Bi/CNS/NB 150: Neuroscience

Lecture

Friday, November 13, 2015

Learning & Memory I

1

We emphasize these points from Kandel in Bi/CNS 150

Read			Lecture
Ch. 65,66,67	Learning & Memory I	**Overview and Declarative Memory** There are multiple memory systems: declarative and nondeclarative There are stages of memory: encoding, consolidation, retrieval There are multiple physiological mechanisms implementing memory There are specific brain systems for different kinds of memory	Nov. 13
Ch. 65,66,67	Learning & Memory II	**Synaptic Plasticity** There are short-term and long-term molecular mechanisms Long-term mechanisms require gene transcription Long-term mechanisms consist also of ultrastructural changes Spike timing-dependent plasticity is the algorithm for learning Different kinds of glutamate receptor participate in learning	Nov. 16
Ch. 65,66,67	Learning & Memory III	Nondeclarative memory and modulation There are many kinds of nondeclarative memory Pavlovian and Instrumental learning are two major kinds The amygdala is necessary for Pavlovian fear conditioning Emotional events are modulated at encoding and consolidation	Nov. 18

Today: what is memory

Types of memory (declarative, nondeclarative)
Stages of memory (encoding, consolidation, retrieval)
Types of declarative memory
Brain systems for declarative memory

Monday: Cellular basis of memory

Wednesday: Nondeclarative memory/modulation

Some core puzzles about memory

How are changes encoded into the brain (a memory "trace" or "engram")?

How are memories stable in the face of a continuously changing brain?

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There are innate/genetic constraints on WHAT classes of stimuli can be learned and on HOW we learn about them.

e.g.: Language

What is memory?

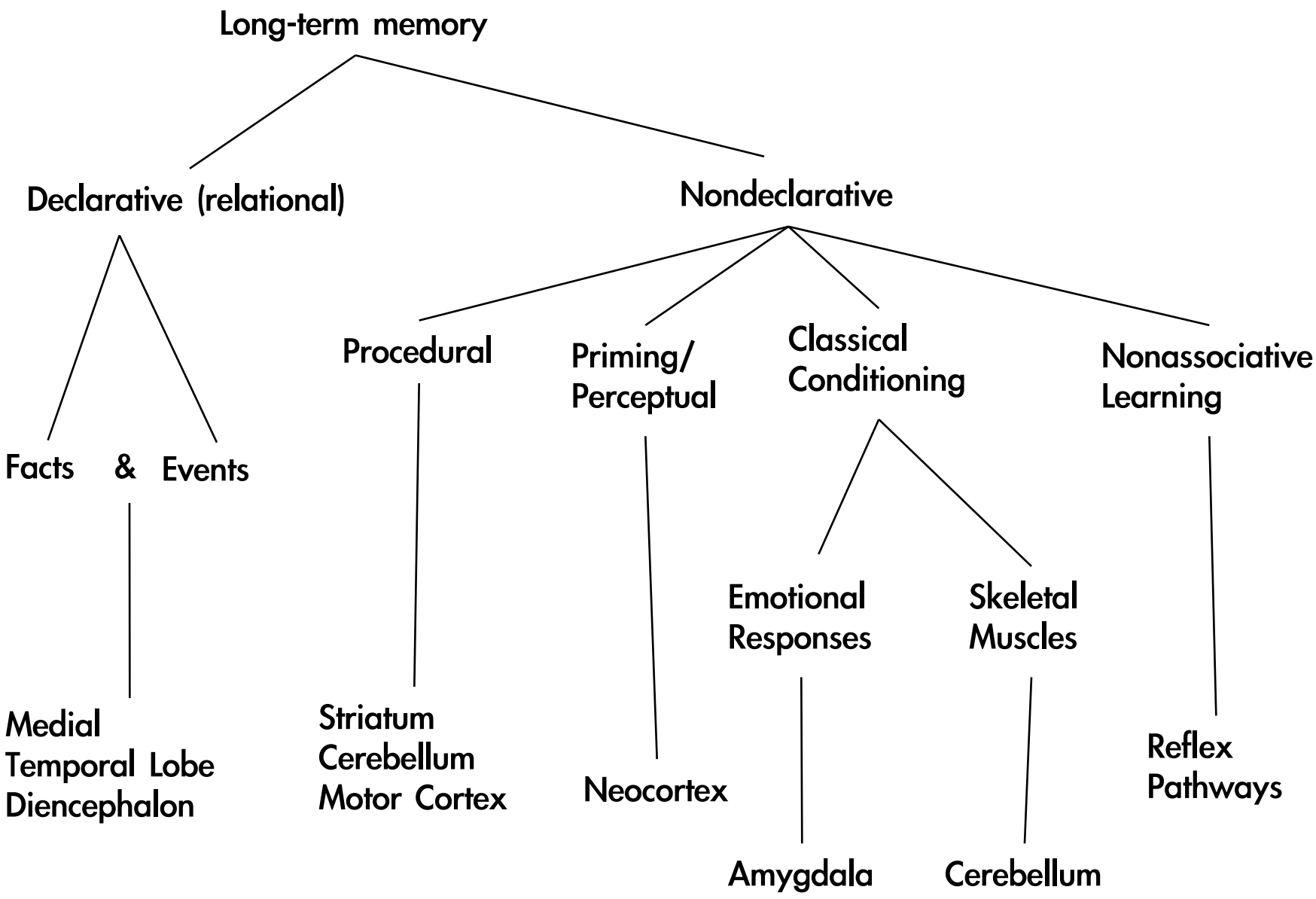
What is remembering/ recollection?

In psychology, **memory** is an organism's ability to store, retain, and recall information and experiences
--Wikipedia

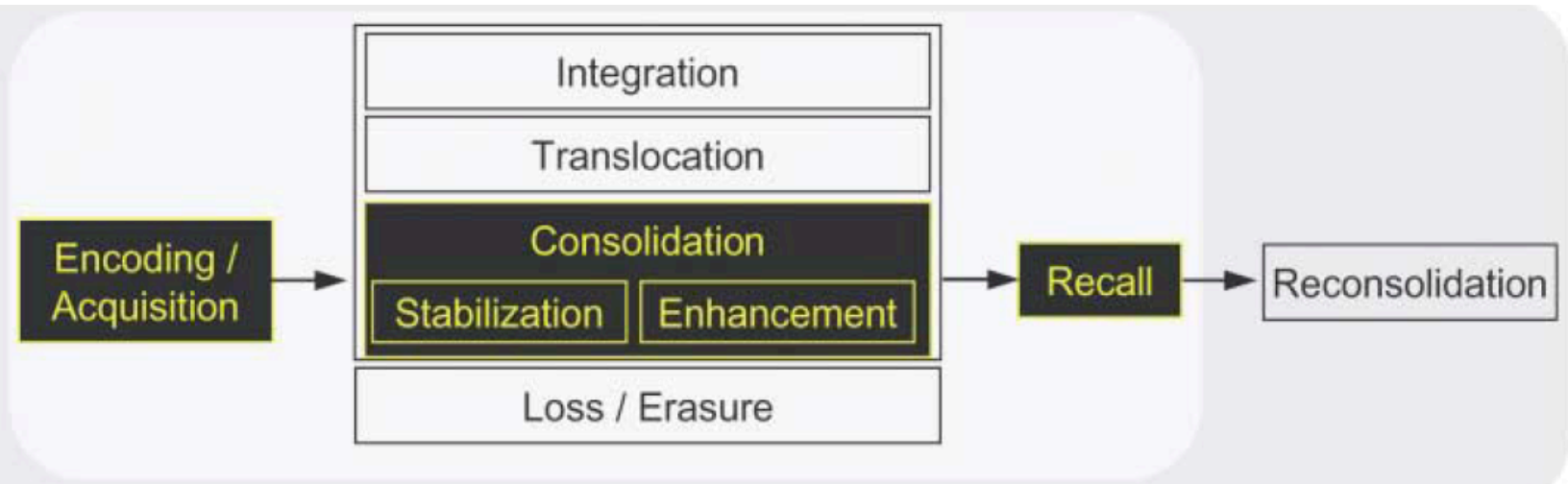
"It took biological evolution a long time to build a time machine in the brain, and it has managed to do it only once, but the consequences have been enormous: by virtue of their mental control over time, human beings now wield powers on earth that in many ways rival and even exceed those of nature itself. It is difficult to imagine a marvel of nature greater than that."

Endel Tulving (2002)

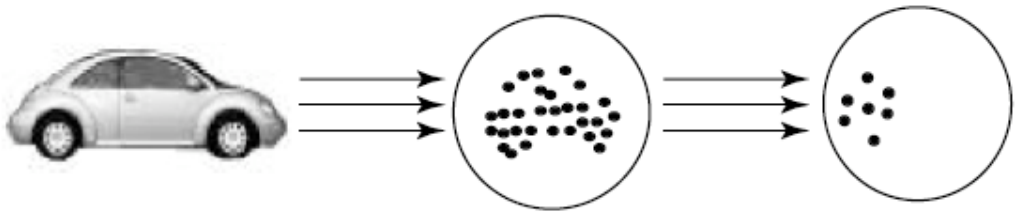
Organization of Memory



Temporal components of memory



Capture



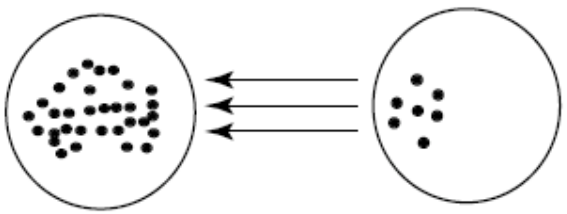
Physical stimulus

Information travels up sensory channels

Neurons in feature maps fire to produce a sensory representation

Conjunctive neurons in an association area capture the sensory representation

Re-enactment / simulation



Neurons in feature maps fire to reenact the earlier sensory representation

Conjunctive neurons in the association area fire to partially reactivate the earlier sensory representation

- Recognition: retrieval triggered by the stimulus that is recognized
- Recall: retrieval triggered spontaneously or by an unrelated cue

