

Centre for Cognitive Science

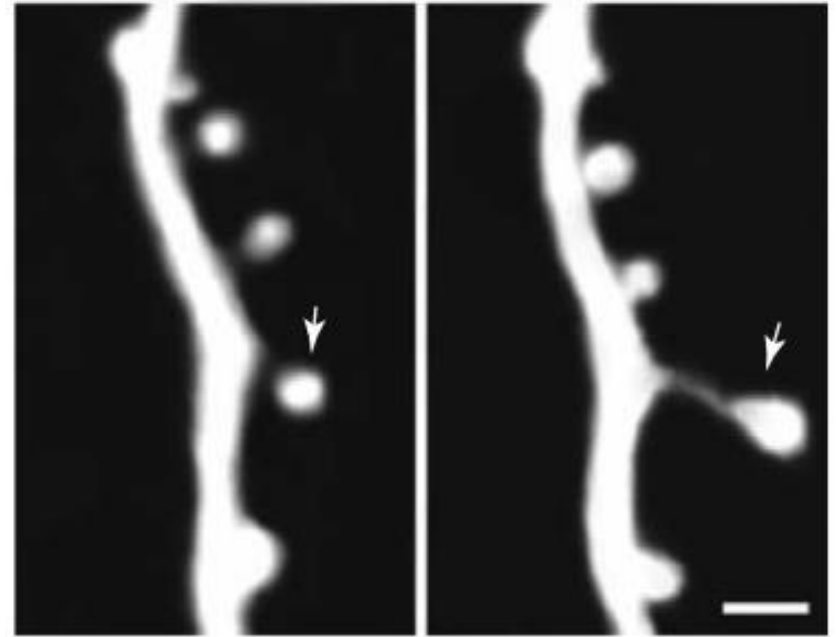
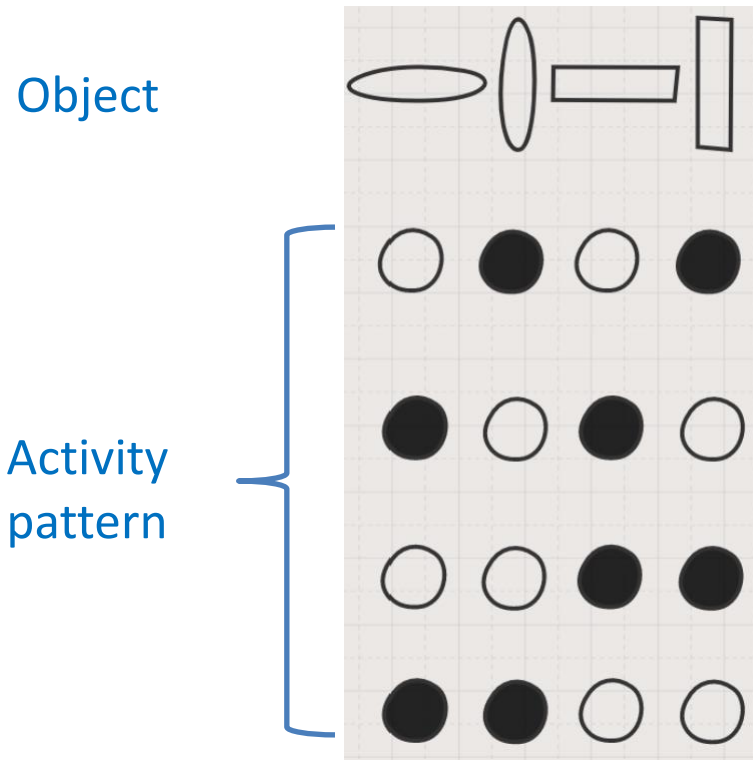
Bratislava



Computational cognitive neuroscience: 8. Memory

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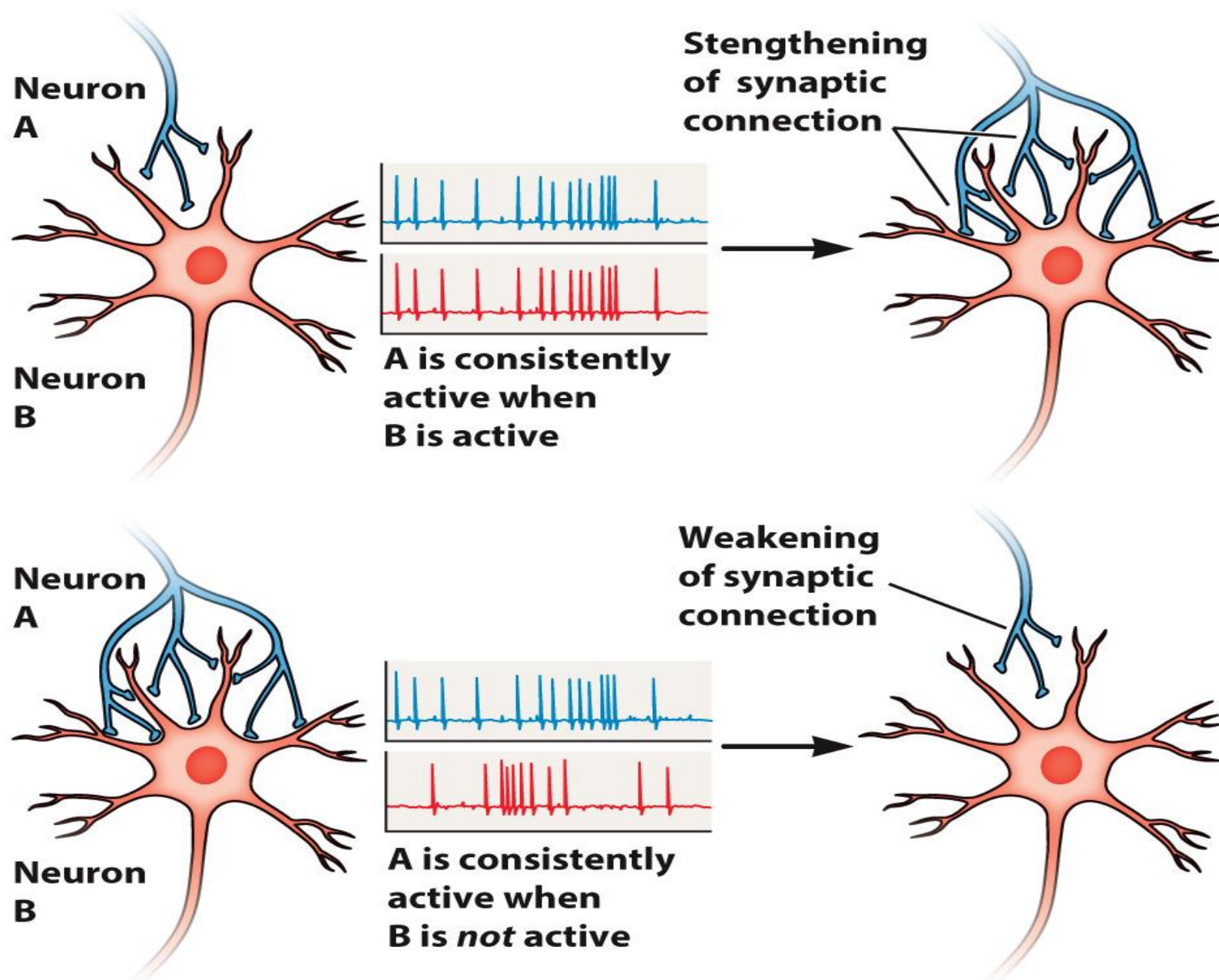
Two neural forms of memory: activity coded versus synaptic changes



