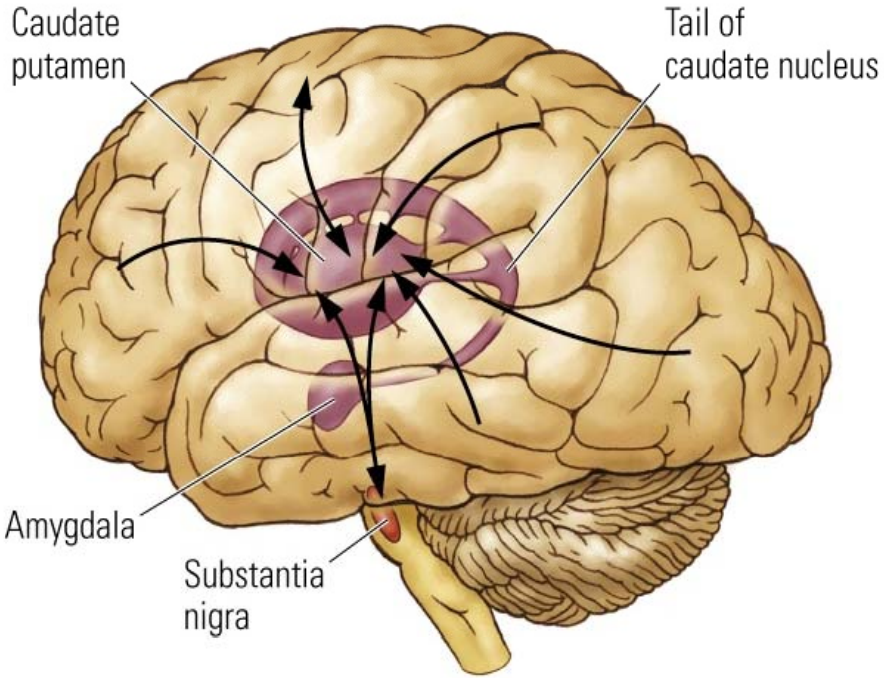
No problem in explicit memory
But implicit memory is impaired



Basal ganglia

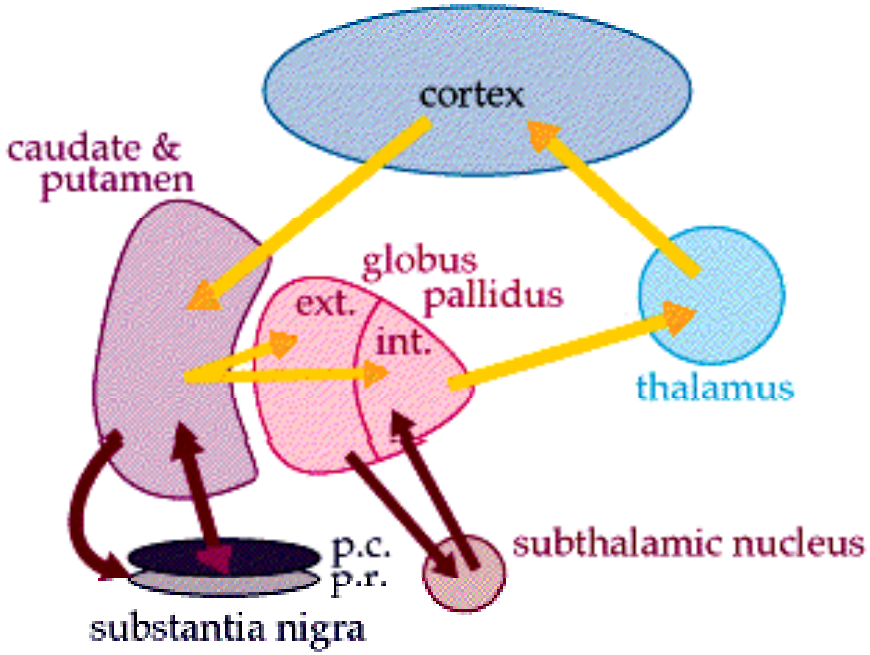
Responsible for ballistic movements (subconscious)
A group of various interconnected brain regions

