

The German Army, An Explosion, and a Bicycle Accident:

How the Brain Learns and Solves Problems

a CSM Pedagogical Seminar

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The Problem: A Working Brain Hypothesis Is Needed

Francis Crick, concluding comment in 1979 Scientific American issue devoted to the brain

- “What is conspicuously lacking is a broad framework of ideas (about the brain).”

Editors Tulving and Craik, Oxford Handbook of Memory (2000): on the state-of-the-art of memory:

- “The uncertain parts of our science have to do with theory, with the question of how best to interpret and integrate the massive amounts of data that experimental and clinical studies of memory have yielded.” (p.vi)
- Memory is a field in flux “a field that is still struggling to find its first Kuhnian paradigm, a field in which theories vie with fact for the observers’ attention.” (p.vii),

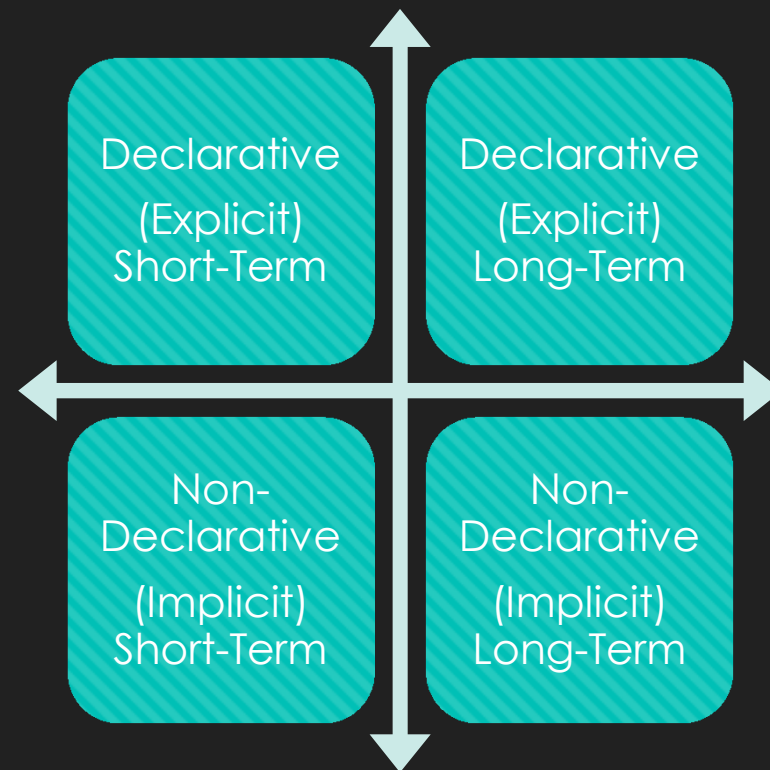
The Claim

1. Biology, Chemistry, & Physics have enabled:
 - Memory definition: biology at microscopic level
 - Macroscopic hypothesis: how brain solves problems
2. Educational Psychology has provided
 - Most of the major pedagogical outcomes
 - Neuroscience: provides underlying fundamentals
 - Reasons may provide new applications
3. 7 Neuroscience Pedagogical Guidelines
 - Handout for you to take
 - Determine your own applications



4 Memory Types

We discuss only declarative long-term



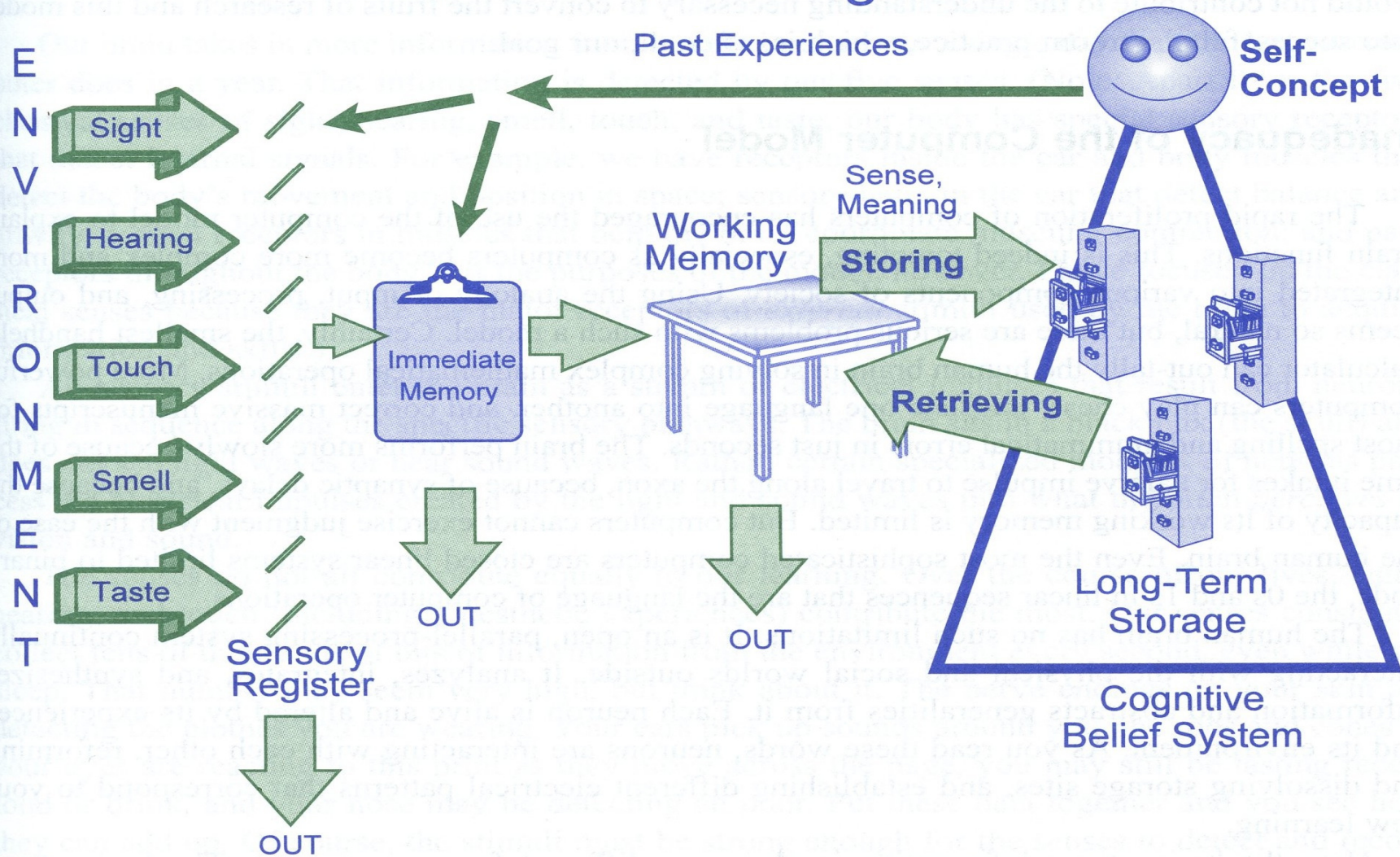
Cognitive Psychology Model For Declarative Memory