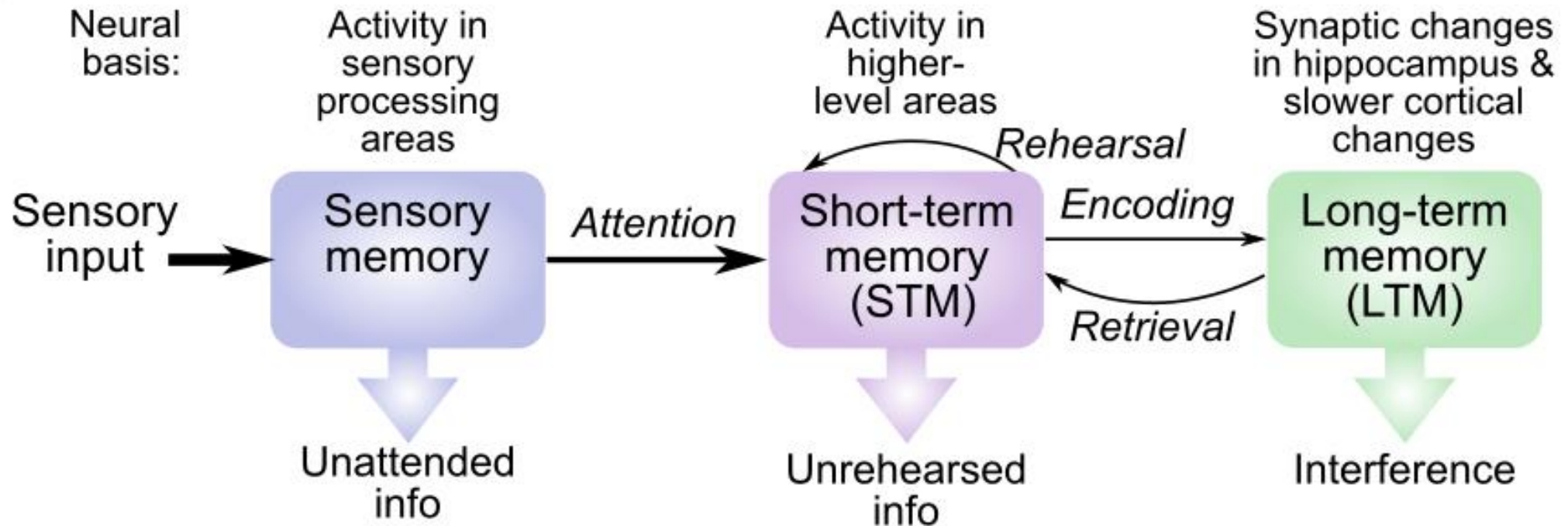
Activity = Neurons continue to fire action potentials, “remembering” what you were just seeing or thinking.
But when firing stops, you forget.

Synapses change strength (weight) during LTP / LTD: this encodes long-term memories that last even after neural activity switches off or to something new pattern.