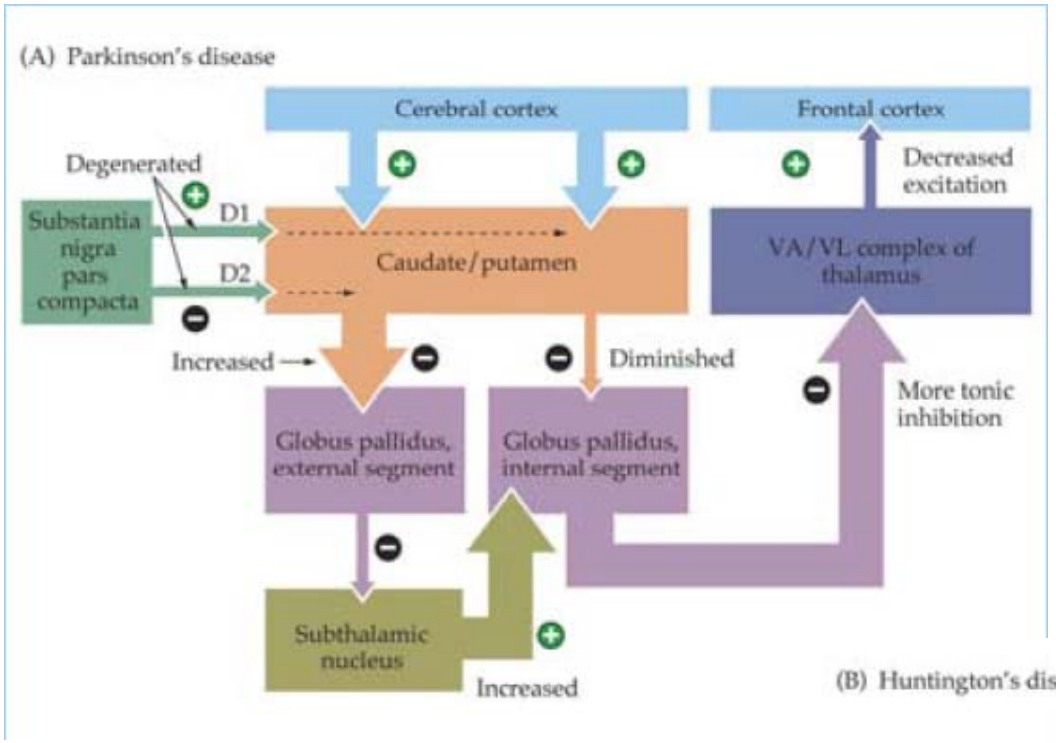


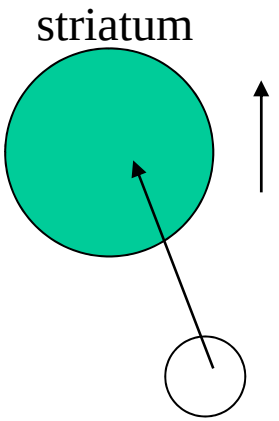


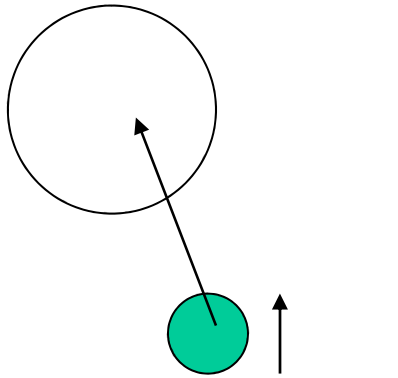
basal ganglia: a collection of nuclei deep to the white matter of cerebral cortex
caudate + putamen + nucleus accumbens + globus pallidus + substantia nigra + subthalamic nucleus + (claustrum + amygdala)
the claustrum and the amygdala, however, do not really deal with movement, nor are they interconnected with the rest of the basal ganglia