David Sousa (2011)

How the Brain Learns (4th Ed)

Cognitive Psychology Model

Information Processing Model

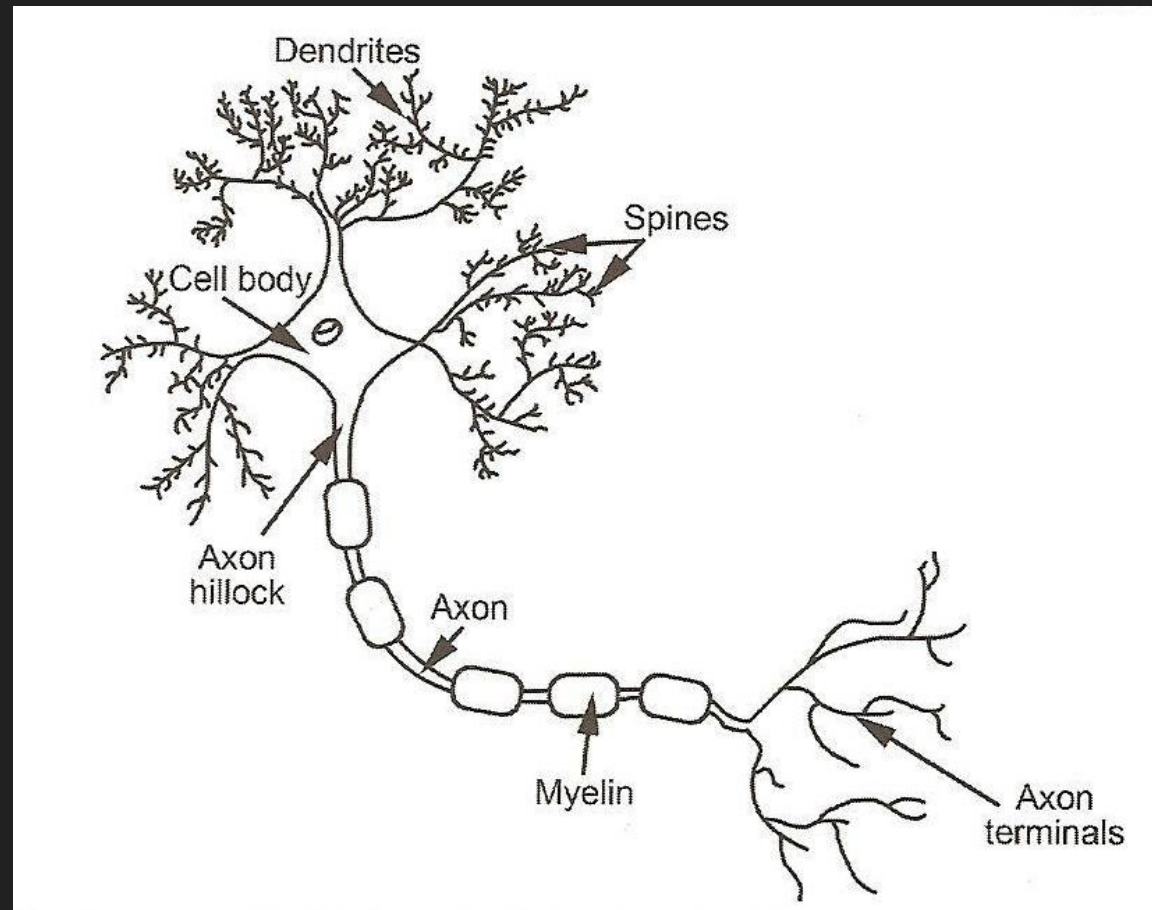


What is Happening at the Brain Cellular Level?