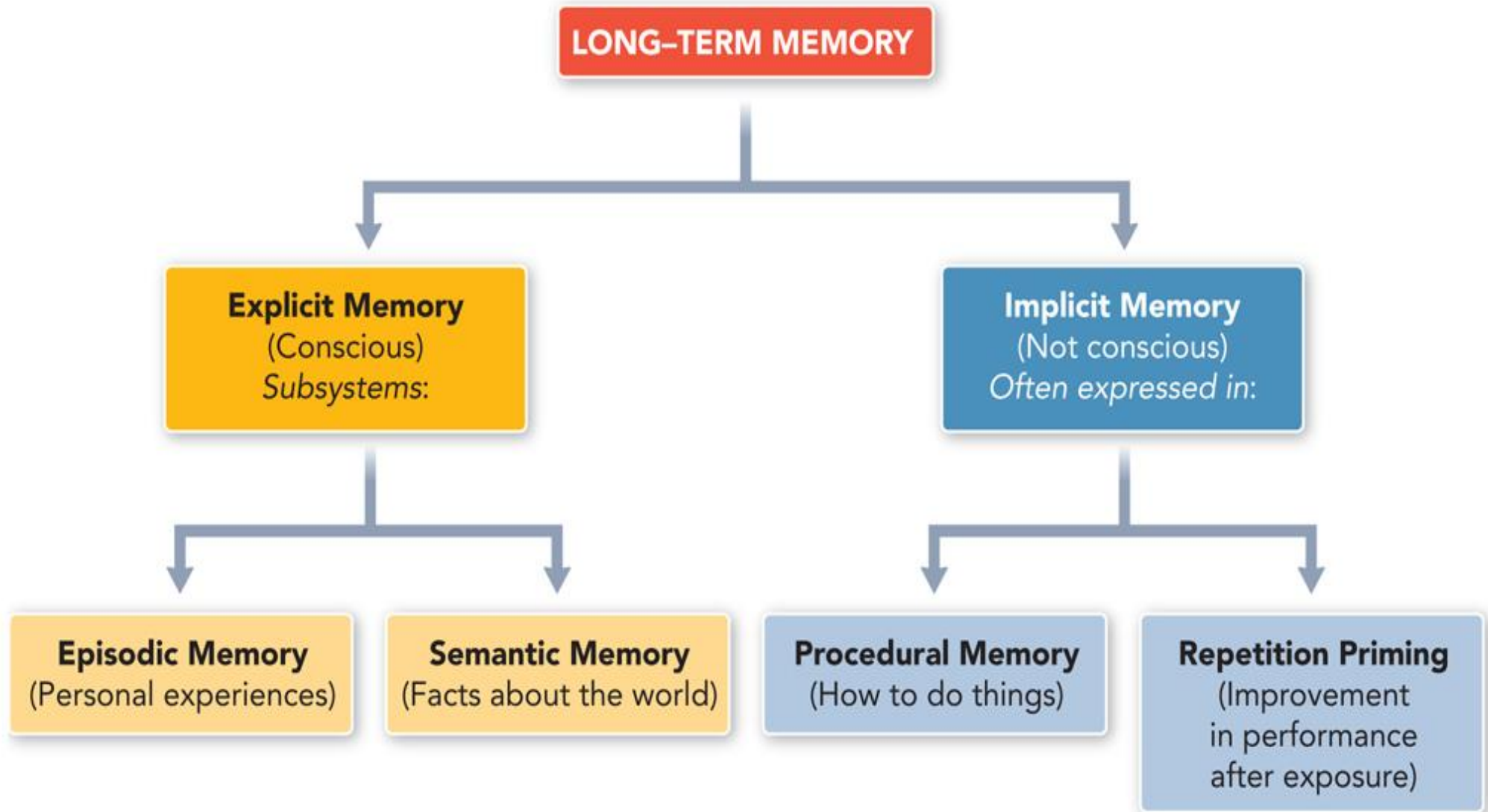
Learning as synaptic change

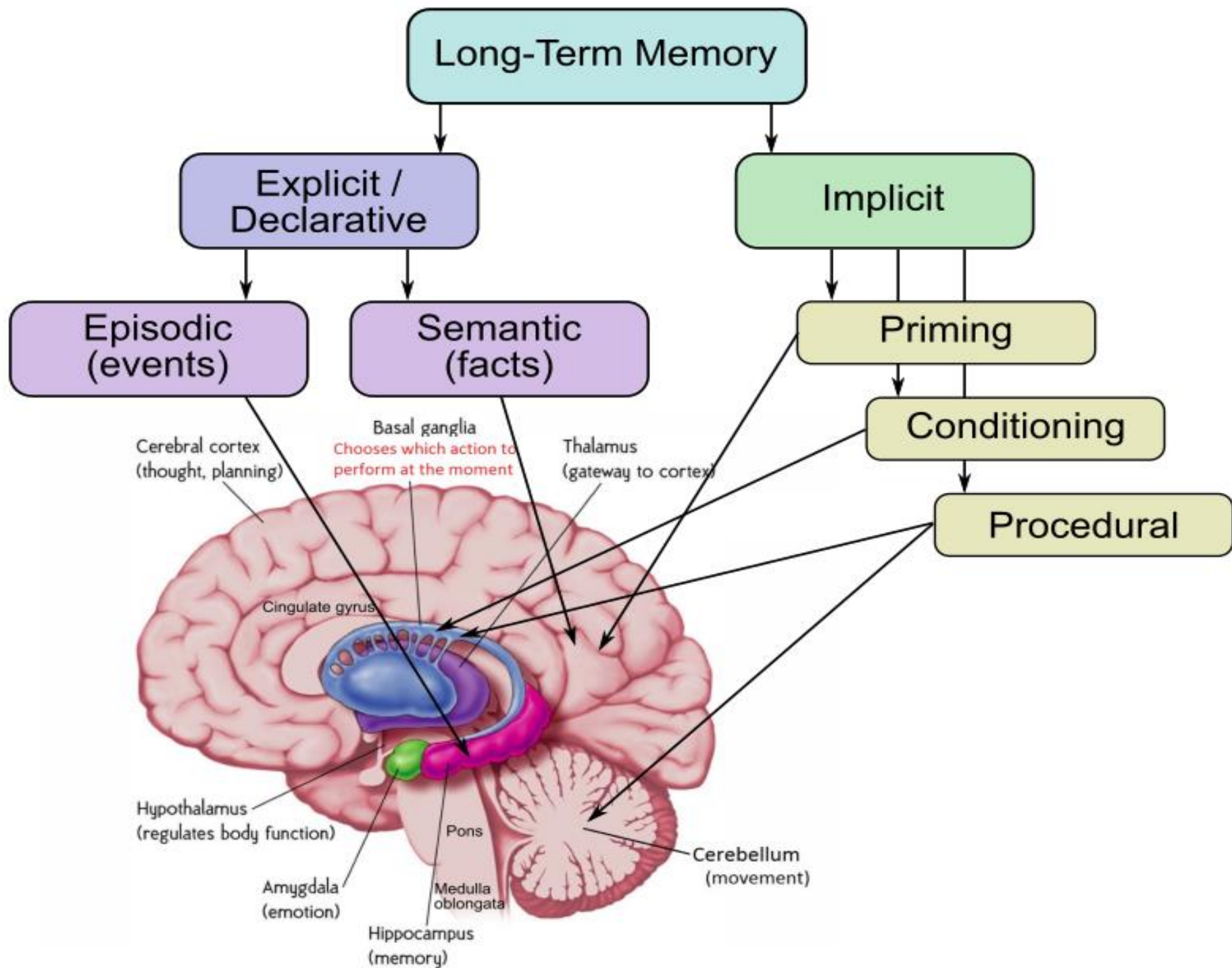


STM versus LTM: stages



Types of Long-Term Memory





Explicit LTM



(a) Semantic



(b) Episodic

Episodic memory

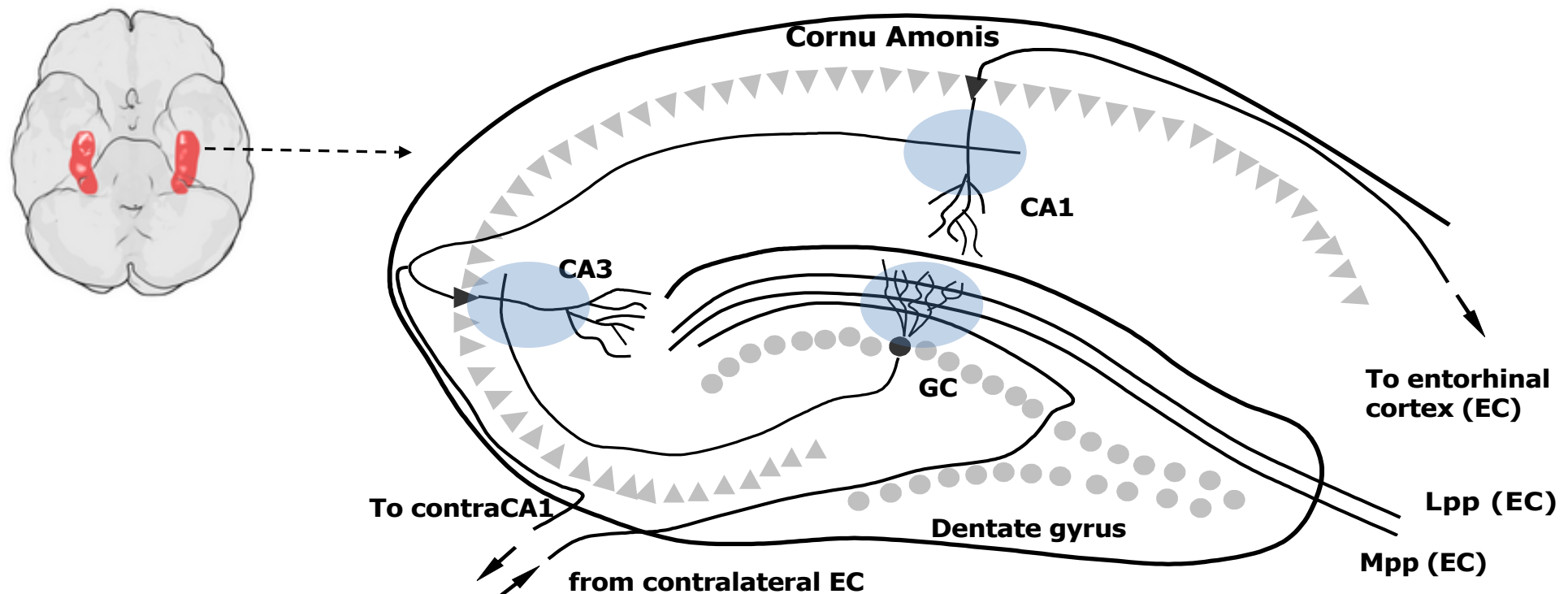
- Memory for specific episodes and events, e.g.
 - special times (holidays, games, trips, etc.)
 - or traumatic times (illness, loss, bullying, etc.)
 - what you had for dinner last night, and who you ate with, etc.
- All people with functioning **hippocampus** can encode everything that happens during our waking lives. We can remember certain events for the whole life.