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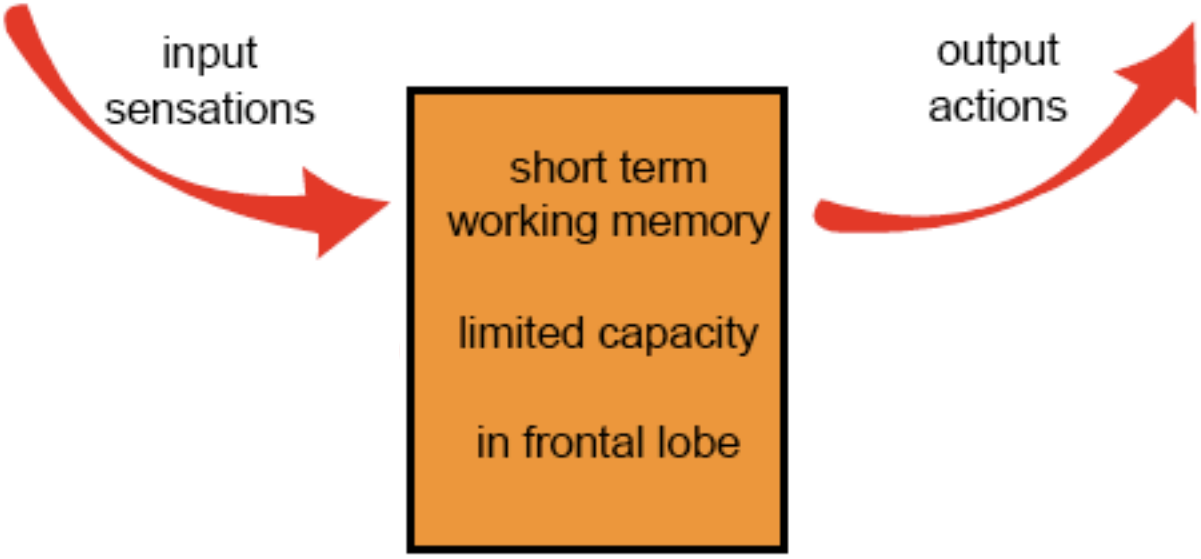
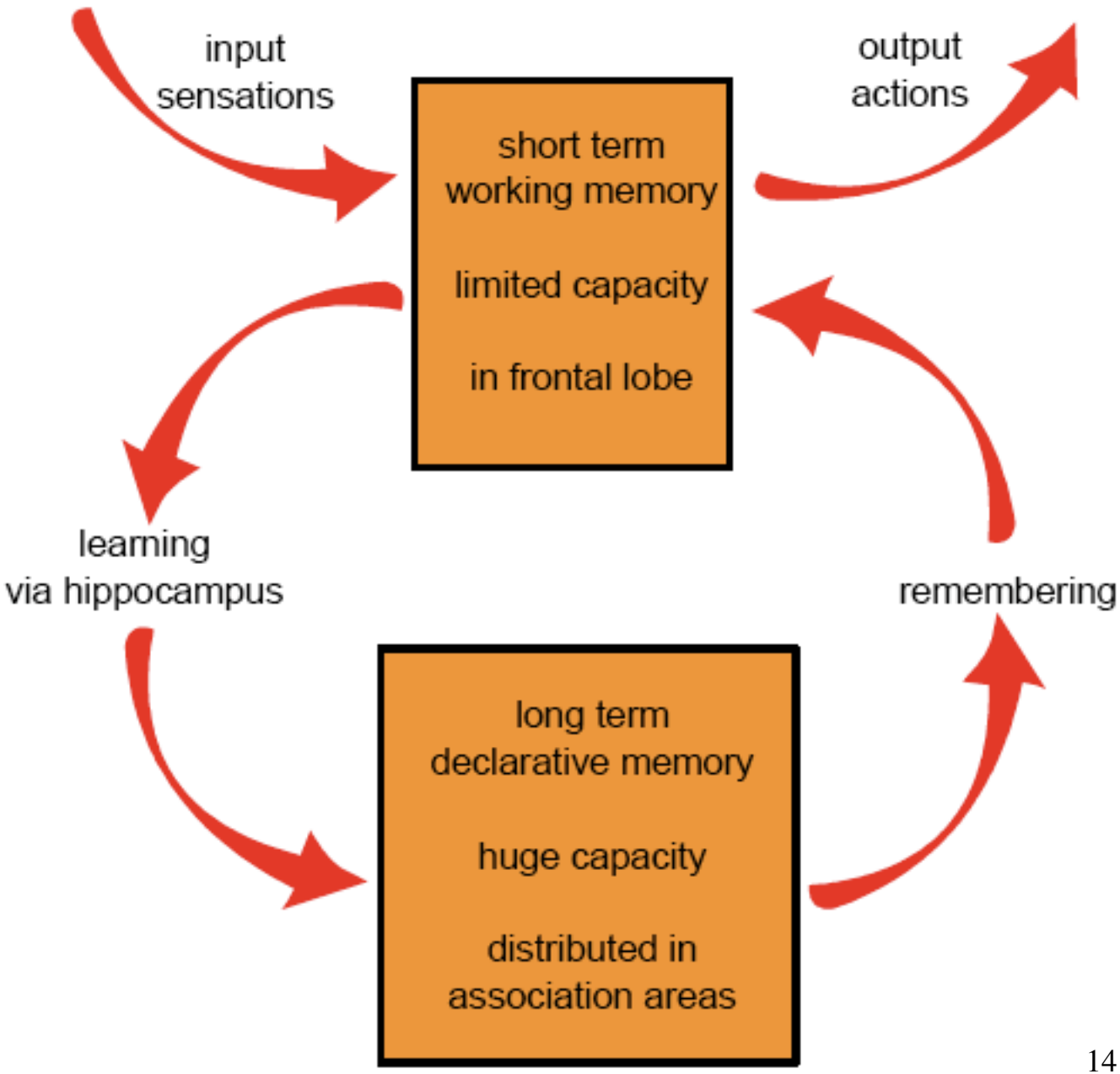
Terms to Know

- *Encoding*: learning new information
- *Consolidation*: processes through which memory traces of newly formed information perseverate
- *Retrieval*: recalling or recognizing previously learned information
- *Working Memory*: online processing of information (short-term memory)
- *Retrograde*, *anterograde*: relative to lesion onset


input
sensations
short term
working memory
limited capacity
in frontal lobe
output
actions


input
sensations
output
actions
short term
working memory
limited capacity
in frontal lobe
learning
via hippocampus
remembering
long term
declarative memory
huge capacity
distributed in
association areas

- Iconic memory: very short (1s) sensory memory
- Working memory: 30-40s declarative memory. At least 2 processes have been studied: visuospatial scratchpad and phonological loop.
- Long-term memory: anything longer than working memory.

- NOTE: short-term and long-term also refer to stages of memory consolidation at the molecular level. This is a different distinction.
- Cellular neurobiology: short is independent of gene transcription; long depends on gene transcription, ultrastructural changes.

Short is ephemeral, long is more permanent.

How is memory related to conscious experience?

Iconic Memory → Working Memory → LTM

conscious, ephemeral

conscious, "thinking"

not conscious, but can be made conscious when recollected

working memory is typically about 7 items
(but can be “chunked”)

7 9 2 2 6 1 3 0 2 9 3 5 1 5 6 2 3 4 1

17

The Sternberg memory paradigm: an example of iconic memory

3	5	6	7
4	1	3	3
2	8	1	0

19

What numbers were there?

3	5	6	7
4	1	3	3
2	8	1	0

21

middle row

S.Inoue & T. Matsuza, Current Biology (2007) 17: R1004-R1005

Things that improve memory:

--recency

--attention

--emotion

--repetition

--elaboration

--distinctiveness

--sleep

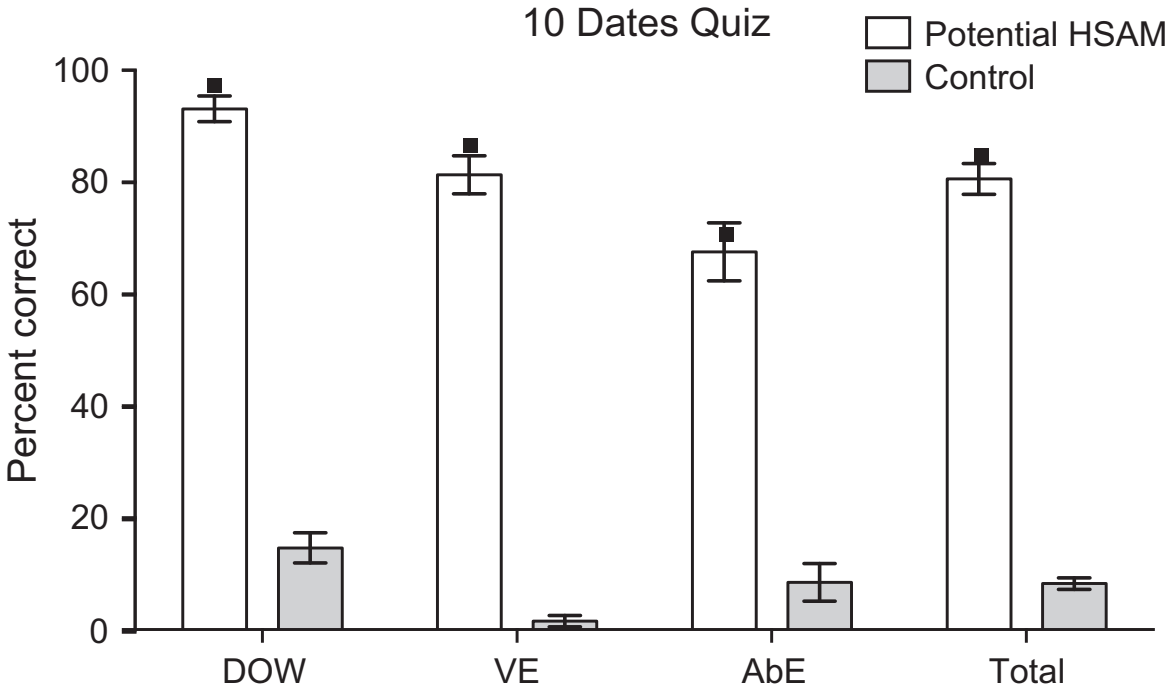


Fig. 2. Performance on the 10 Dates Quiz for individuals who contacted us claiming to have HSAM and scored 50% or higher on the Public Events Quiz (white, $n = 36$) and for age- and sex-matched controls (grey, $n = 13$). The total percentage scored (mean ± standard error of the mean) on all three categories combined (total) along with the percentage scored (mean ± standard error of the mean) on each individual category, day of the week (DOW), verifiable event (VE), and autobiographical event (AbE), are shown. Single data points indicate the average score achieved in each category by the eleven HSAM participants.

LePort et al. (2012). Neurobiology of Learning and memory 98: 78-92.

Things that compromise memory:

--Alzheimer's disease

--Normal aging

--Encephalitis/anoxia

--chronic alcoholism

--benzodiazepines, scopolamine

Brain systems involved in declarative memory:

Medial temporal lobe

Association cortices

Sensory cortices

Basal forebrain

Anterior thalamus

Prefrontal cortex

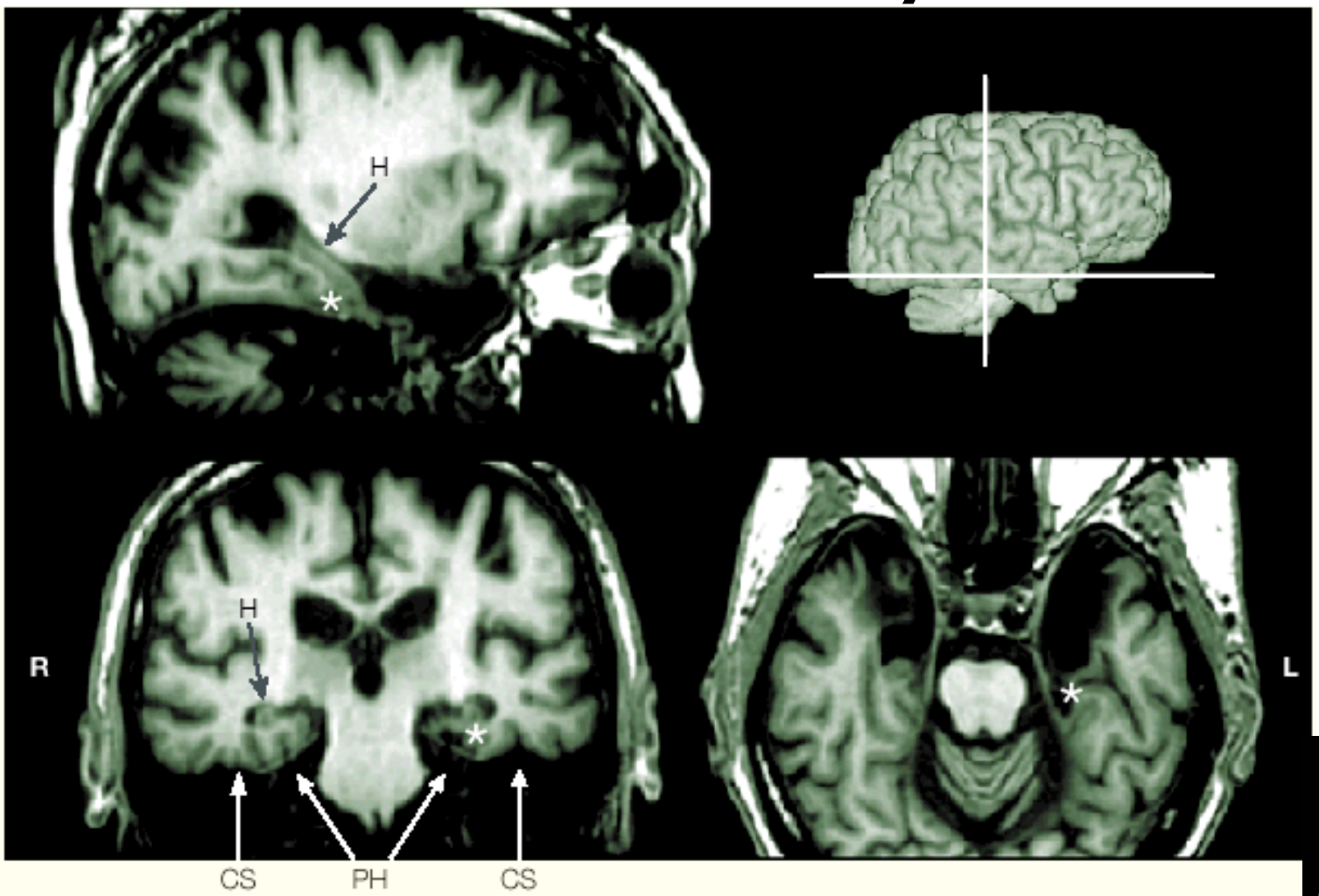
Mammillary bodies

The medial temporal lobe (MTL) and declarative memory

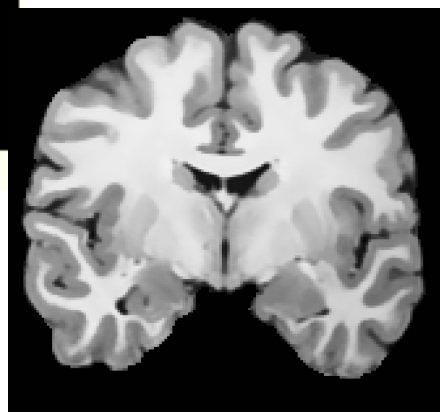
-Prior to 1953, the role of the MTL in memory was relatively unknown