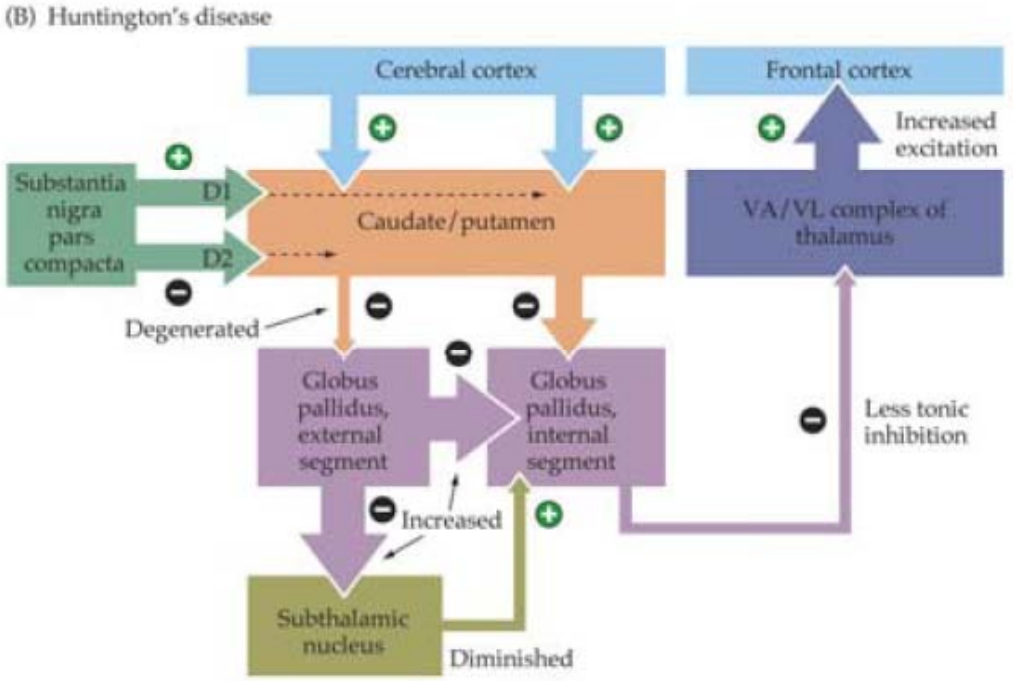
Striatum: caudate + putamen + nucleus accumbens
corpus striatum: striatum + globus pallidus
lenticular nucleus: putamen + globus pallidus




(A) Parkinson's disease
Cerebral cortex
Frontal cortex
Degenerated
Substantia nigra pars compacta
D1
D2
Caudate/putamen
VA/VL complex of thalamus
Decreased excitation
Increased
Diminished
More tonic inhibition
Globus pallidus, external segment
Globus pallidus, internal segment
Subthalamic nucleus
Increased


striatum


substantia nigra


(B) Huntington's disease
Cerebral cortex
Frontal cortex
Increased excitation
Substantia nigra pars compacta
D1
D2
Caudate/putamen
VA/VL complex of thalamus
Degenerated
Globus pallidus, external segment
Globus pallidus, internal segment
Less tonic inhibition
Increased
Subthalamic nucleus
Diminished

Memories are stored in the connections between neurons: synapse

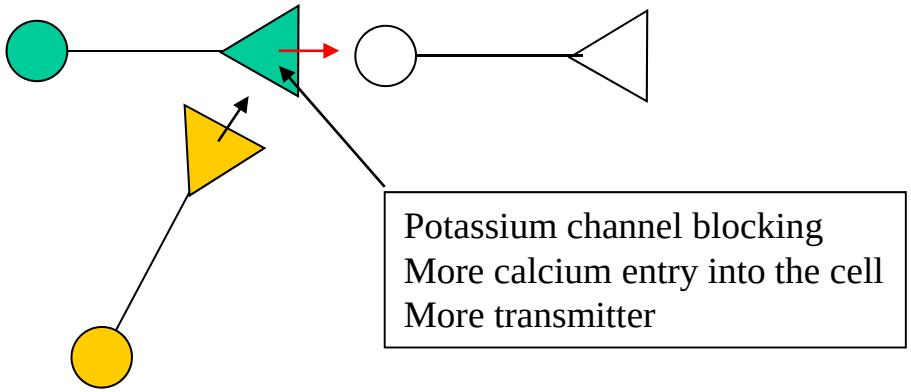
Ramon Y Cajal (1894)