"The tests show you're not losing your memory. Are you doing anything worth remembering?"

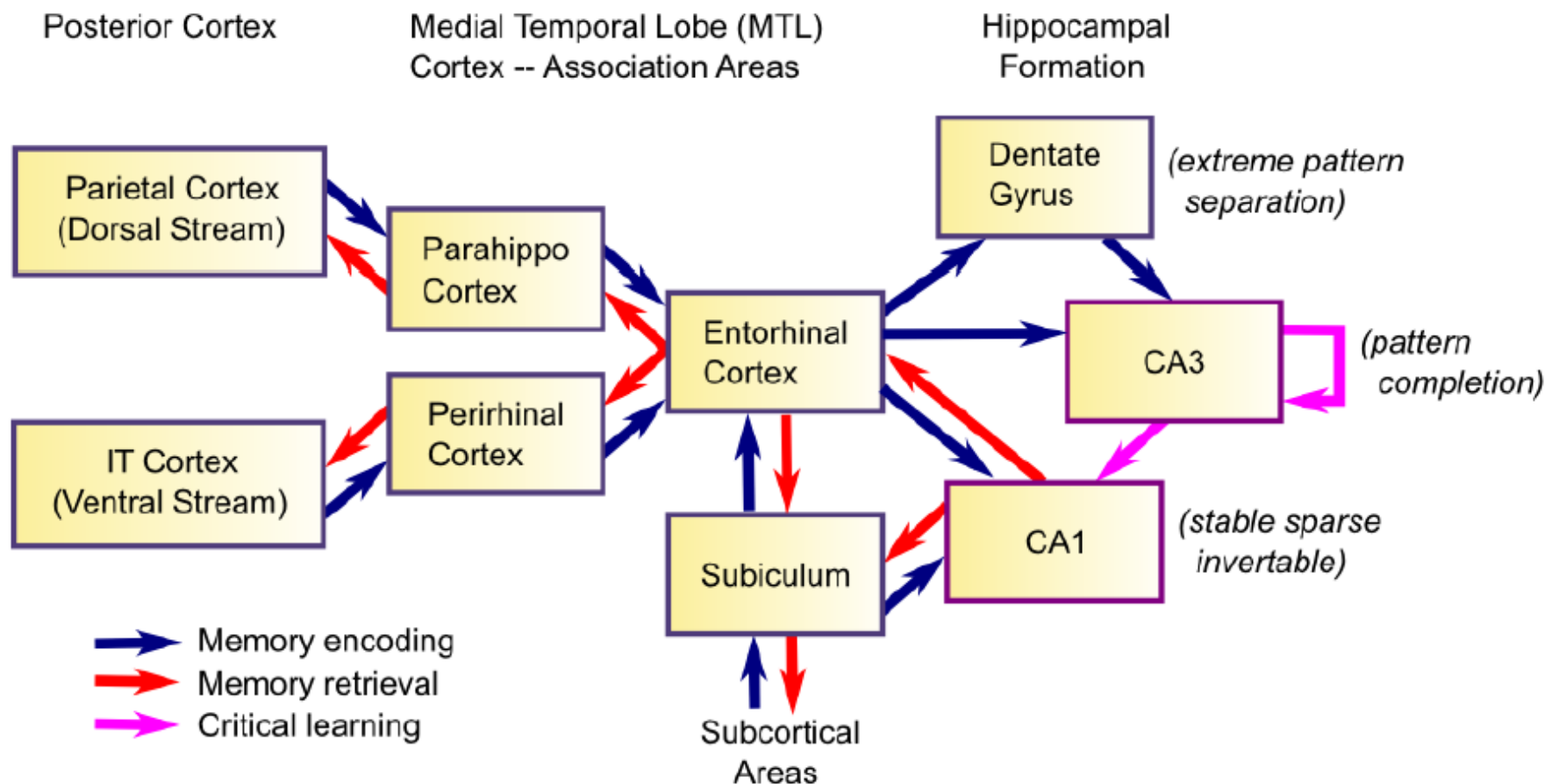
Hippocampus: the three-synaptic circuit

- **Input:** lateral perforant pathway (Lpp) and medial perforant pathway (Mpp) originating in the entorhinal cortex (EC) making synapses on **granule cells** (GC) **in the dentate gyrus** (DG) – first synapses.
- GC axons called mossy fibers make next synapses on **CA3** pyramidal cells.
- Axons of CA3 cells (Schaffer collaterals) synapse on **CA1 cells**, the axons of which are the output from hippocampus going back to EC.



Hippocampus: connections with the cortex

- Dorsal (parahippocampal) and ventral (perirhinal) cortical pathways converge into the EC, which is the input and output of the hippocampus.
- CA3 encodes the "engram" for the episodic memory, while CA1 provides an encoding for EC, such that subsequent recall of the CA3 engram activates CA1 and then EC, to reactivate the full episodic memory out into the cortex.