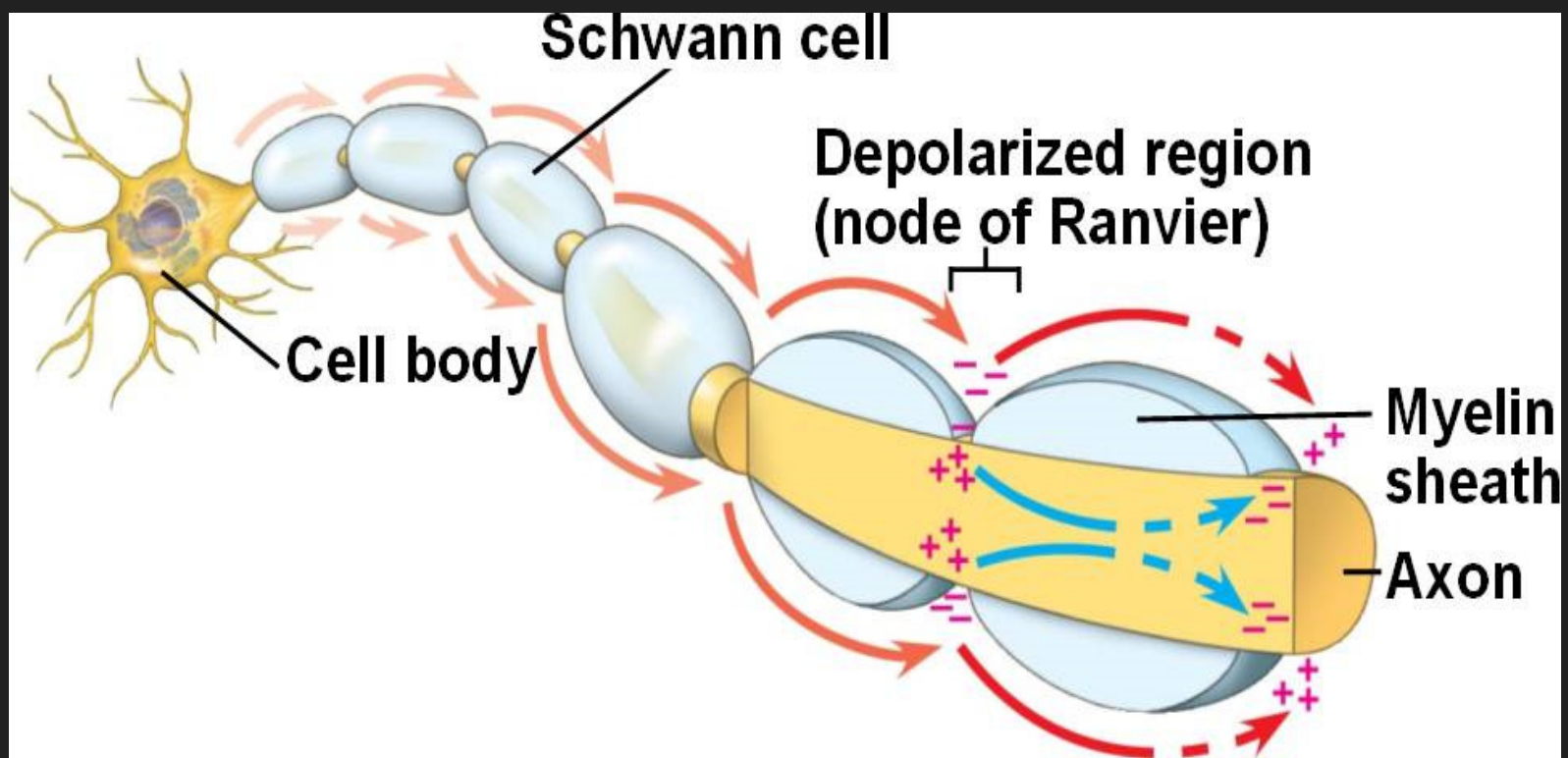
Biochemistry is Memory

Cells that make up the brain

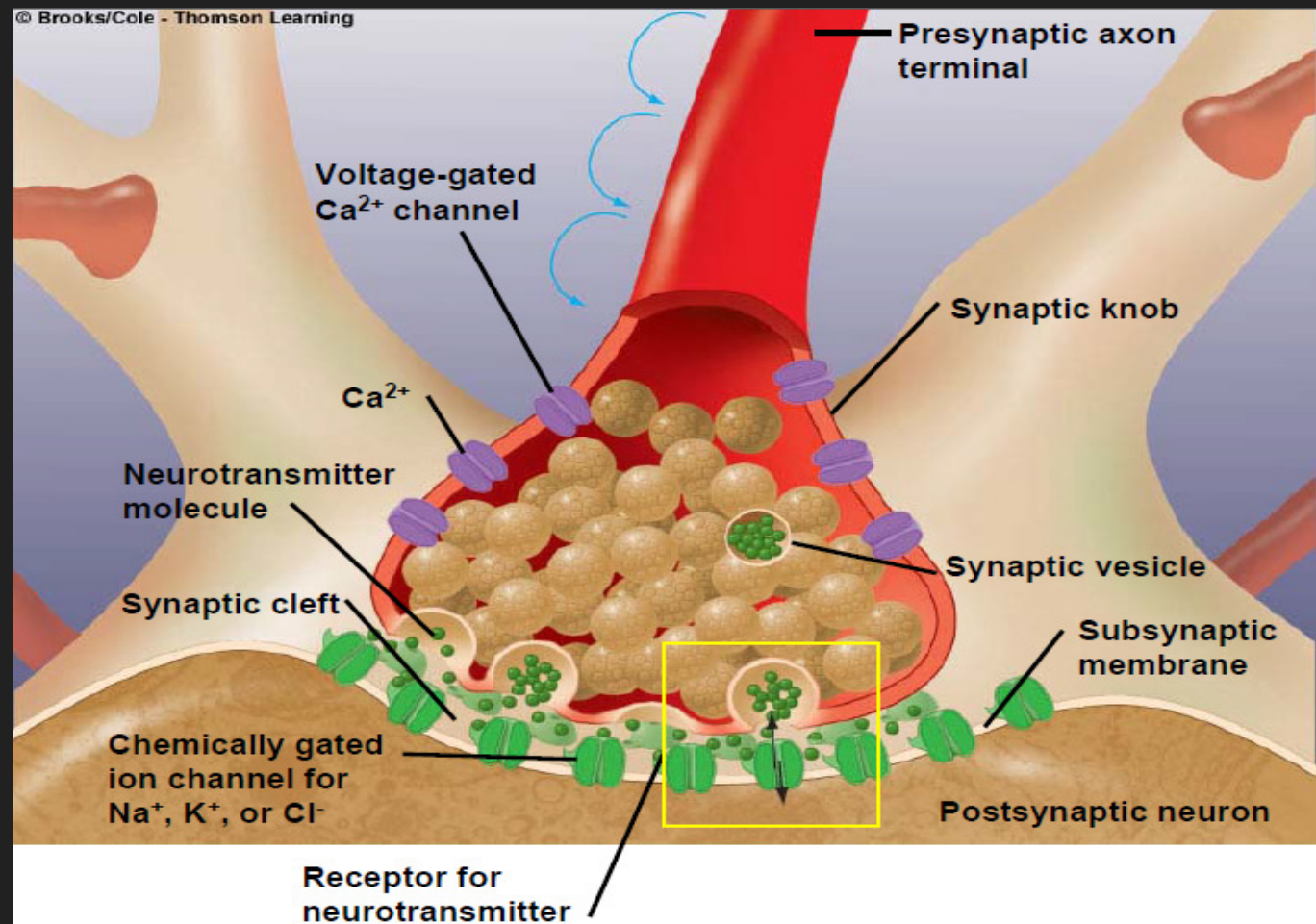
○ The Neuron: general view



Firing of an Action Potential

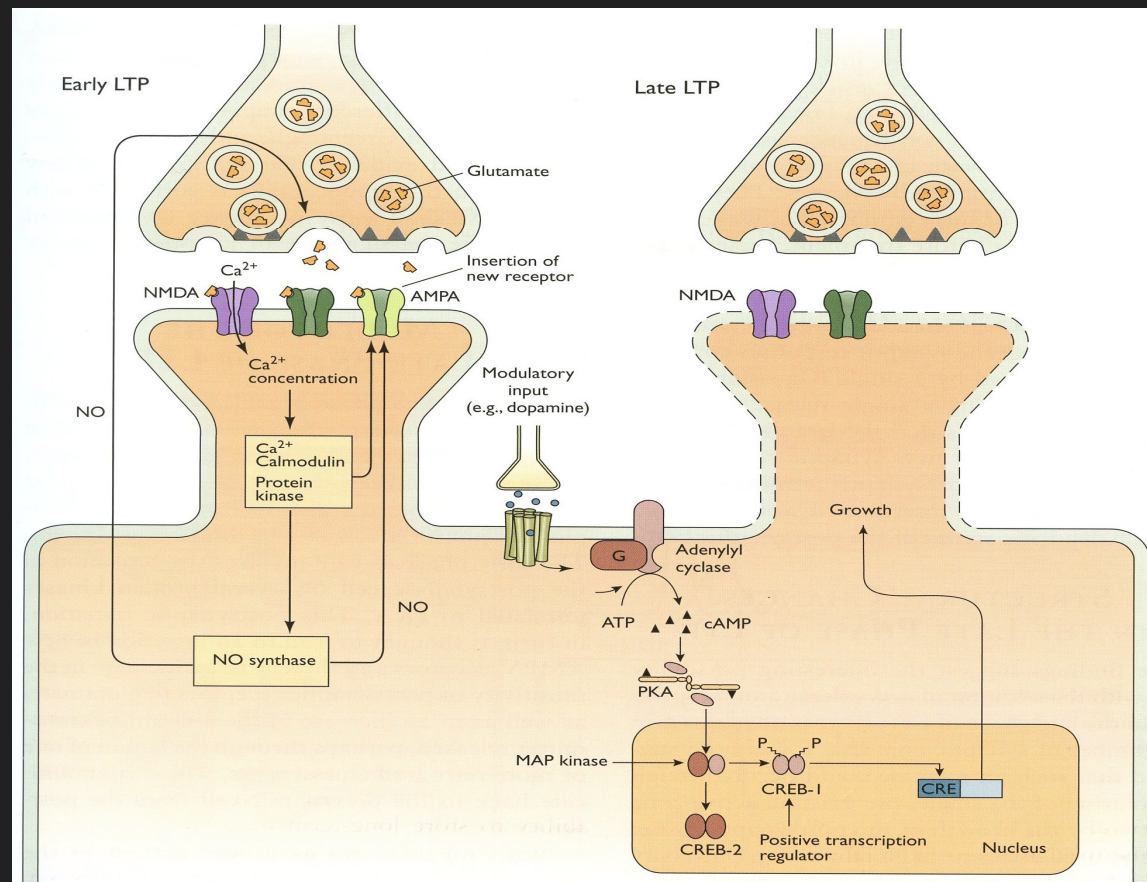


When an Action Potential Reaches the Synapse



Early & Late LTP Declarative Model

LTP grows
Protein in
Motor
Neuron



Two Mnemonics Summarize Hebbian Learning:

1. Neurons which Fire Together, Wire Together
2. Out of Synchrony, Lose Your Link (Between Neurons)

A Neuroscience Perspective

Macroscopic Level

Sigmund Freud: On Narcissism

- “We must remember that all our provisional ideas in psychology will one day be explained on the basis of organic substrates.”