-H.M. changed all that: bilateral temporal lobectomy = complete anterograde amnesia

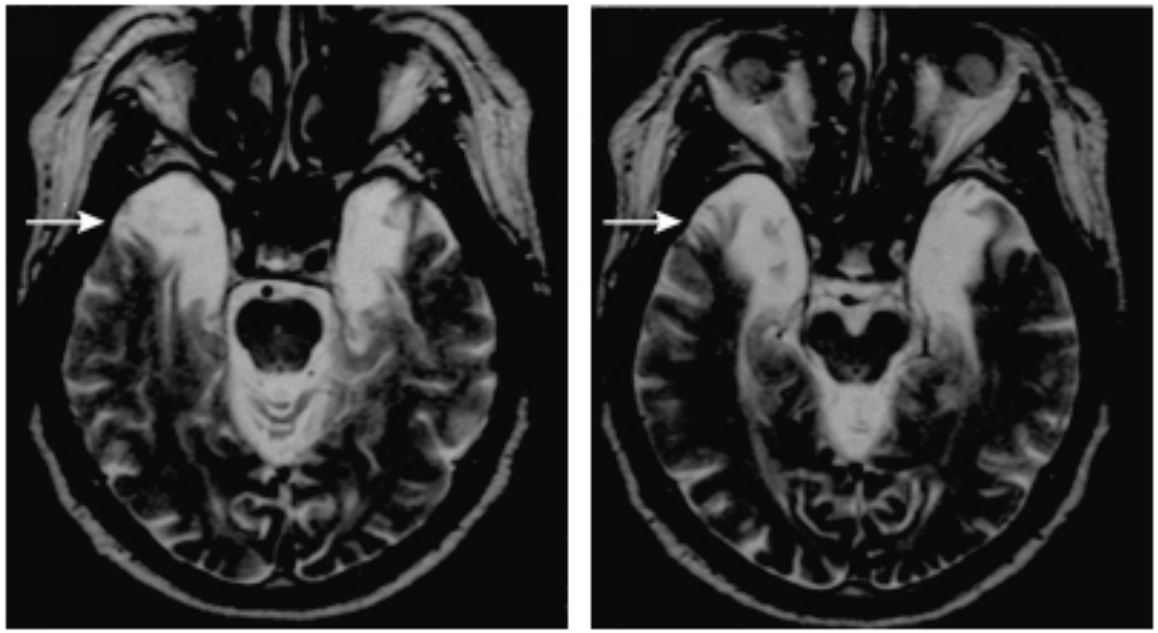
Functional anatomy of amnesia



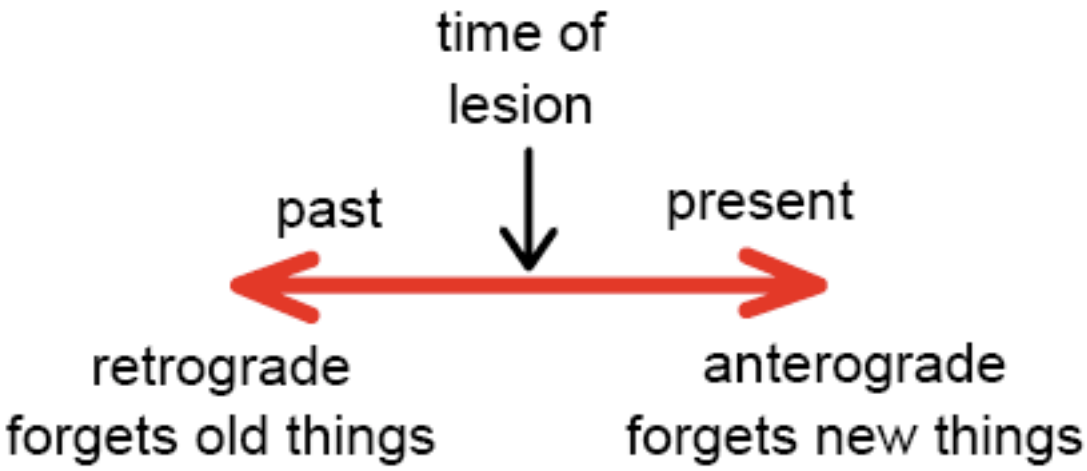
Normal Brain



from Corkin, 2002 Nature Rev. Neurosci. 3: 153-160



Patient H.M.
(post-mortem brain ready to be sliced at UCSD)

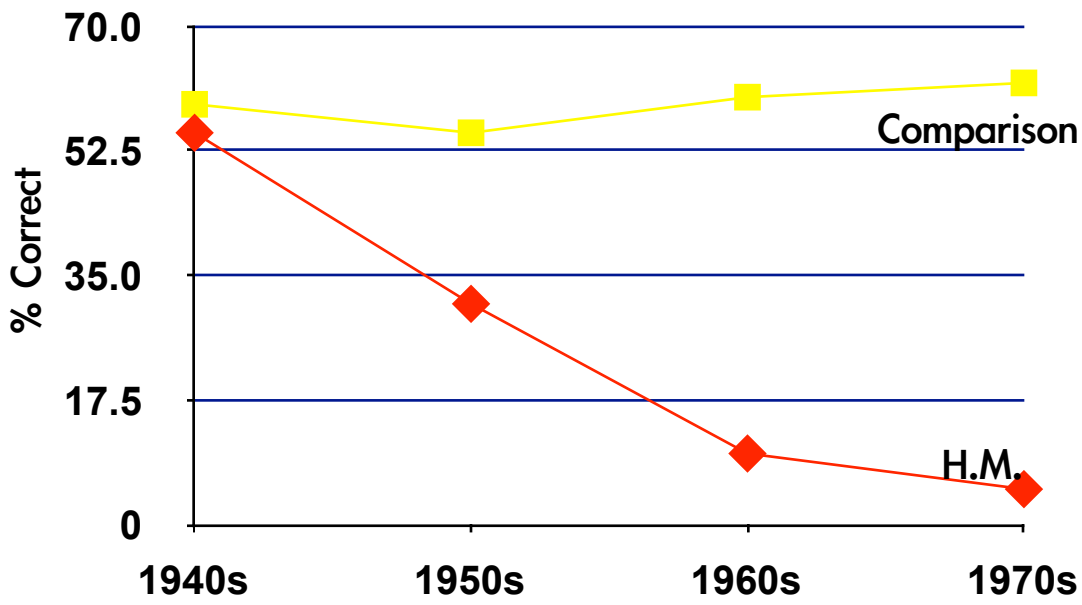


MTL Amnesia:
--complete anterograde
--graded retrograde

H.M.'s retrograde amnesia

-H.M.s RA extends back ~11 years pre-surgery

-Famous Faces performance is normal for 40s, then below normal for 50s, then severely impaired in the 60s & 70s