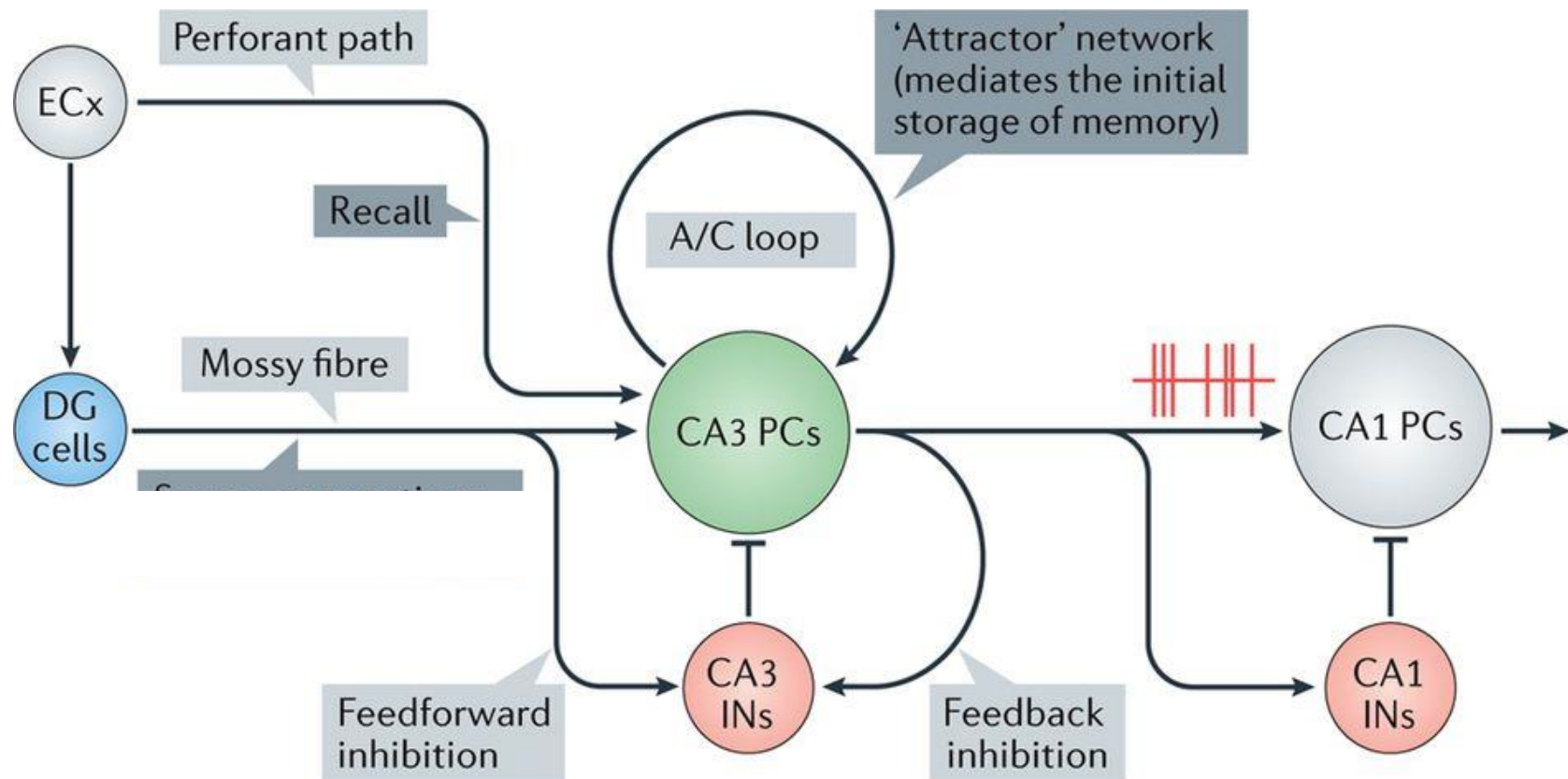


Hippocampus: encoding

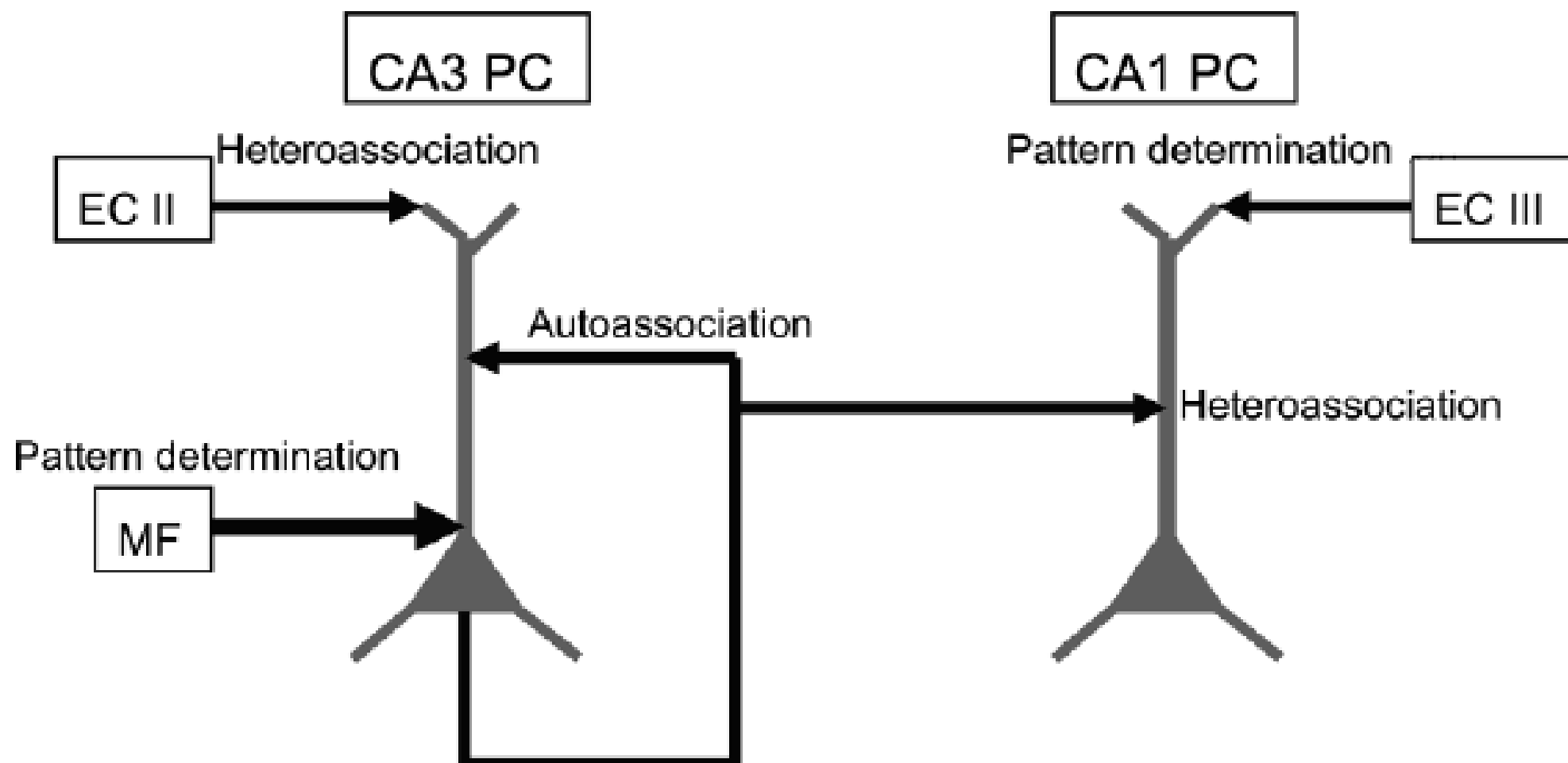
- The basic episodic memory encoding goes like this:
 - The high-level summary of everything in the cortex is activated in the EC, which then drives the GC via the perforant pathway and then the CA3 area through the mossy fibers -- the end result of this is a highly sparse, distinct pattern of neural firing in CA3, which represents the main "engram" of the hippocampus.
 - The output of CA3 cells via the Schaffer collaterals plus the EC fibers drive activity in CA1, which has the critical feature of being able to then re-activate this same EC pattern all by itself (i.e., an invertible mapping or auto-encoder relationship between CA1 and EC).