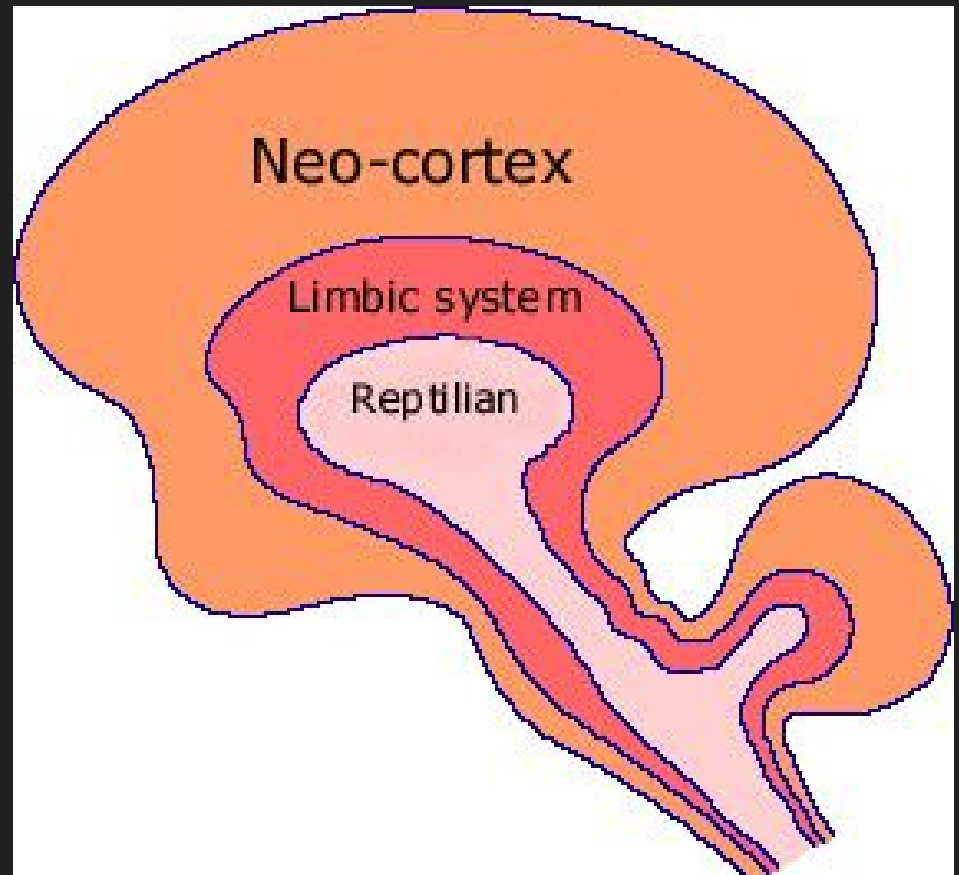


Three Brain Theory of Paul MacLean

The reptilian brain
survival

The mammalian brain
emotion

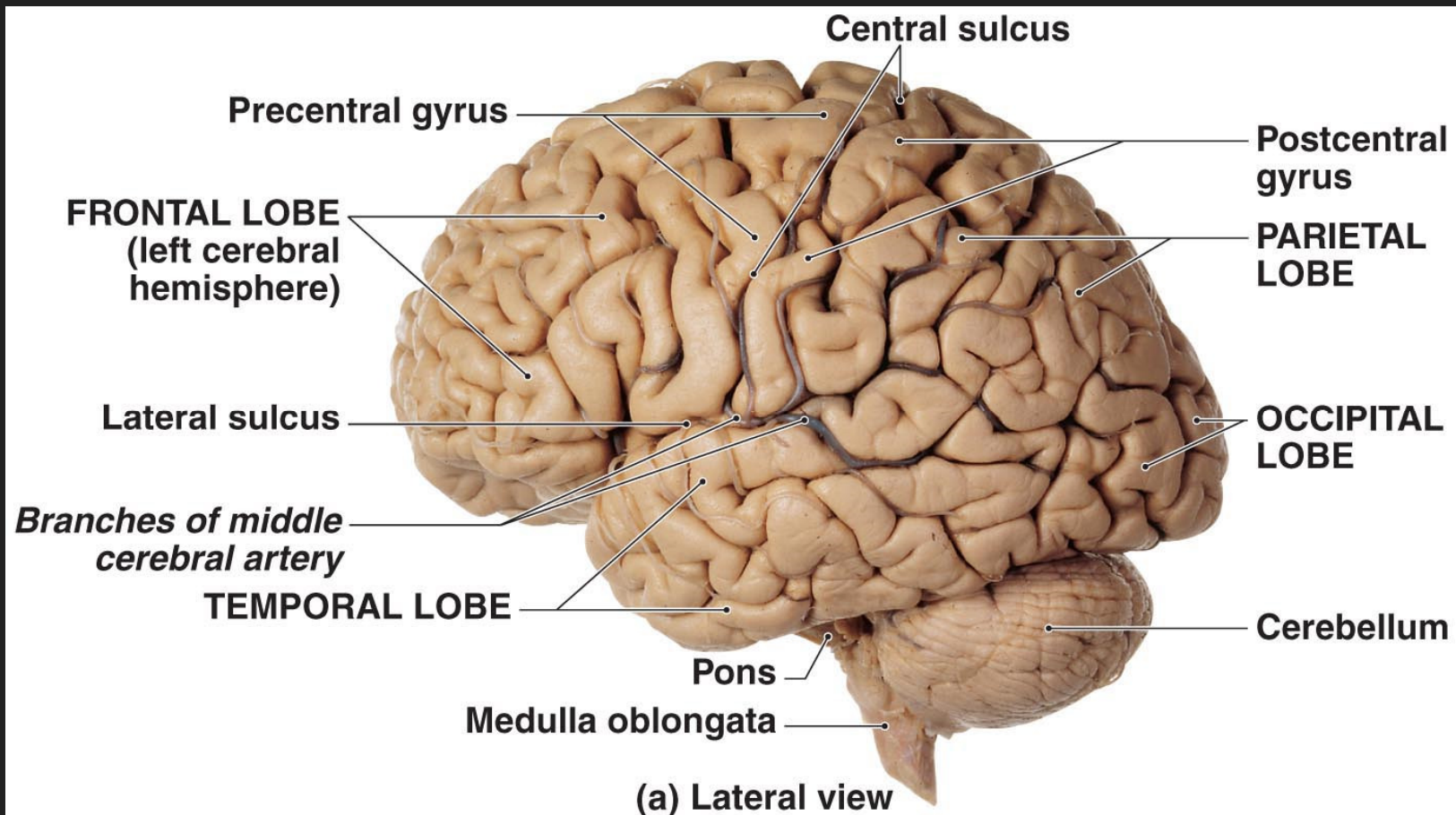
The neocortex
executive function



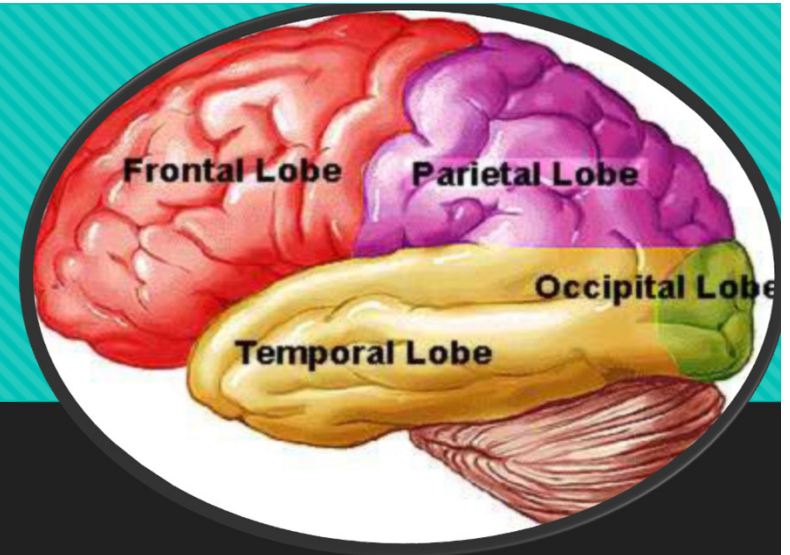
The Three Brains

1. without the neocortex, purposeful problem solving ability is gone;
2. without the mammalian cortex, one is physically, but not psychologically, alive;
3. without the reptilian hindbrain, bodily functions cease.