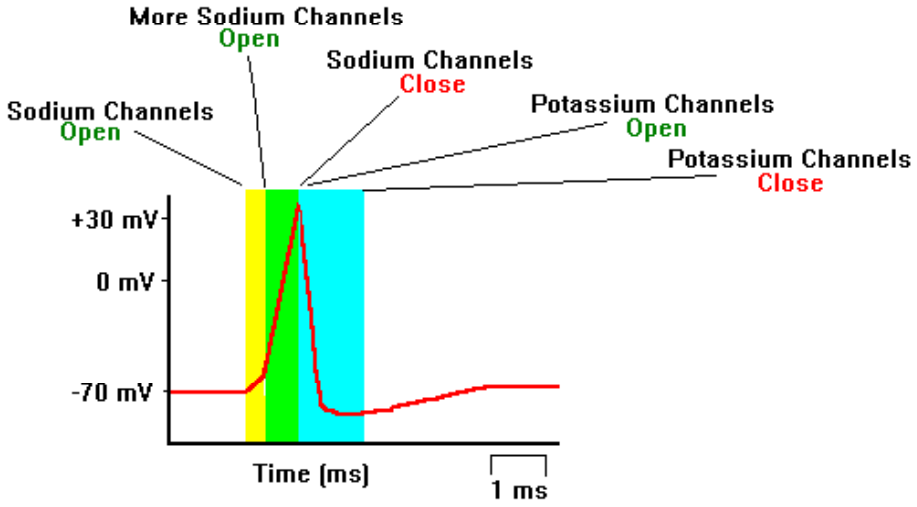
Lord Sherrington (1897)

Donald Hebb (1949)

“When an axon of cell A is near enough to excite cell B and repeatedly or persistently takes part in firing it, some growth process or metabolic change takes place in one or both cells such that A's efficiency, as one of the cells firing B, is increased”

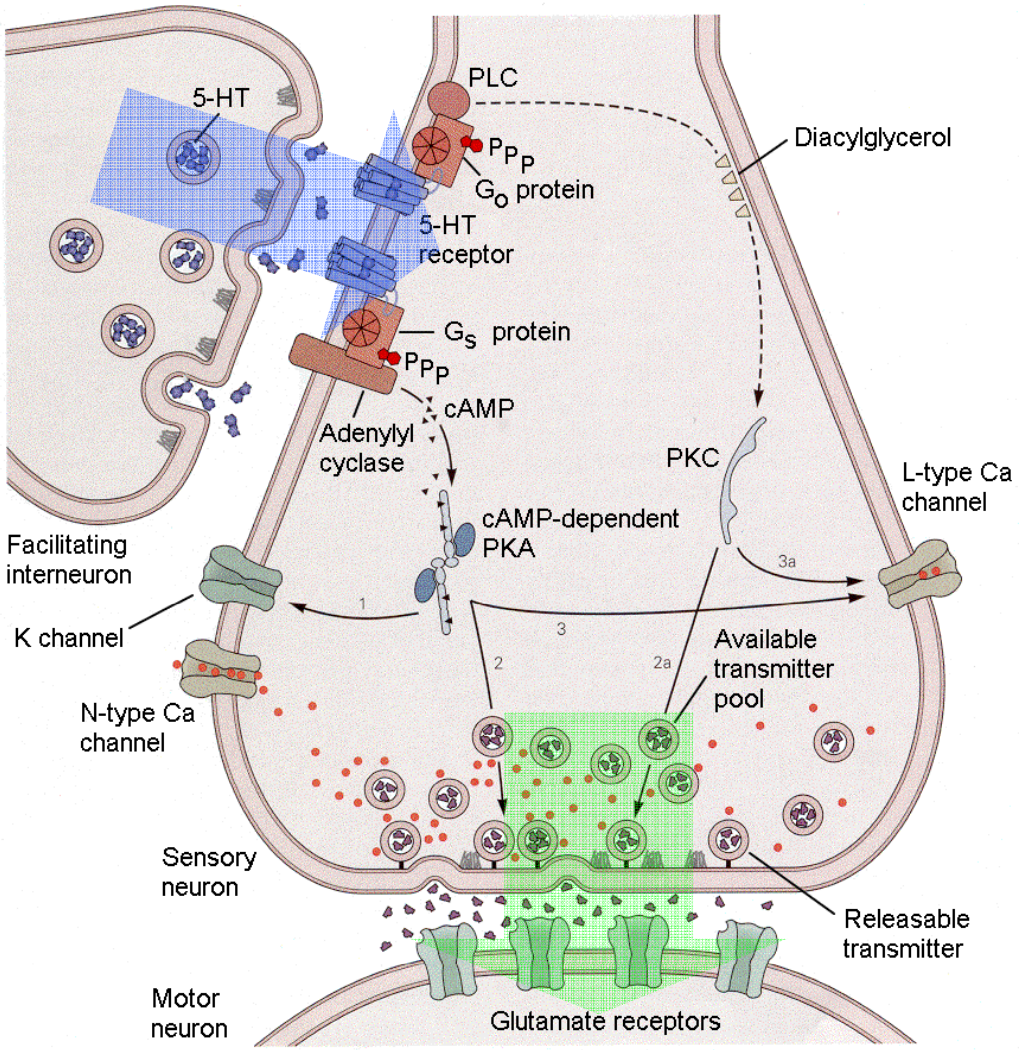
Presynaptic & postsynaptic strengthening in Aplasia