Dentate gyrus (DG), CA3 and CA1

- Internal connectivity in the CA3 subfield is richer than in other hippocampal regions. Recurrent axon collaterals of CA3 pyramidal cells ramify extensively making excitatory contacts with neighboring excitatory and inhibitory neurons (INs).



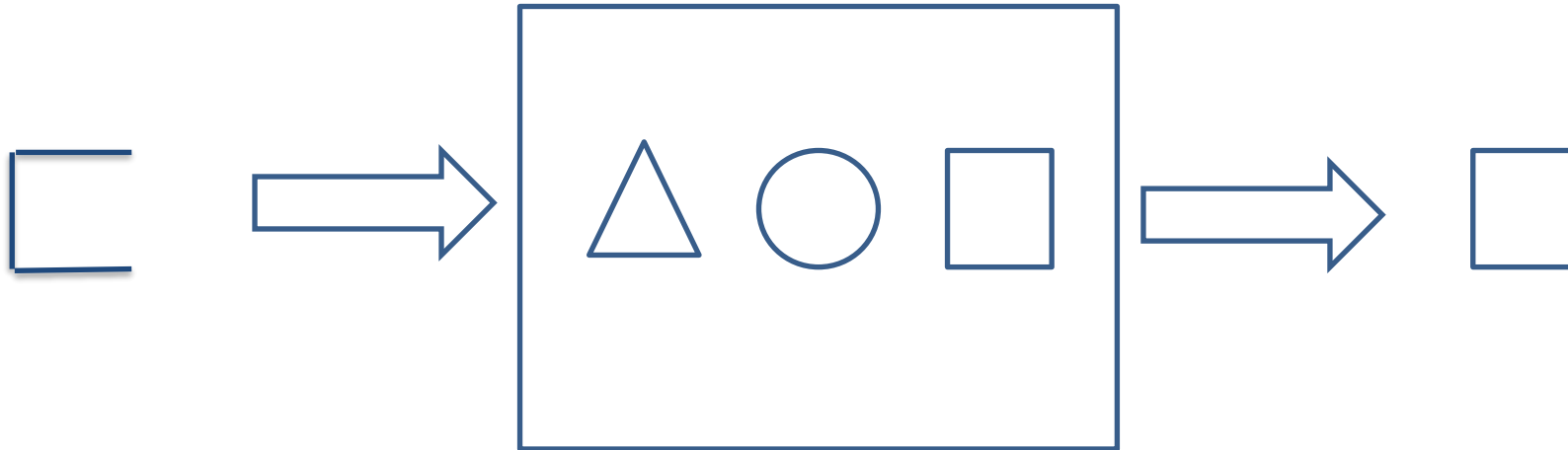
CA3 and CA1



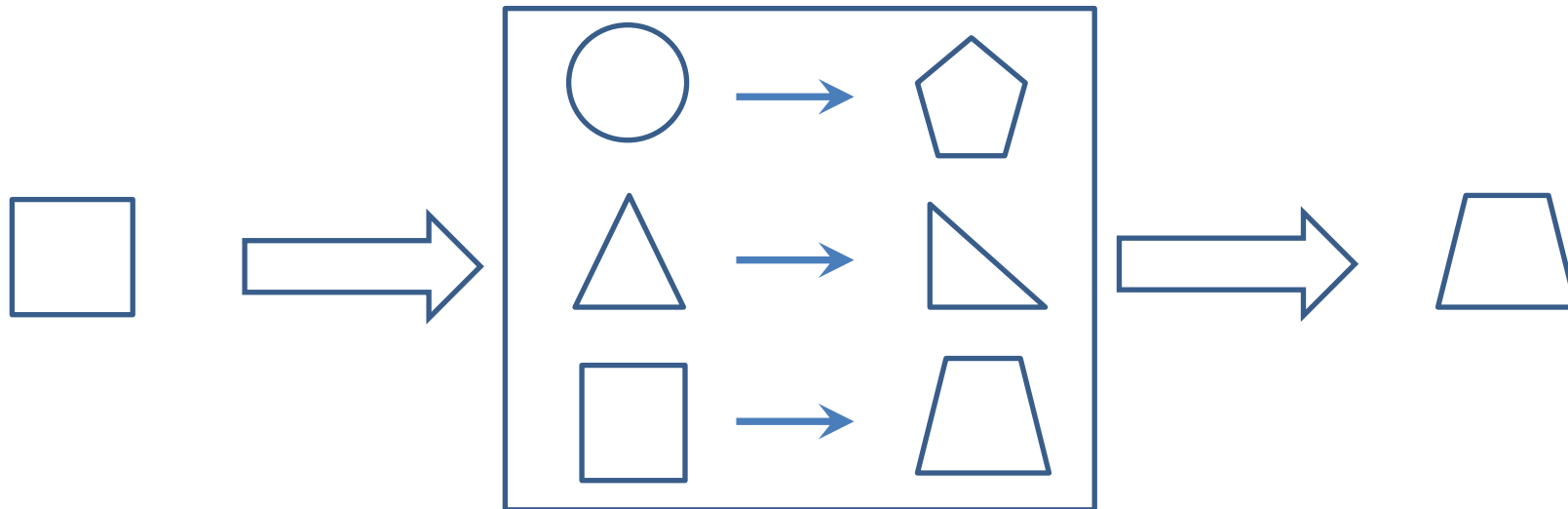
CA3 PC are pyramidal cells in the region CA3, CA1 PC are pyramidal cells in the region CA1, EC II means the 2nd layer of entorhinal cortex, EC III means the 3rd layer of entorhinal cortex, MF are mossy fibers, axons of granule cells.