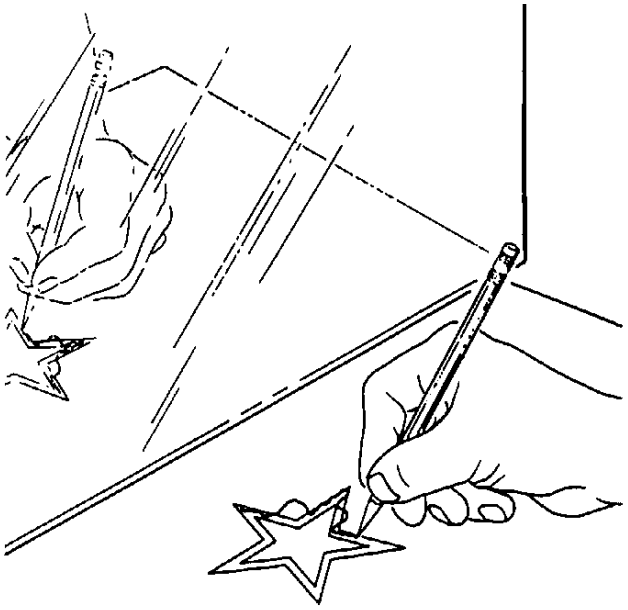


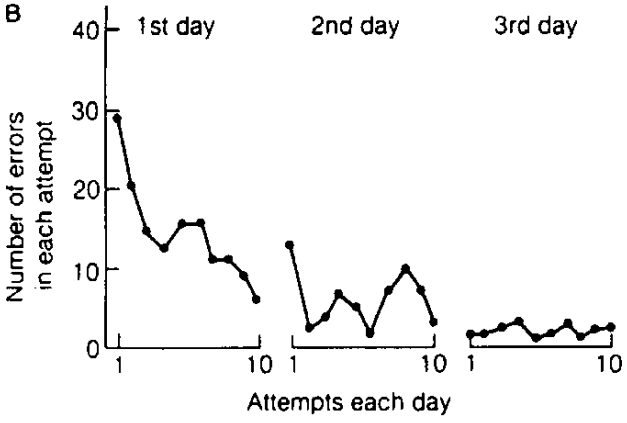
Famous Faces Recognition by Decade

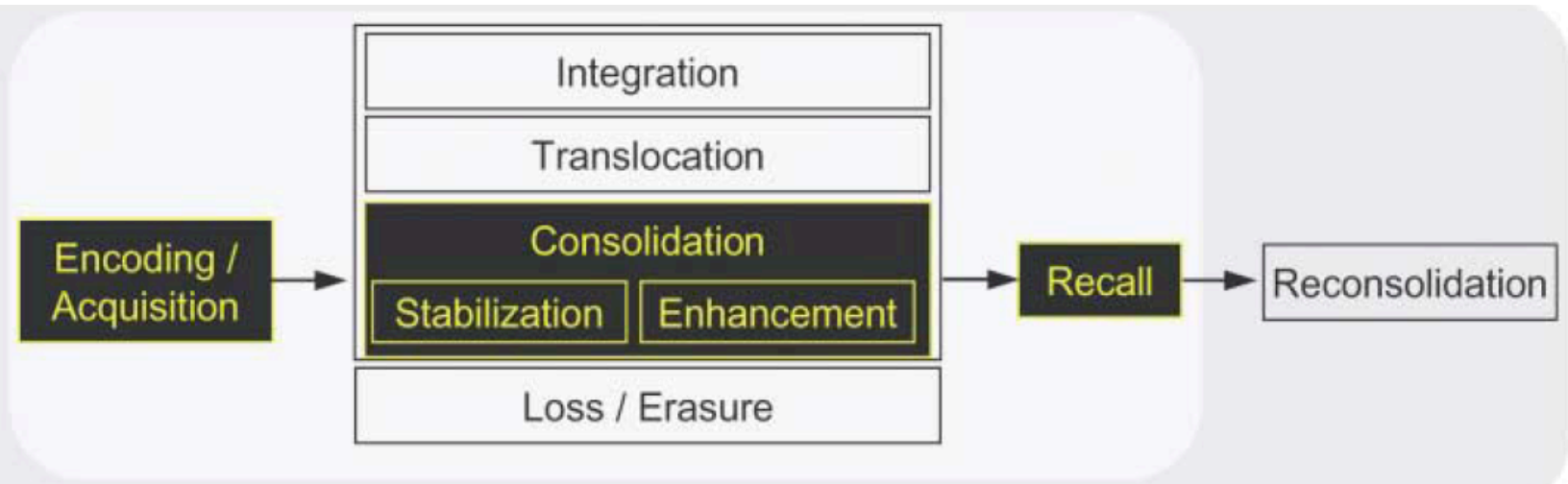
Intact domains of memory in amnesia

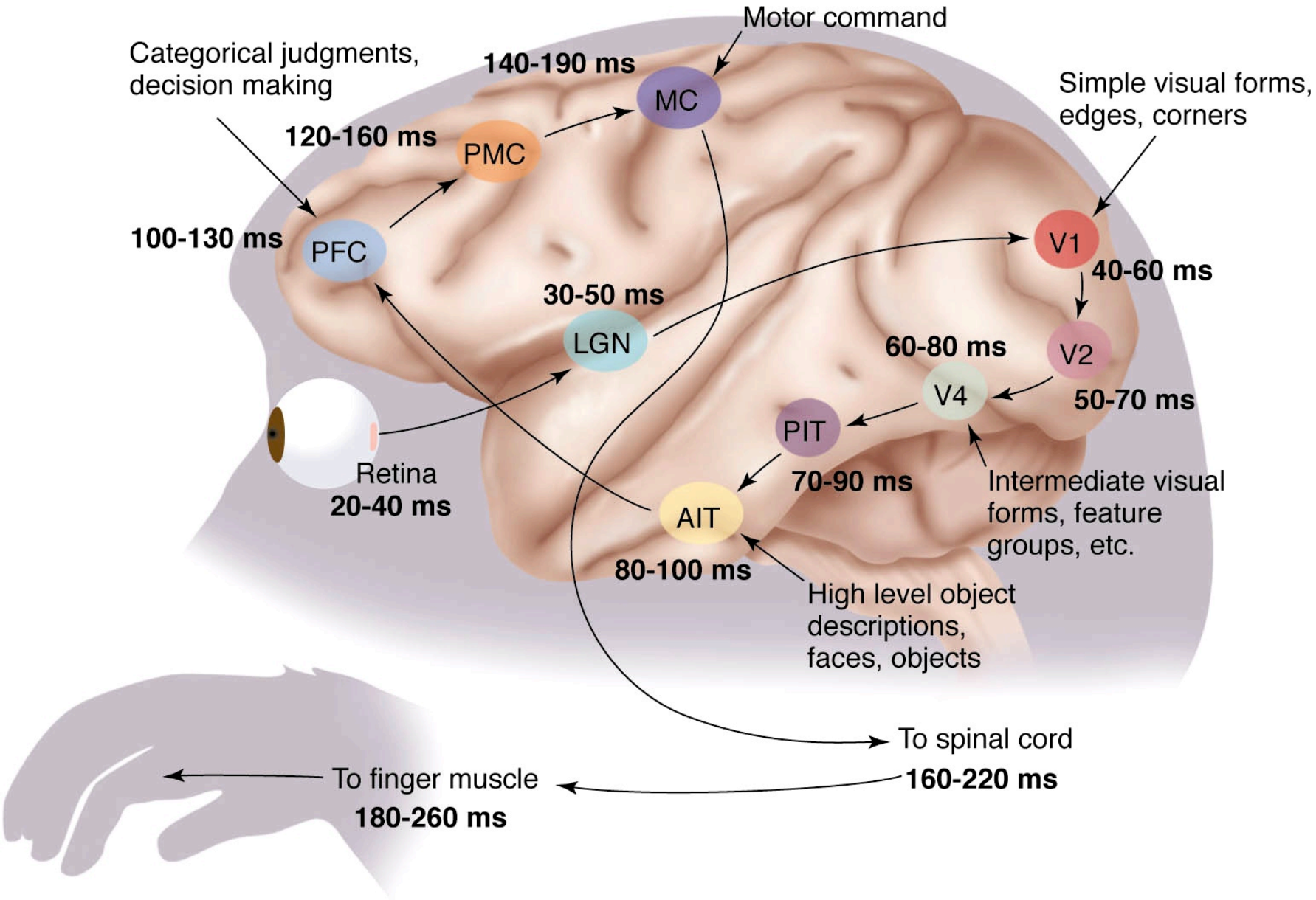
-Working memory: HM's digit span is normal