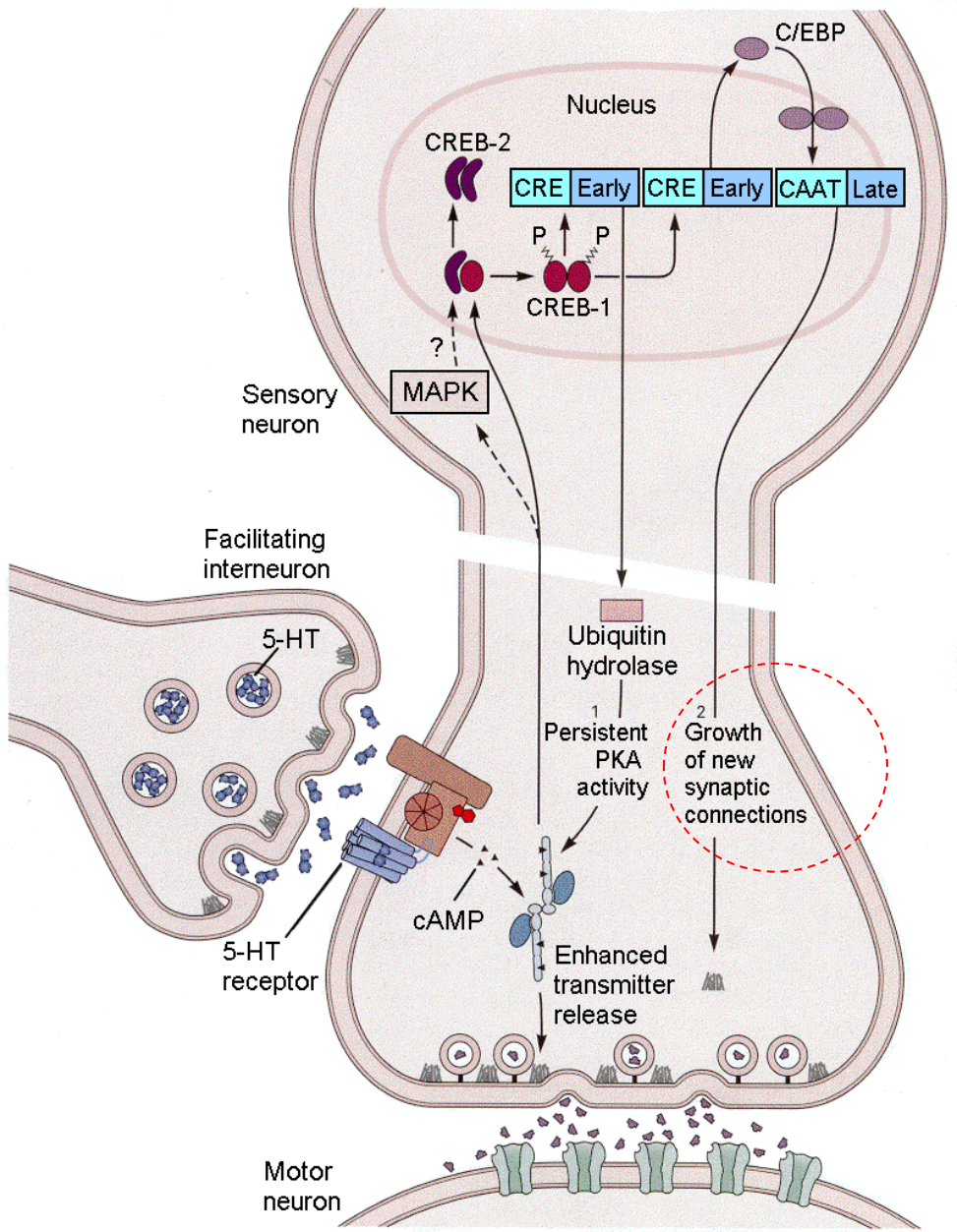


The molecular mechanism of sensitization. The synaptic and chemical events underlying presynaptic facilitation involved in producing sensitization. See text for details. (Kandel, ER, JH Schwartz and TM Jessell (2000) *Principles of Neural Science*. New York: McGraw-Hill.)