The Cerebrum



The Cerebrum

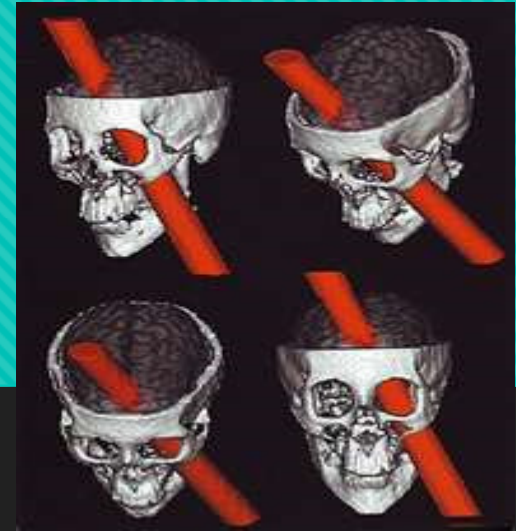


- Frontal Lobe
 - Executive function, Judgment, Social appropriateness
 - Consequences, Personality , Motor
- Parietal Lobe
 - Major association area for sensory input
- Occipital lobe
 - Major area for visual input and processing
- Temporal Lobe
 - Memory , Hearing, Bilateral damage is devastating
 - Seizure disorders common from here
 - Deja vu, jamais vu, Aura. smell, sound, religiosity, hallucinations

Three Case Studies: Illustrative of much other evidence

1. Cortical Lesions in German Army (WWI)
 - Memory is stored throughout the neocortex
2. Pre-Frontal Cortex lesion in Phineas Gage
 - Loss of reason: reverts to animal behavior
3. Bilateral Hippocampus Loss Henry Molaison
 - Unable to establish long term memory

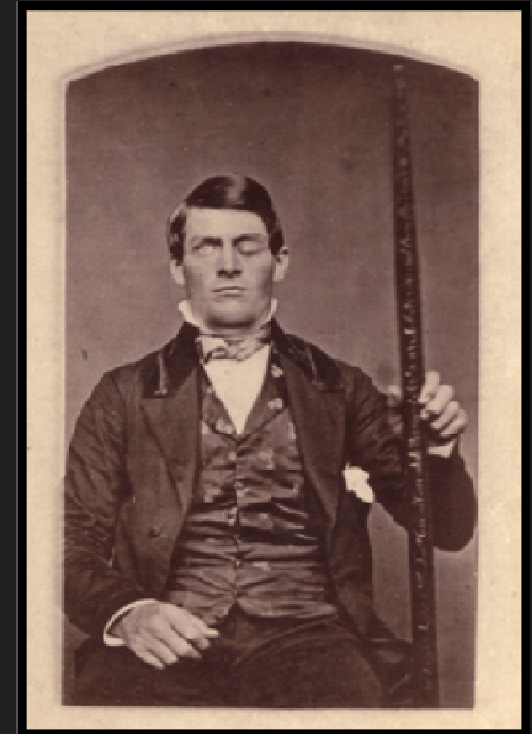
Phineas Gage



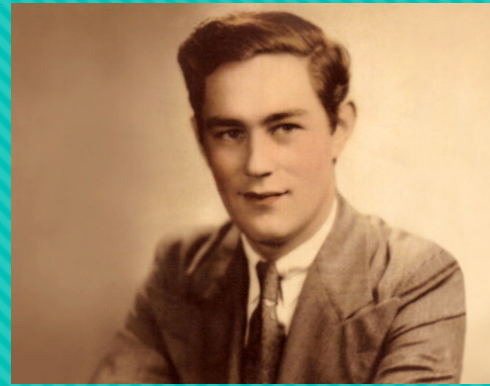
1848 Explosion destroyed left prefrontal cortex.

He was treated by Dr. Harlow and survived. He lived 12 more years

He lost ability to reason and was considered “enfeebled”



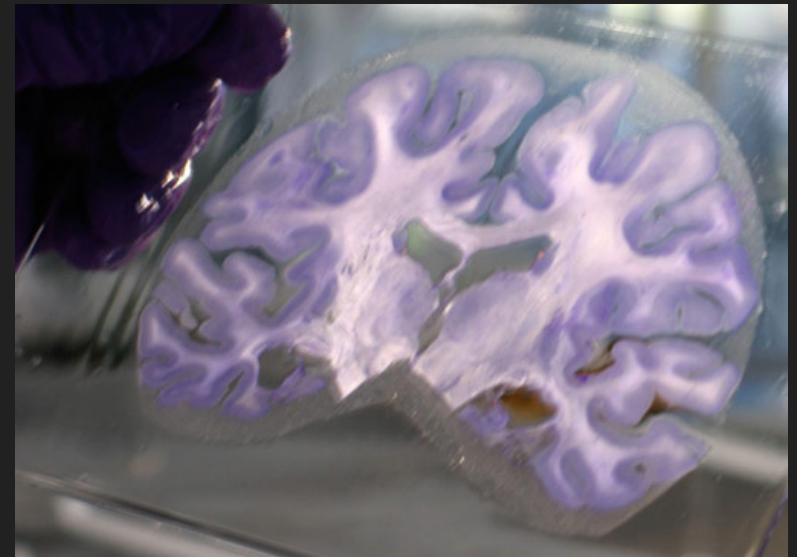
Henry Molaison



Bilateral hippocampal removal
for intractable seizures.

Anterograde amnesia ensued.