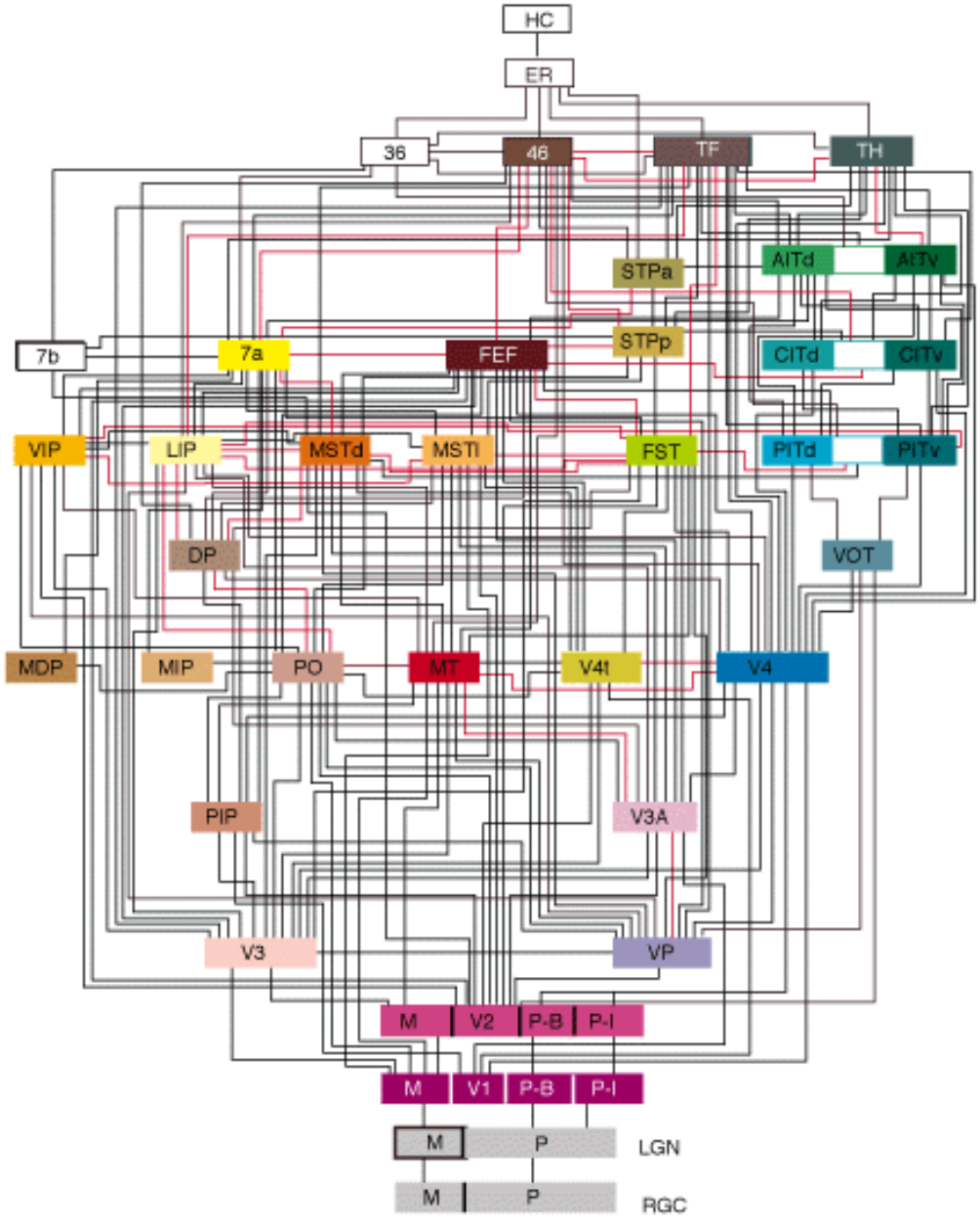
-Skill and Perceptual learning

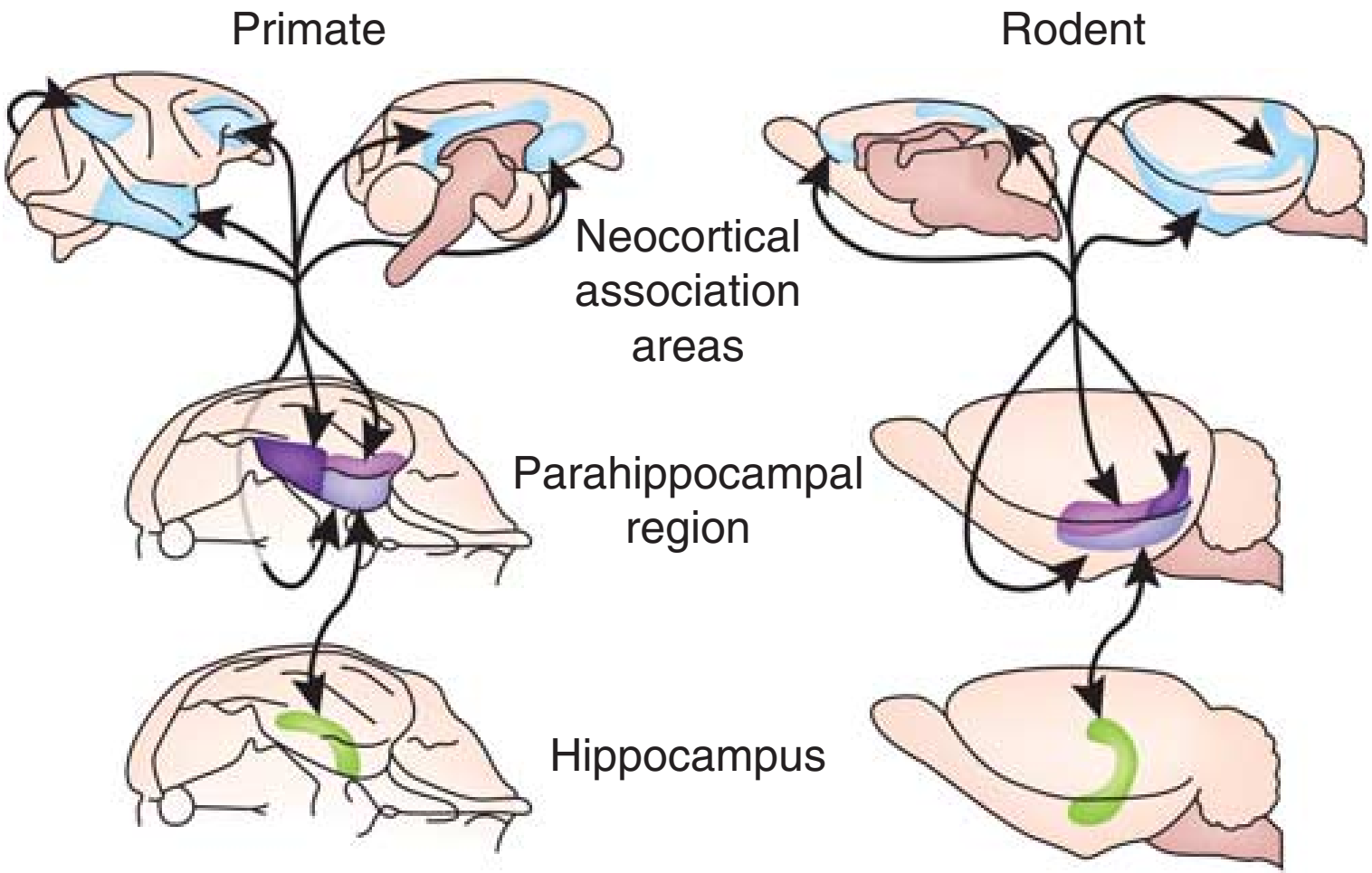


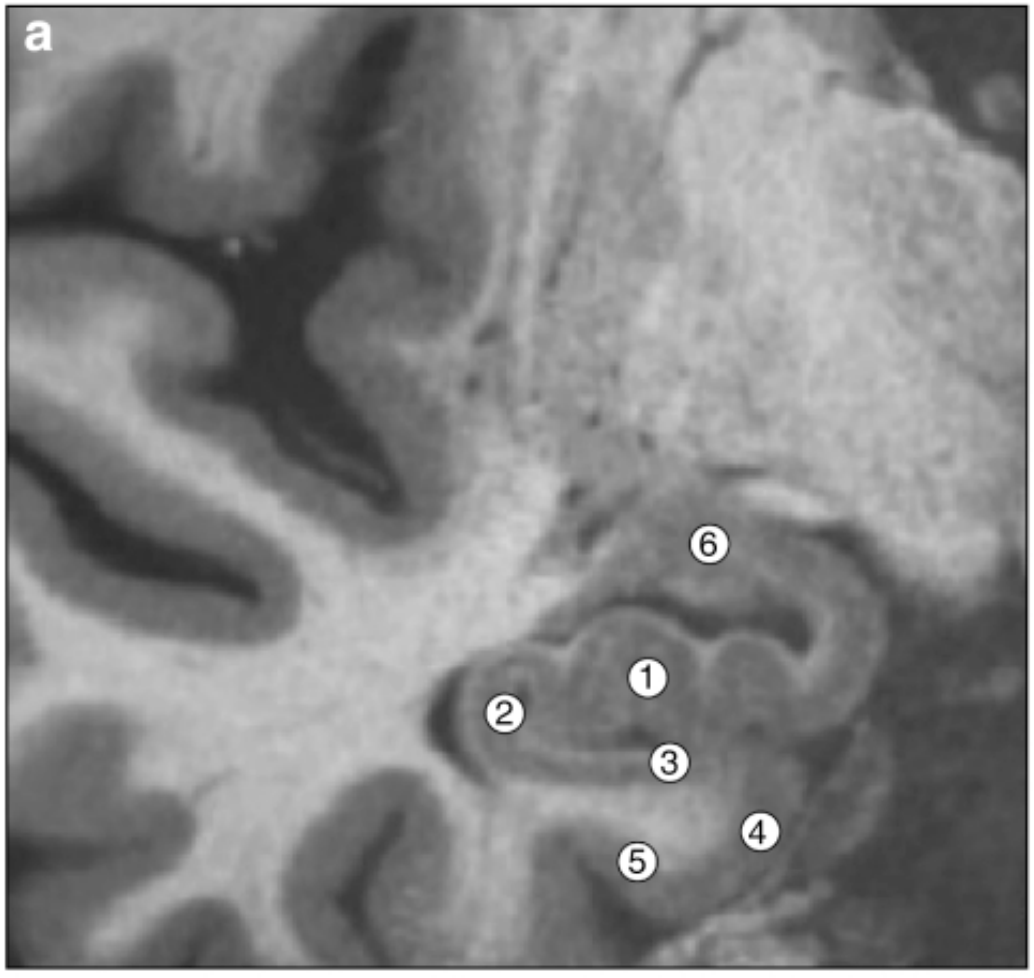



Integration
Translocation
Consolidation
Stabilization
Enhancement
Loss / Erasure
Encoding / Acquisition
Recall
Reconsolidation

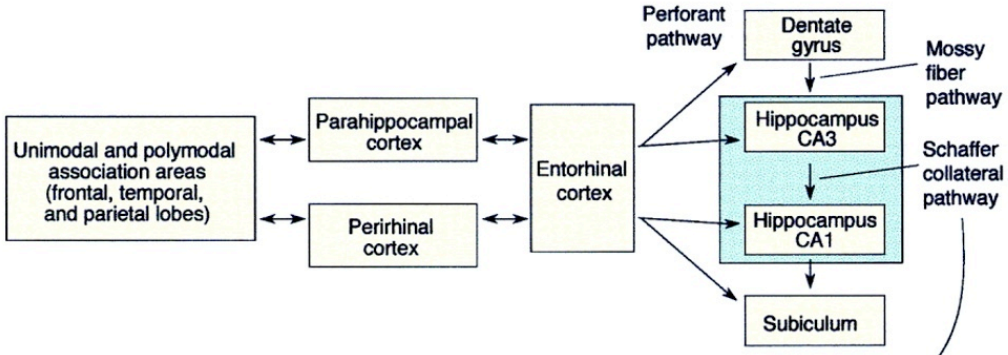

Motor command
Categorical judgments, decision making
140-190 ms
MC
Simple visual forms, edges, corners
120-160 ms
PMC
100-130 ms
PFC
V1
40-60 ms
30-50 ms
LGN
60-80 ms
V2
V4
50-70 ms
PIT
Retina
20-40 ms
70-90 ms
Intermediate visual forms, feature groups, etc.
AIT
80-100 ms
High level object descriptions, faces, objects
To spinal cord
To finger muscle
160-220 ms
180-260 ms


HC
ER
36
46
TF
TH
STPa
AITd
AITv
7b
7a
FEF
STPp
CITd
CITv
VIP
LIP
MSTd
MSTl
FST
PITd
PITv
DP
VOT
MDP
MIP
PO
MT
V4t
V4
PIP
V3A
V3
VP
M
V2
P-B
P-I
M
V1
P-B
P-I
M
P
LGN
M
P
RGC

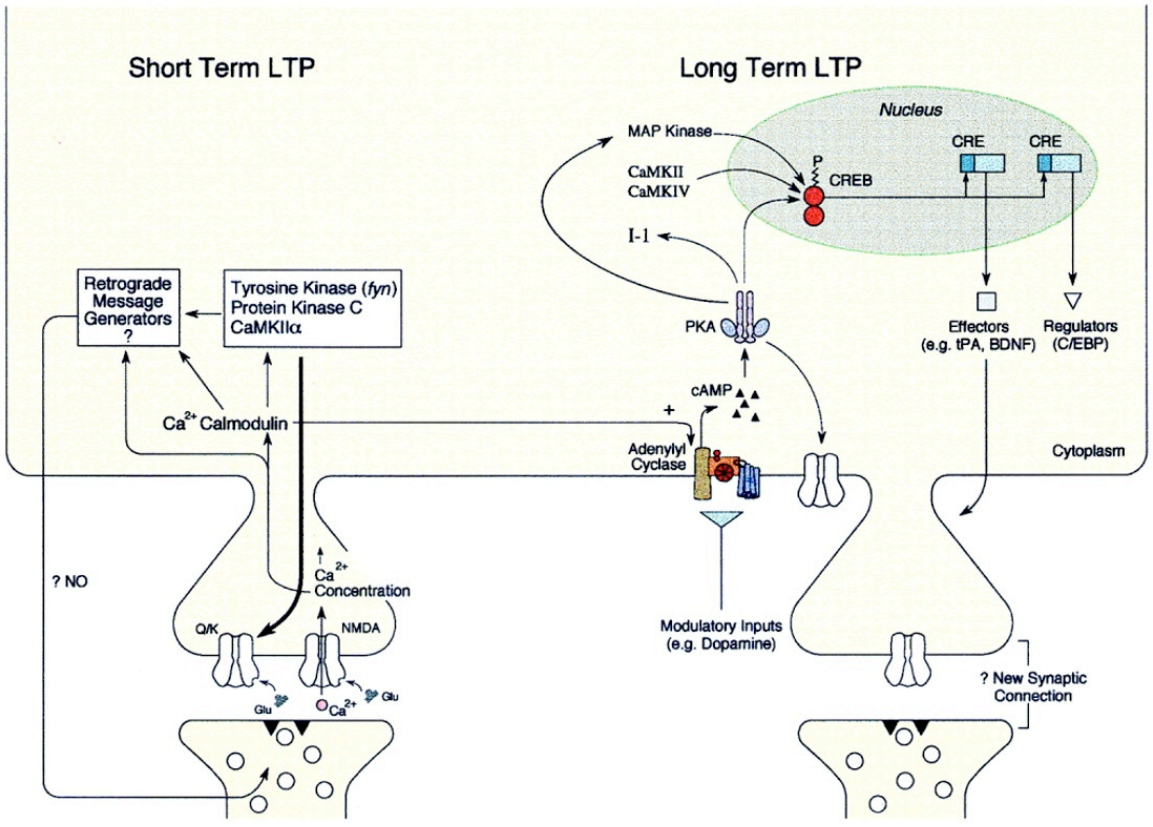

Primate
Rodent
Neocortical association areas
Parahippocampal region
Hippocampus

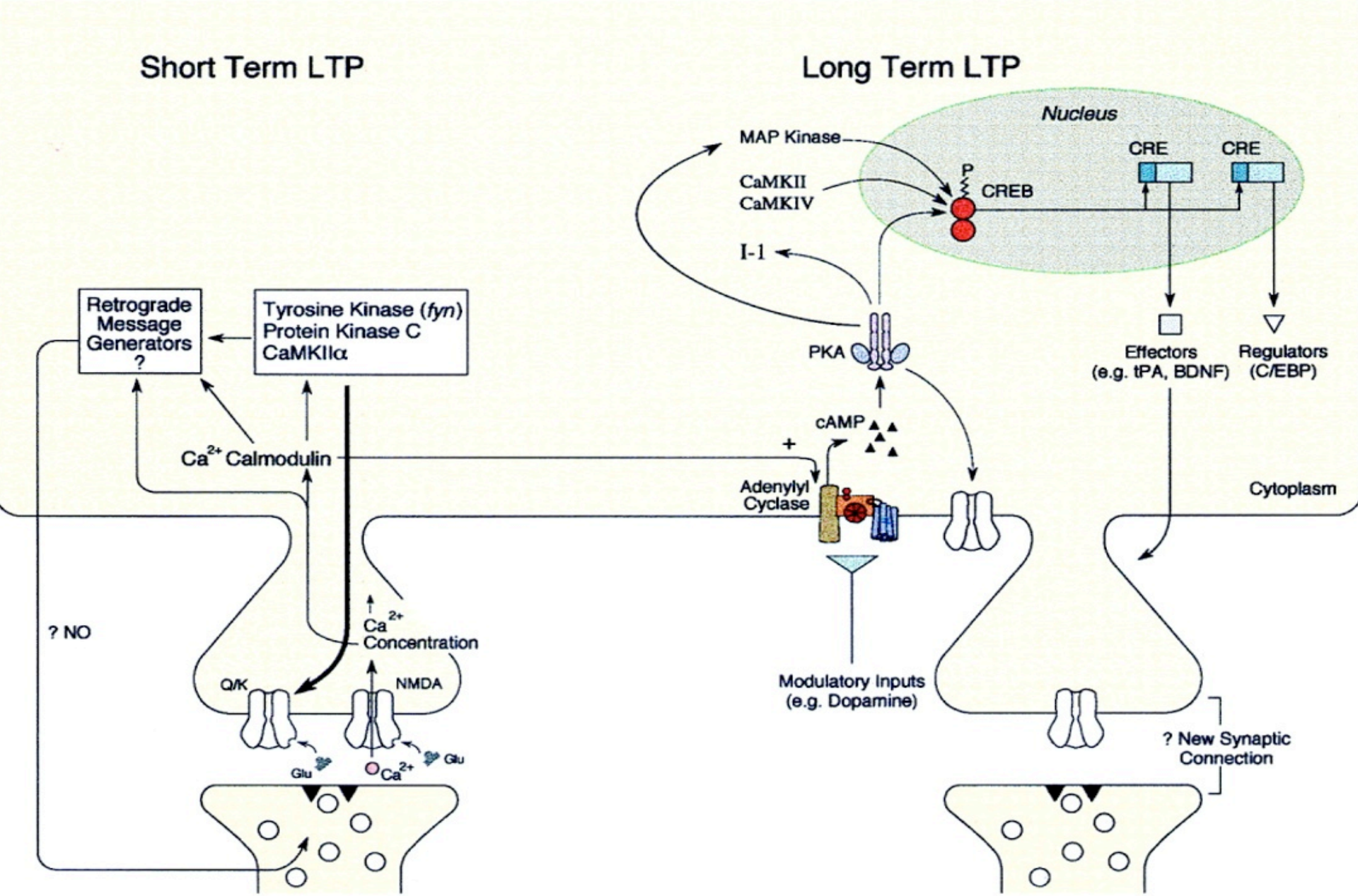

a
6
1
2
3
4
5

A


Perforant pathway
Dentate gyrus
Mossy fiber pathway
Unimodal and polymodal association areas (frontal, temporal, and parietal lobes)
Parahippocampal cortex
Entorhinal cortex
Hippocampus CA3
Schaffer collateral pathway
Perirhinal cortex
Hippocampus CA1
Subiculum