5-HT
cAMP
PKA activation
Phosphorylation of K channel
Closing K channel
Increased Ca transport
Increased neurotransmitter release



Long-term storage of implicit memory for sensitization involves changes in protein synthesis that result in formation of new synaptic connections. (Kandel, ER, JH Schwartz and TM Jessell (2000) *Principles of Neural Science*. New York: McGraw-Hill.)



Long-term memory
Permanent changes inside the targeting cell

Hebb rule:

The hypothesis proposed by Donald Hebb that the cellular basis of learning involves strengthening of a synapse that is repeatedly active when the postsynaptic neuron fires.

“Neurons that fire together get wired together.”

What permanent changes?

Genes, proteins, cellular responses
(receptor gene, receptor, increased transport)
Connections (synaptic contacts)
The more experiences, the more connections
Two important proteins: cell adhesion molecules (CAM), growth-associated protein (GAP-43)
CAM: sugar incorporation is important

GAP-43: high expression during exon growth & activated during LTP

Memory improvement: by making more associations in any kinds

Increase of Dendritic Spines in animals housing in a Complex Environment

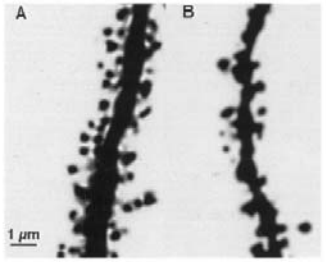
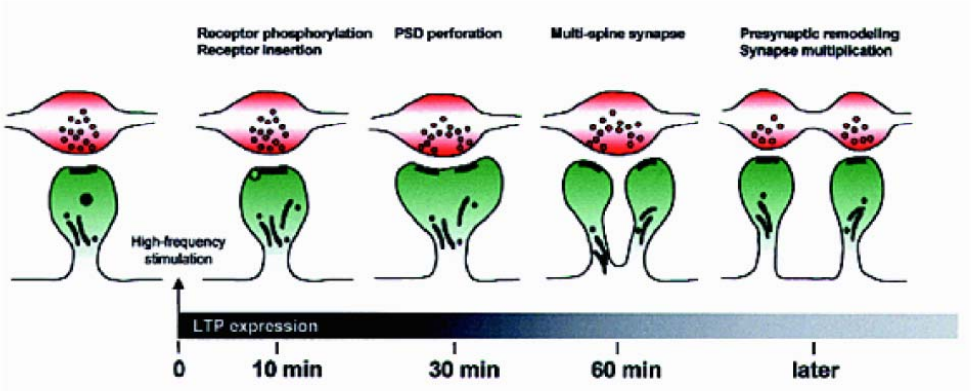


Figure 2. Examples of basal dendritic segments from CA1 pyramidal cells in a rat trained in the complex environment (*A*) and in an isolated rat (*B*). The spine densities for these two segments were 2.71 and 1.75 spines per micrometer, respectively. Spine densities in isolated rats were usually < 2.0 spines per micrometer and never exceeded 2.4 spines per micrometer. Reprinted with permission from [56]: © (1994) National Academy of Sciences, USA.