Auto-association versus hetero-association

- **Auto-association** fills in the pattern, i.e., associates a pattern with itself

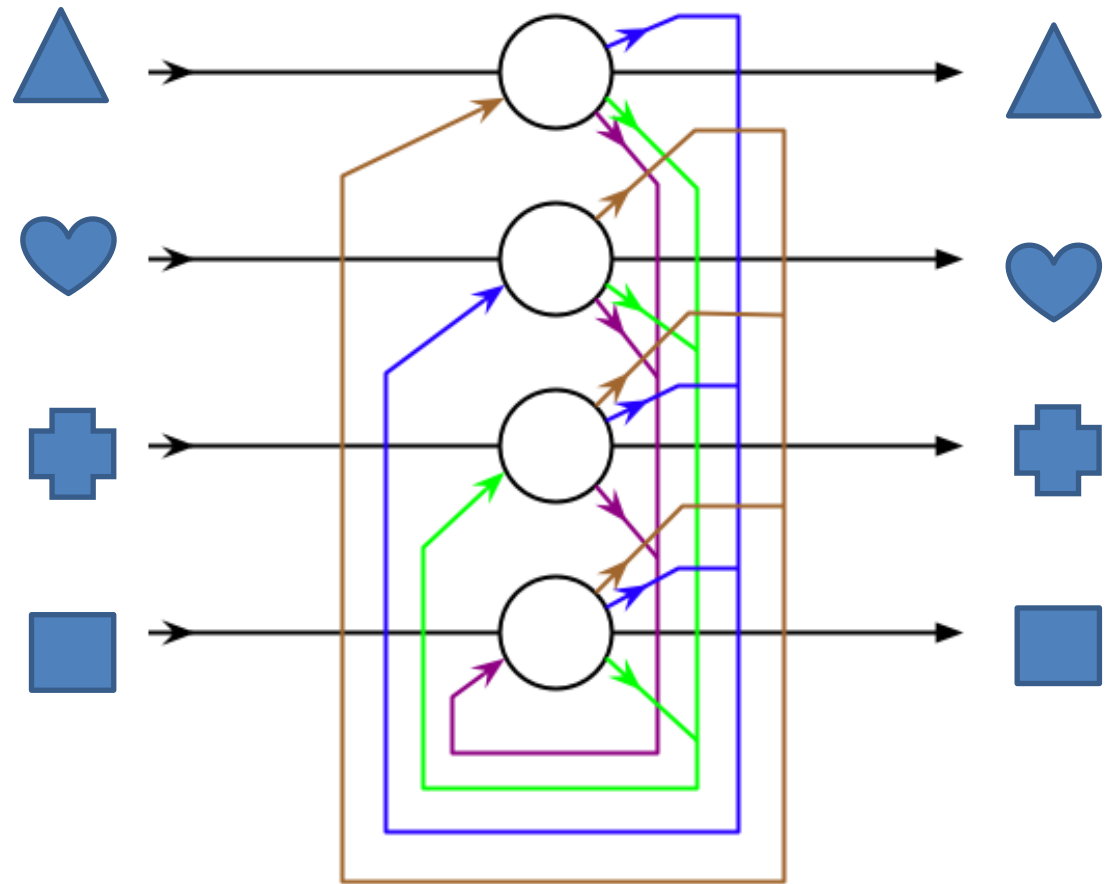


- **Hetero-association** associates one pattern with another one



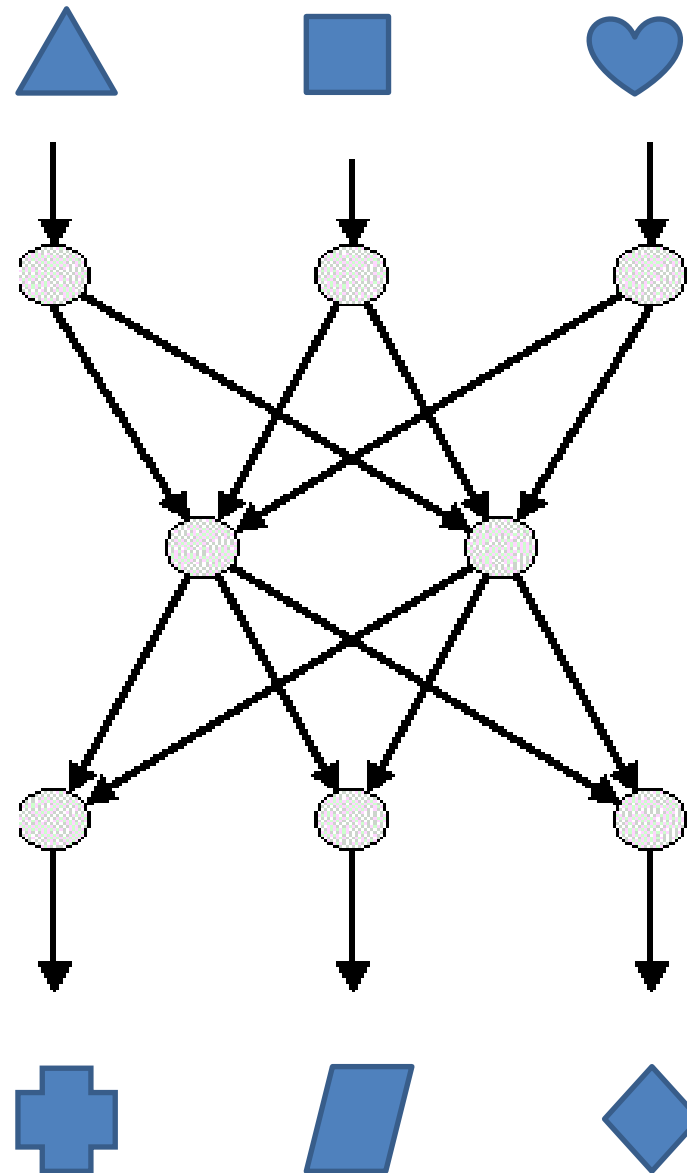
Auto-association: fully recurrent network

- Internal connectivity in the CA3 subfield is **richer** than in other hippocampal regions.
- **Recurrent** axon collaterals of CA3 pyramidal cells ramify extensively making excitatory contacts with both neighbouring excitatory and inhibitory neurons.



Hetero-association: feedforward network

- A typical architecture known as multilayer perceptron (MLP) contains a series of layers, composed of neurons and their **feedforward** connections.
- This is an architecture required for heteroassociation.