B


Short Term LTP
Long Term LTP
Nucleus
MAP Kinase
CaMKII
CaMKIV
P
CREB
CRE
CRE
I-1
Retrograde Message Generators ?
Tyrosine Kinase (fyn)
Protein Kinase C
CaMKIIα
PKA
Effectors (e.g. tPA, BDNF)
Regulators (C/EBP)
cAMP
+
Ca2+ Calmodulin
Adenylyl Cyclase
Cytoplasm
? NO
Ca2+ Concentration
Q/K
NMDA
Glu
Ca2+
Glu
Modulatory Inputs (e.g. Dopamine)
? New Synaptic Connection


Short Term LTP
Long Term LTP
Nucleus
MAP Kinase
CaMKII
CaMKIV
I-1
P
CREB
CRE
CRE
Retrograde Message Generators ?
Tyrosine Kinase (fyn)
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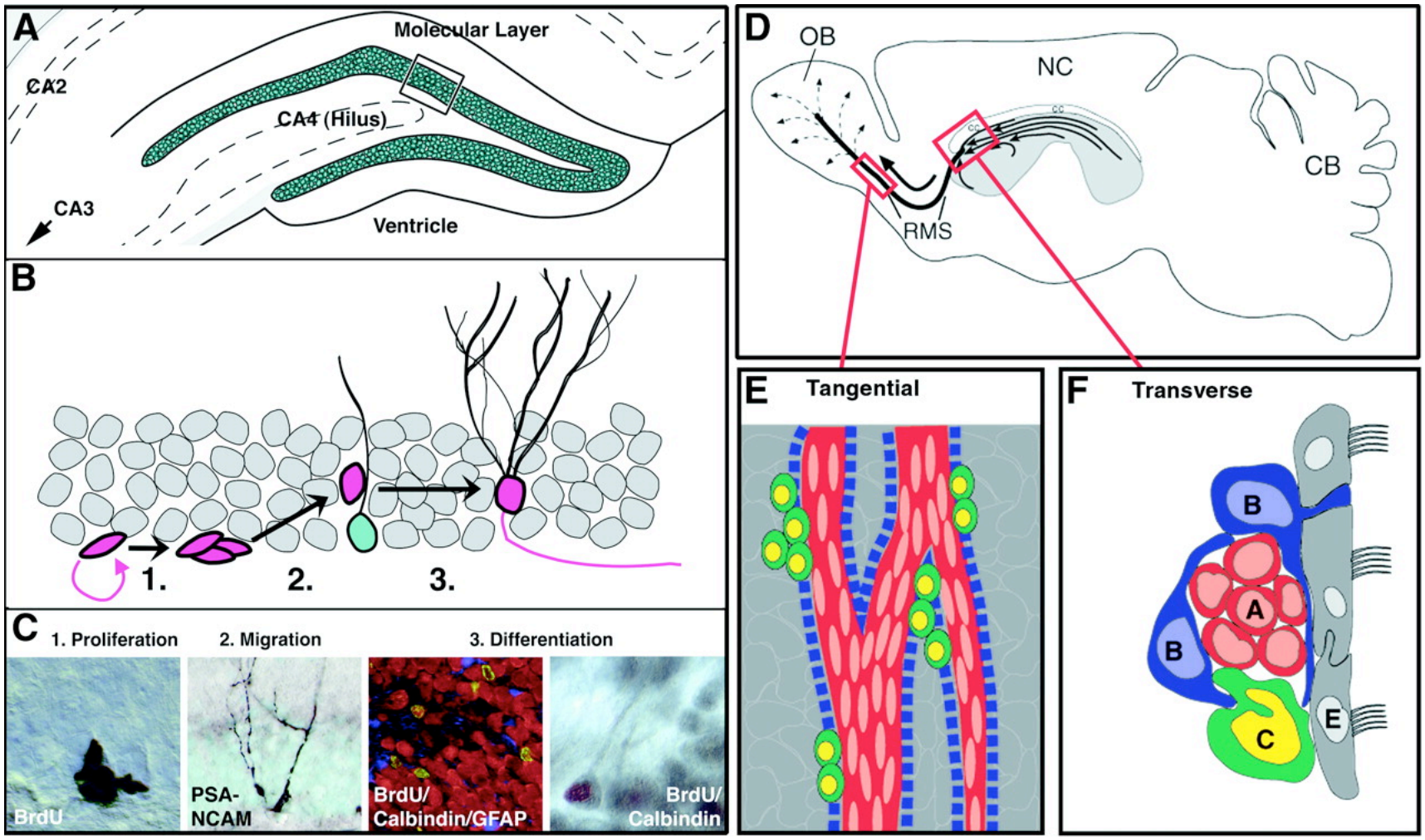
Effectors (e.g. tPA, BDNF)
Regulators (C/EBP)
cAMP
+
Ca2+ Calmodulin
Adenylyl Cyclase
Cytoplasm
? NO
Ca2+ Concentration
Q/K
NMDA
Glu
Ca2+
Glu
Modulatory Inputs (e.g. Dopamine)
? New Synaptic Connection

Neurogenesis: new neurons are born in the adult rodent brain
. . . and **definitely** happens in the primate brain.