Moser et al. PNAS 1994

Strengthening of Synapse at different time-scales



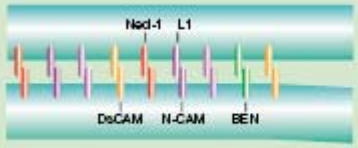
Cell Adhesion Molecules in the CNS

Toshiaki Sakisaka and Yoshimi Takai

Journal of Cell Science
jcs.biologists.org

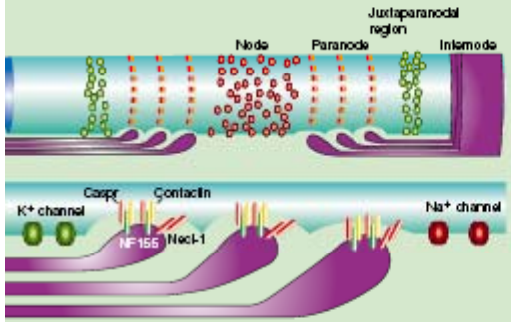
Axon-axon contacts

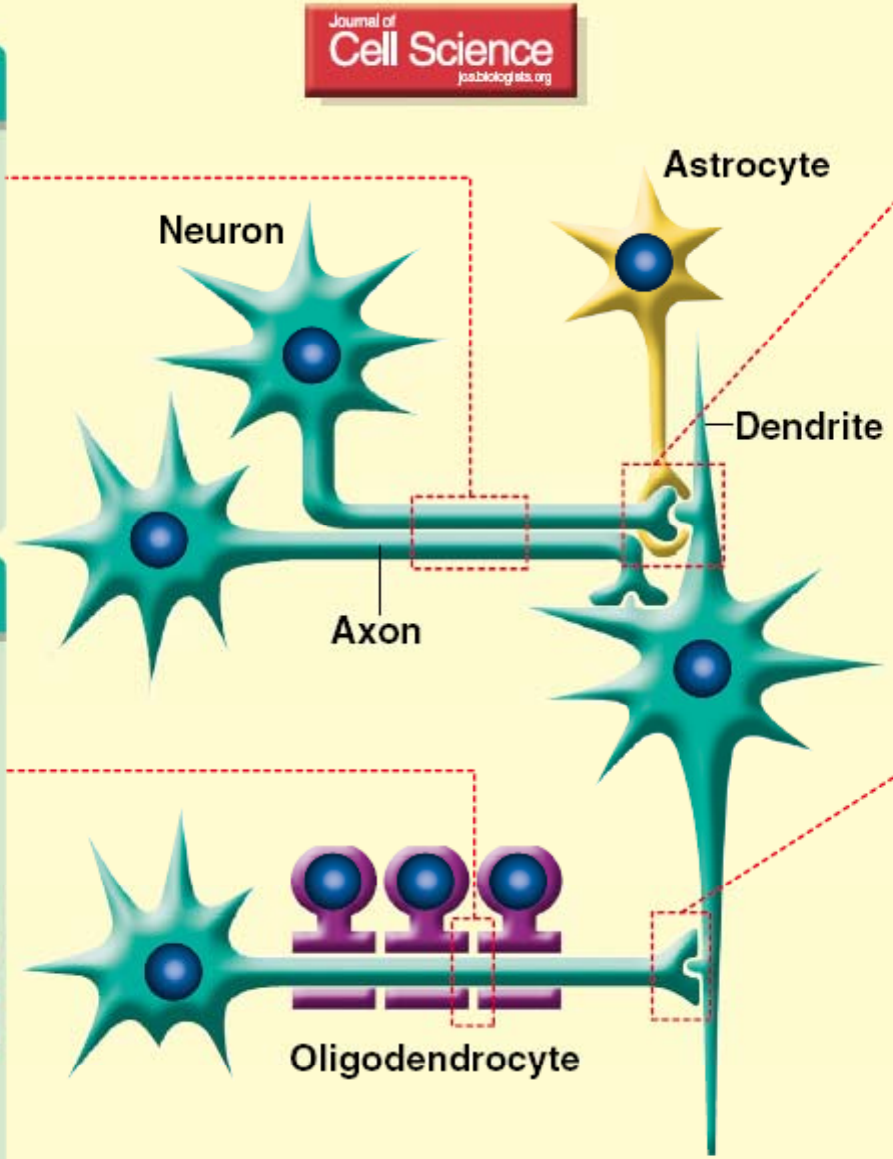
L1
N-CAM
BEN/DM-GRASP
DsCAM
Necl-1



Paranodal junctions

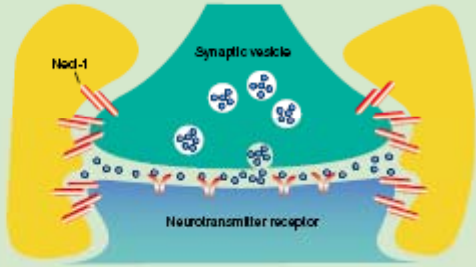
Contactin
Caspr
NF155
Necl-1





Axon-astrocyte contacts

Necl-1



Synapses

Cadherins	N-CAM
Nectin-1/-3	Neuroligin
Neurexin	SYG-1/SYG-2
Protocadherins	Sidekick
Eph/ephrin	L1