No new long term memories



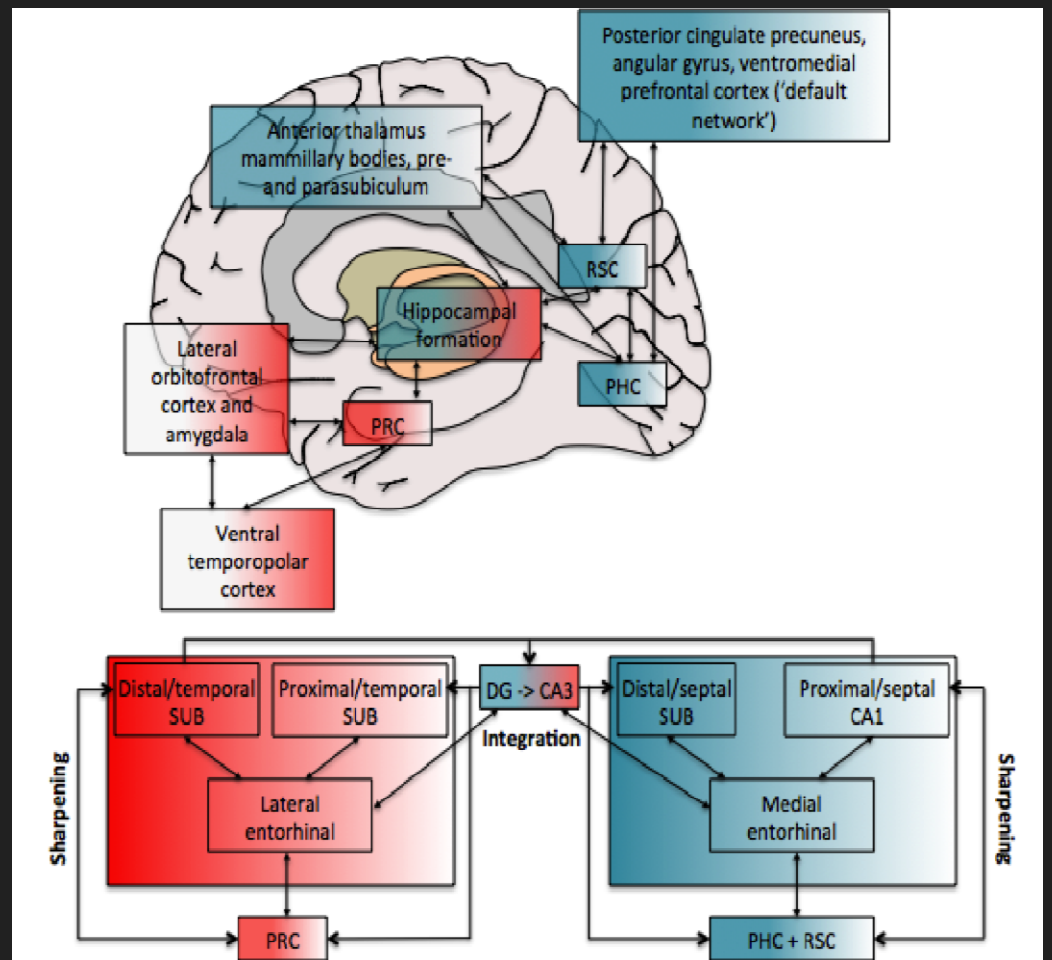
Good bye from me, time for Dendy



Ranganath & Ritchey

Model connects
Hippocampus to
the Neocortex

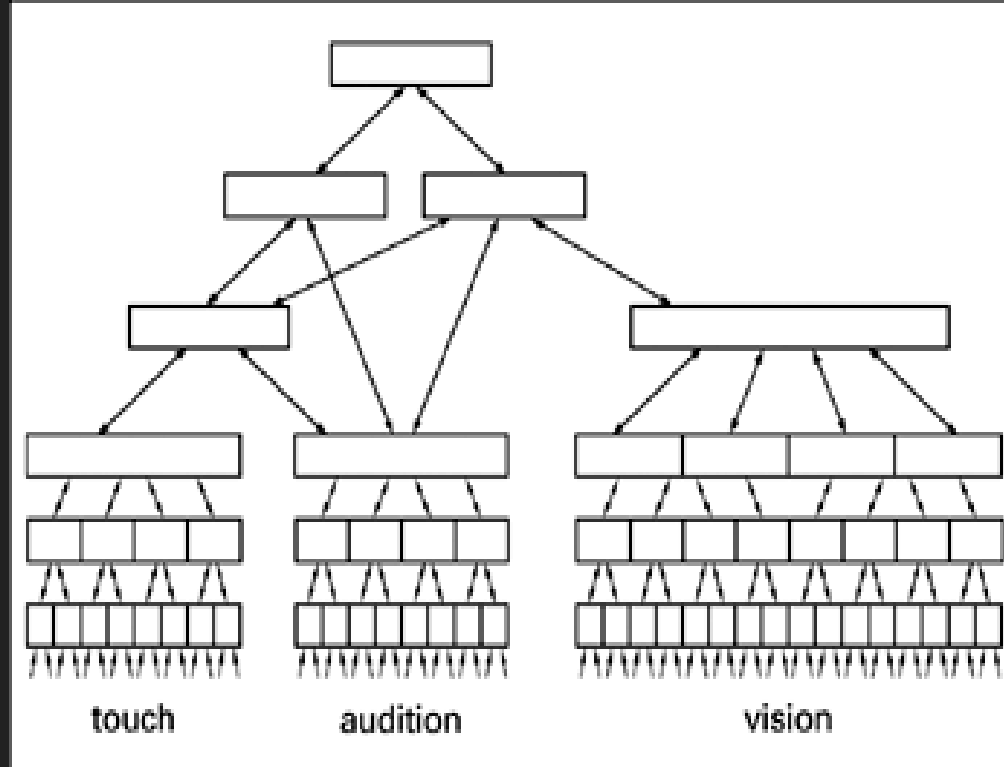
Nature Reviews
Neuroscience, Oct. 2012
pp. 713-726



Neocortex Memory Hypothesis

1. Intelligence = accurate predictions of future
 - from past memories
2. Many think memory connects present to past
 - It also connects past & present, to the future
3. Memories are formed by interactions of
 - Hippocampus with cortex
 - Interactions over years: final storage in cortex
 - Transfer occurs during sleep
4. Patterns are established in 6 cortical layers
 - For memory encoding & retrieval