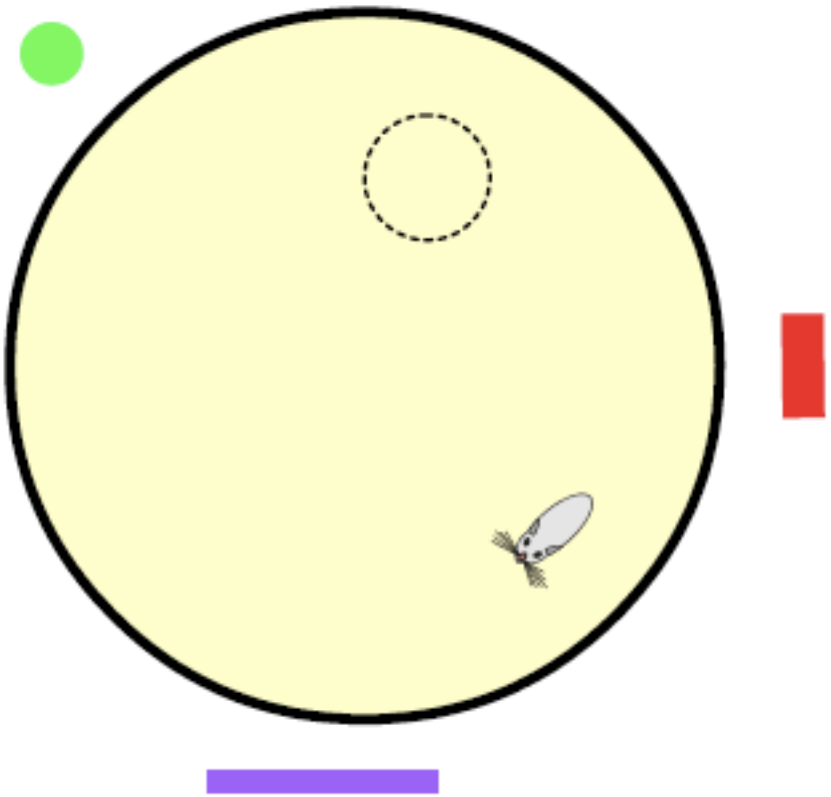
Hippocampus **Olfactory Bulb**

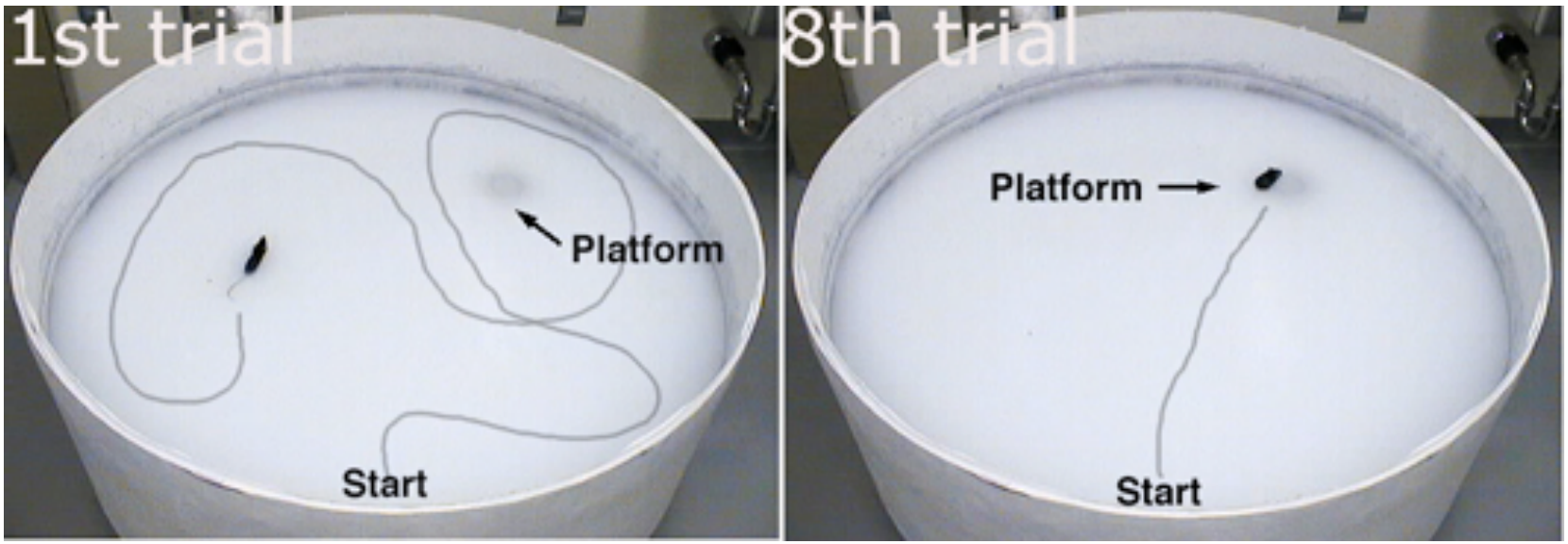


Gage, F.H. (2000) Science *287*:1433-1438

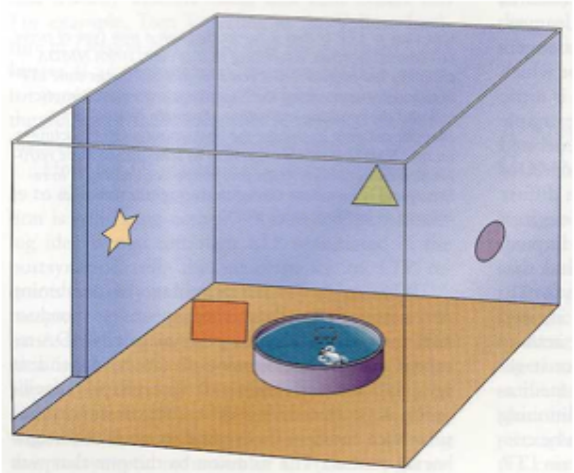
Testing Declarative Memory in Animals

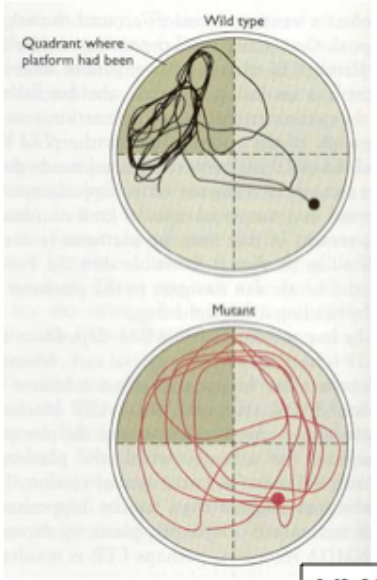
The Morris Water Maze

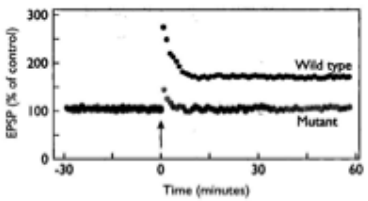


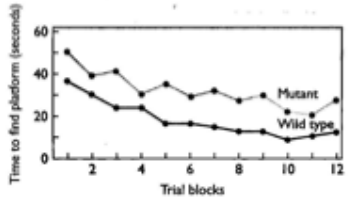

1st trial
Platform
Start
8th trial
Platform
Start

LTP and spatial Memory: Morris water maze

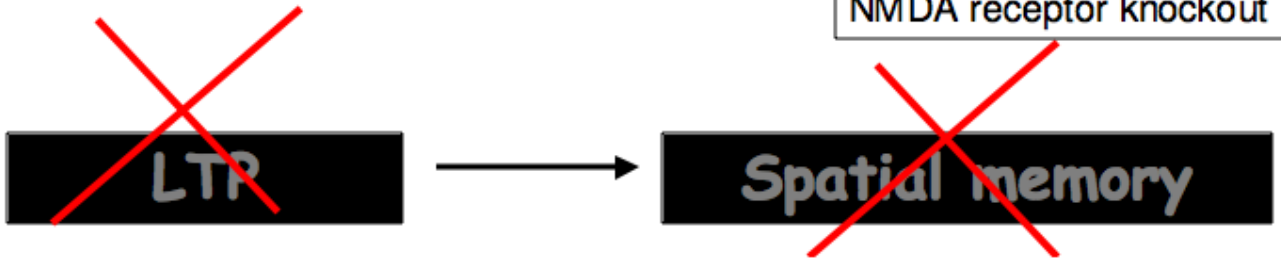








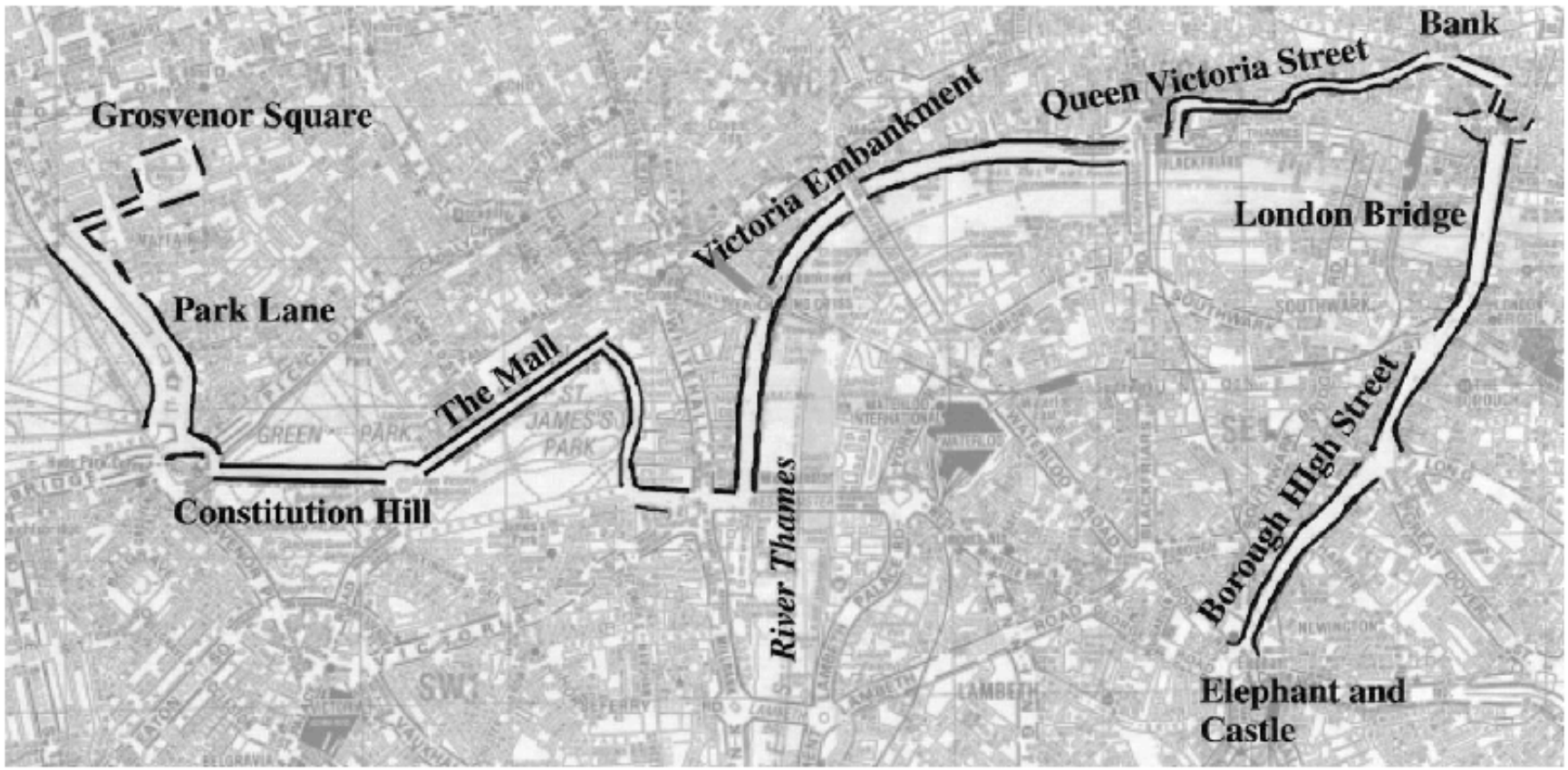
NMDA receptor knockout

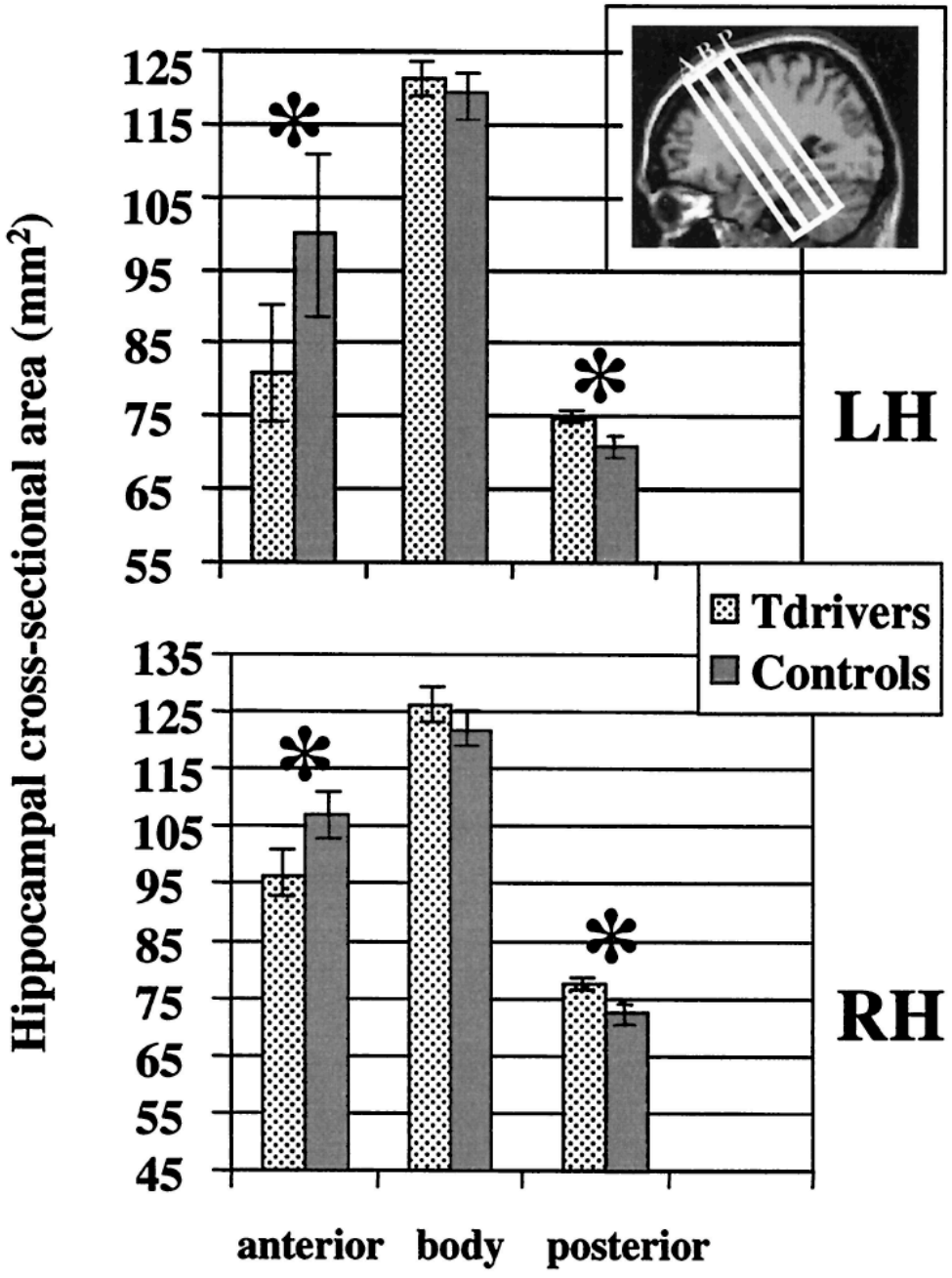


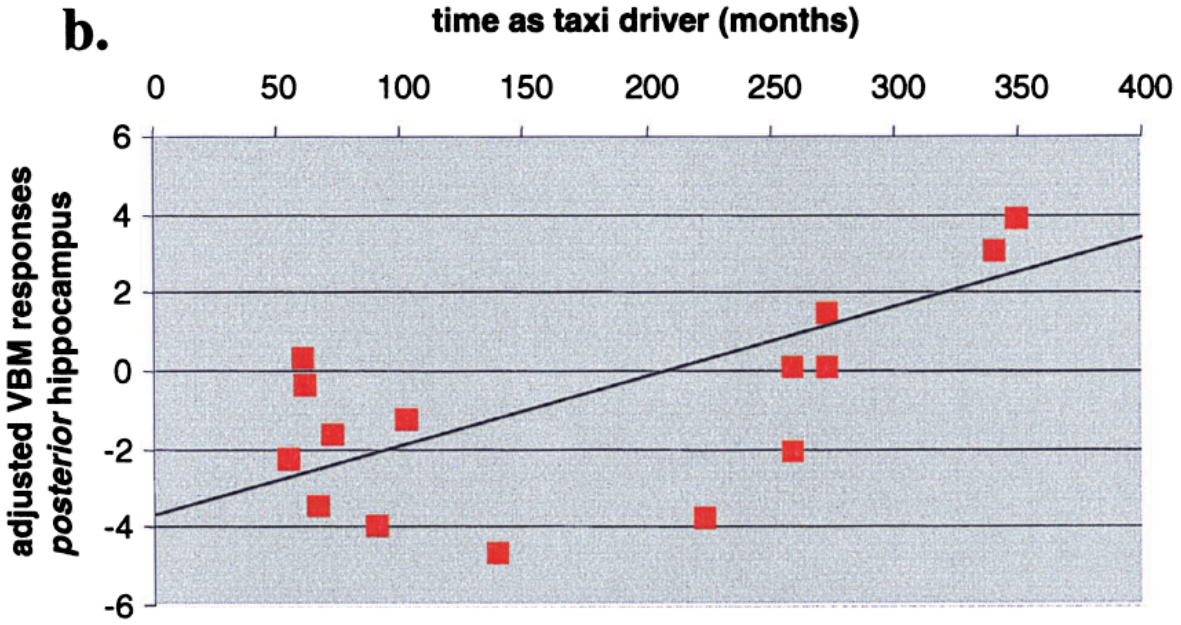
Recalling Routes around London: Activation of the Right Hippocampus in Taxi Drivers