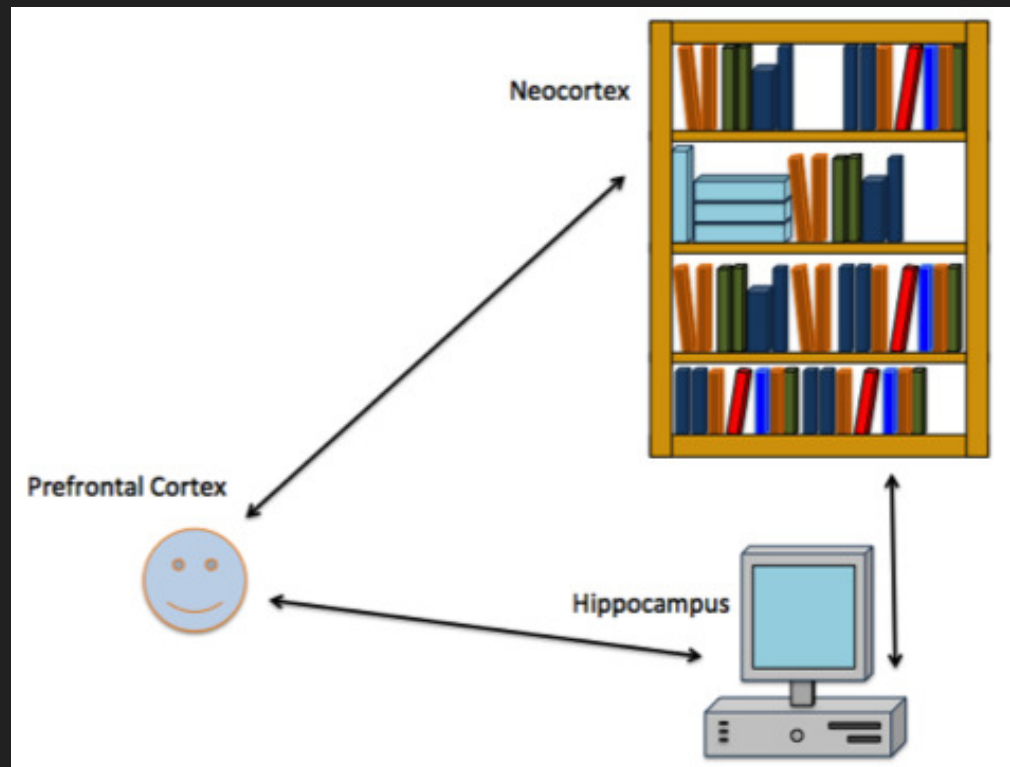
Cortical Hierarchy



A Macroscopic Hypothesis: How the Brain Solves Problems

1. Neocortex (NC): Long term memory storehouse
 - Memory is distributed across neocortex
 - Lesions cause specific, not global losses
2. Hippocampus (HC): entryway for memory
 - Takes info from neocortex
 - Re-establishes memory in neocortex
 - Over time, releases memory to neocortex
3. Pre Frontal Cortex: Judges use of memory
 - New memories from NC through HC
 - Older memories directly from NC
 - Judges memory to solve problems

A Brain Metaphor for Problem Solving: Using the library to design a garden



How to Use the Library to Design a Garden

How the Brain Might Solve a Problem

1. A person (PFC) wants to design a garden for her backyard
2. Comes to reference librarian for indexing computer (HC)
 - determines the location of some appropriate books
 - reference librarian HC sends PFC to library shelves (neocortical memory patterns) which contain books in categories:
 - 1) styles of gardens/landscaping, 2) plant types, 3) soil/fertilizer, and 4) climate
3. Some initially-referenced books may be missing/misplaced on shelves
 - PFC can find other similar books in the same topic area
 - from the same shelves of Neocortex
 - from the references in the originally-referenced books, and/or
 - by returning to the indexing computer for other, perhaps newer references.
4. PFC combines information on 4 topics to successfully plan her garden.

Metaphor Explains 3 Major Facts Regarding Memory Loss:

1. if the indexing computer (hippocampus) is destroyed, e.g. H.M., it is impossible to log in new books (or create new memories),
2. cortical damage (i.e. the loss of a few books on the upper floor) produces selective memory loss (e.g. German soldiers), but not global loss as would occur with the indexing computer (hippocampal) fire, and
3. hippocampal damage spares older memories, but not recent memories. As memories are repeatedly retrieved, they link together, so they can be accessed without the hippocampus.

Seven Bottom Lines

1. Cannot Fool Mother Nature (Survival comes before Learning)
2. Learning: Establishing & Retrieving Long-Term Memory (LTM)
3. LTM: Dialogue between Hippocampus and Cortex
4. Cortex: Storehouse of LTM
5. Memories: Connections at Spaces Between Brain Cells
6. a) Short-Term Memory: Electro-Chemical Synaptic Connections
b) Long-Term Memory: Protein Growth Synaptic Connections
7. Working memory in prefrontal cortex: where problems are solved
Draws new memory from Hippocampus; old from Cortex

Major Drivers for Brain Hypothesis: (Electrical Engineers for mobile computing)

- Jeff Hawkins (inventor of Treo – which S. Jobs put on steroids for iPhone)
 - Hawkins, J., Blakeslee, S., (2004) On Intelligence, Times Books
- George, D., (2008) How the Brain Might Work: A Hierarchical and Temporal Model for Learning and Recognition, Stanford PhD Dissertation, UMI No. 3313576
- Kurzweil, R., (2012) How to Create a Mind: The Secret of Human Thought Revealed, Viking
- Bar, M., (Ed) (2011) Predictions in the Brain: Using our Past to Generate a Future, Oxford

Four References:

1. Tulving, E. & Craik, F.I.M. (Eds). (2000) The Oxford Handbook of Memory, Oxford U. Press
2. Macmillan, M., (2000) An Odd Kind of Fame: Stories of Phineas Gage, MIT Press
3. Corkin, S., (2013) Permanent Present Tense: The Unforgettable Life of the Amnesic Patient, H.M., Basic Books
4. Sloan, D. & Norrgran, C. (2013) Neuroscience, Memory, and Learning, Createspace