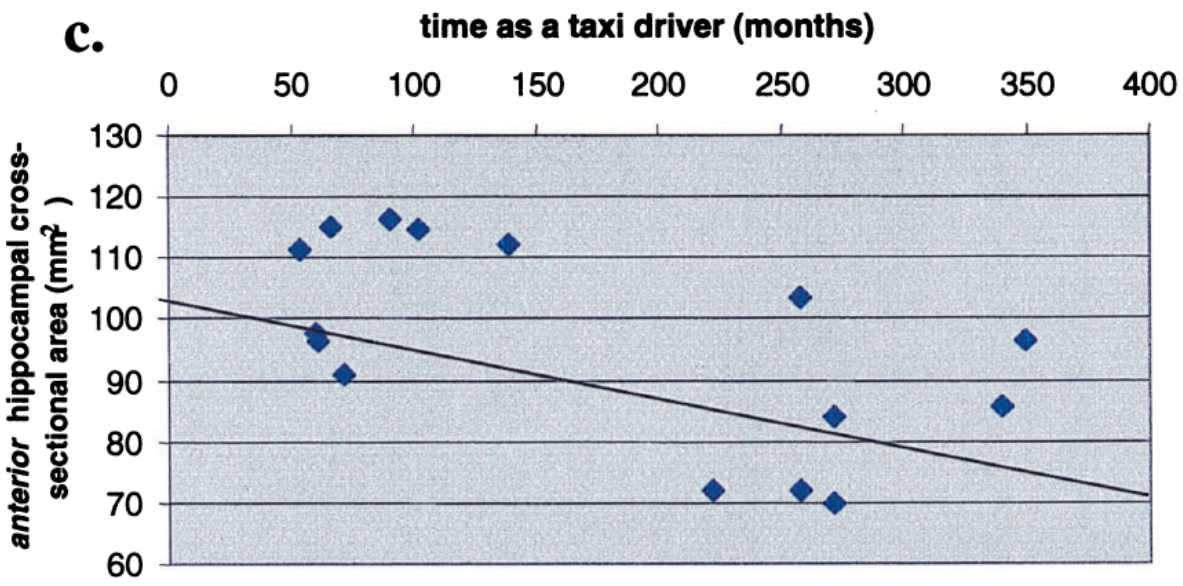
Eleanor A. Maguire, Richard S. J. Frackowiak, and Christopher D. Frith

Wellcome Department of Cognitive Neurology, Institute of Neurology, London WC1N 3BG, United Kingdom




Hippocampal cross-sectional area (mm²)
125
115
105
95
85
75
65
55
LH
Tdrivers
Controls
135
125
115
105
95
85
75
65
55
45
RH
anterior
body
posterior
A
P

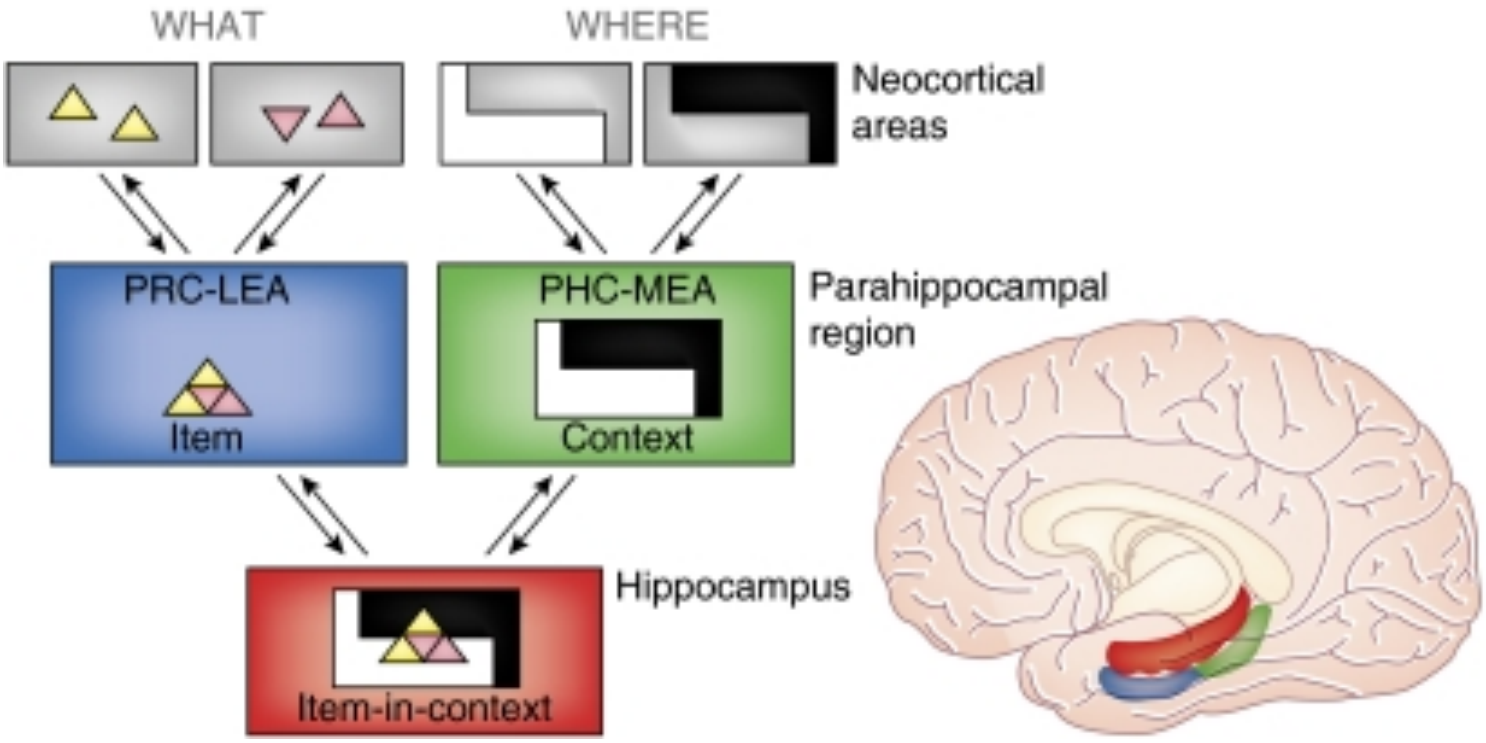

b.
time as taxi driver (months)
0
50
100
150
200
250
300
350
400
6
4
2
0
-2
-4
-6
adjusted VBM responses
posterior hippocampus


c.
time as a taxi driver (months)
0
50
100
150
200
250
300
350
400
130
120
110
100
90
80
70
60
anterior hippocampal cross-sectional area (mm2)

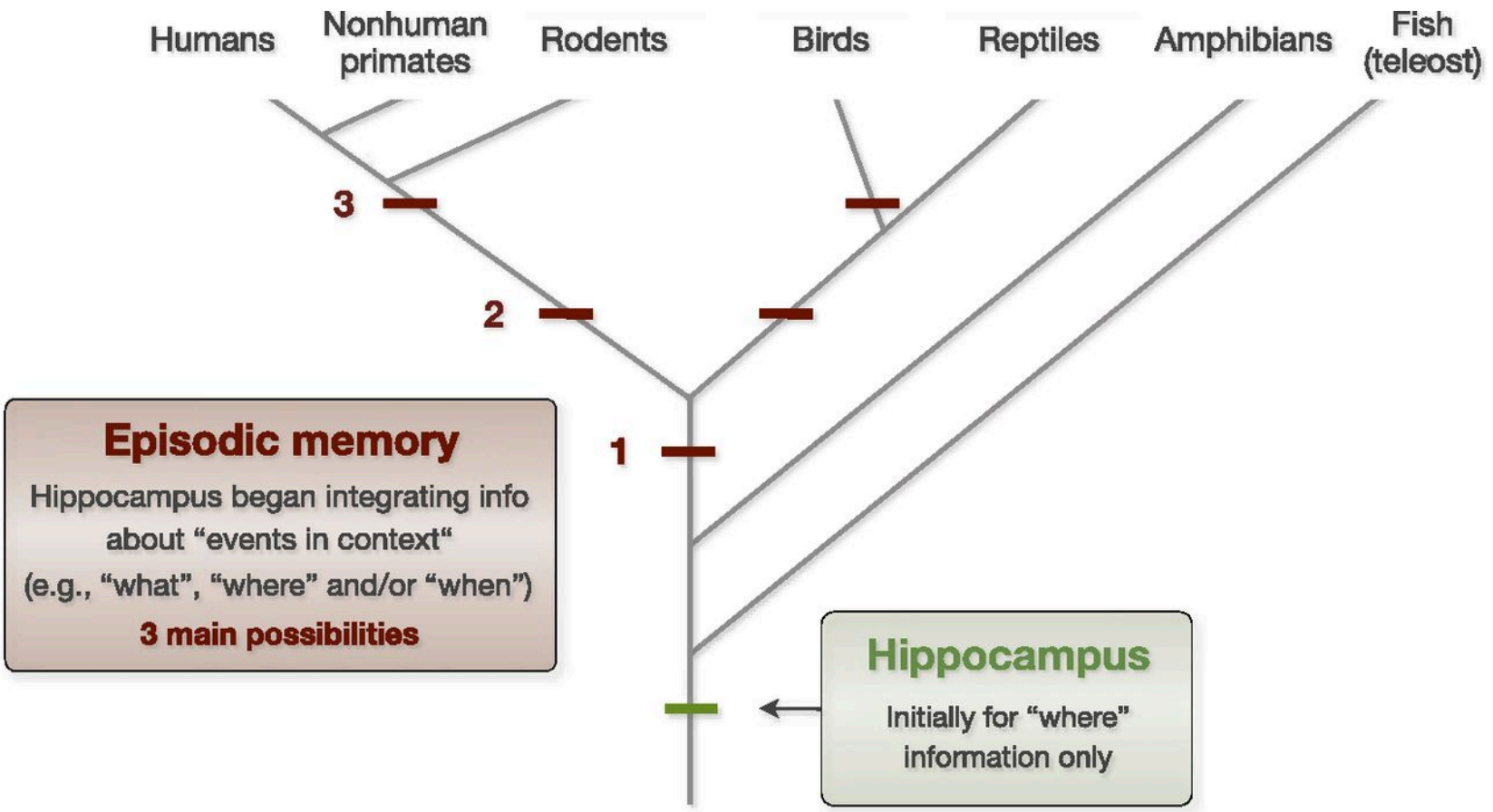
Declarative memory for facts and events
Memory for spatial layouts (water maze, taxi driving)

What do these have in common?

Declarative memory is relational


WHAT
WHERE
Neocortical areas
PRC-LEA
Item
PHC-MEA
Context
Parahippocampal region
Hippocampus
Item-in-context

Possible time points for the emergence of episodic memory in evolution.



Timothy A. Allen, and Norbert J. Fortin PNAS 2013;110:10379-10386