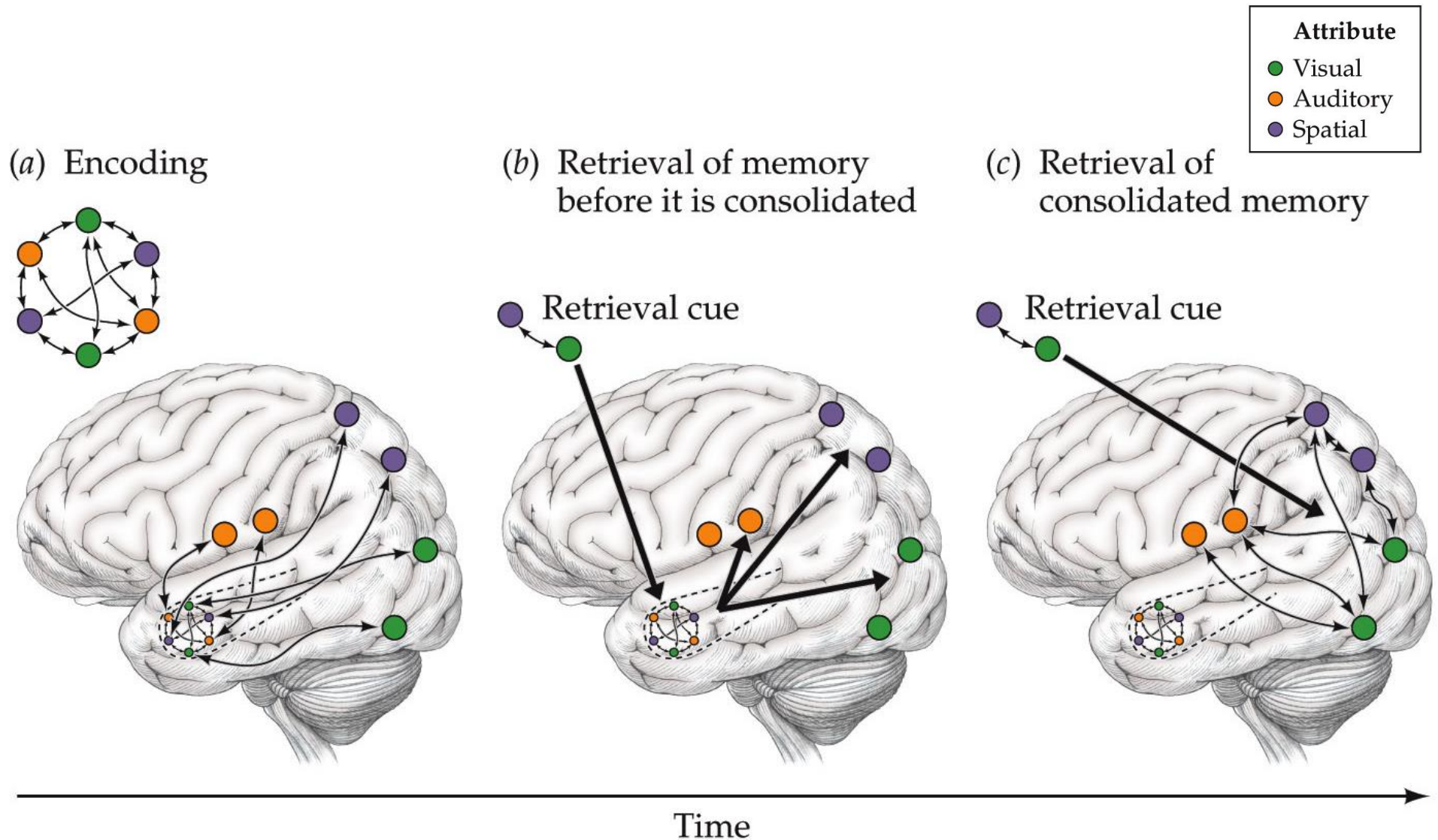


Hippocampus: learning

- These patterns of activity then drive synaptic plasticity (learning) in all the interconnected synapses, with the most important being the synaptic **connections among CA3 neurons** (in the CA3 recurrent pathway), and the **connections between CA3 and CA1** (the Schaffer collateral pathway).
- These plastic changes effectively "glue together" different neurons in the **CA3 engram**, and associate them with the CA1 activity pattern, so that subsequent retrieval of the CA3 engram can then activate the CA1, then EC, and back out to the cortex.
- Thus, the primary function of the hippocampus is to **bind together** all the disparate elements of an episode, and then be able to retrieve this memory and reinstate it out into the cortex during recall.

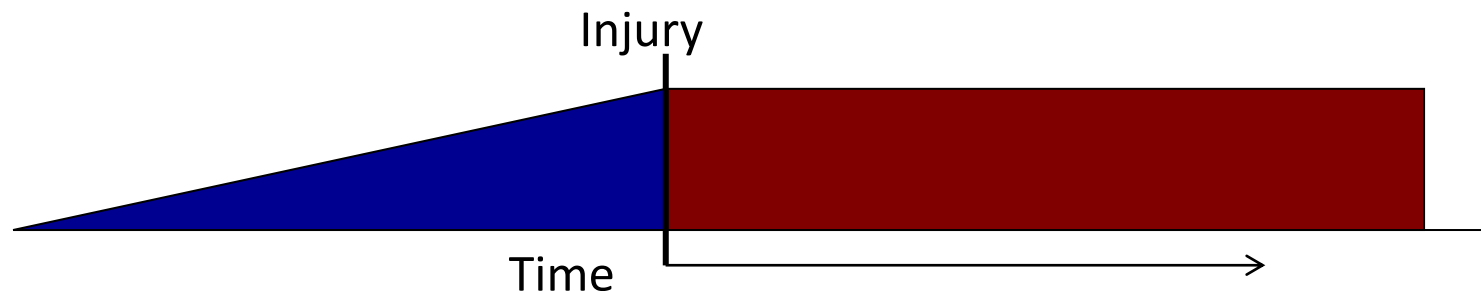
Interplay of the hippocampus and cortex

- Interplay between encoding, consolidation (months, years) and retrieval



Amnesia: loss of memory

- Three different aspects of amnesia
 - Source of the damage (e.g., illness, injury, surgery)
 - Location of the area of damage (hippocampus, cortex, etc.)
 - Functional deficit (i.e., what kind of memory is impaired)
- Two broad categories of functional deficit:
 - *Retrograde*: loss of memories for events prior to damage (cortical damage)
 - *Anterograde*: loss of ability to store new memories of events after damage (hippocampal damage)



Priming

- Phenomenon in which the introduction of one stimulus affects how people respond to the next stimulus. **Priming works by activating an association in memory just before another stimulus or task is introduced.** This phenomenon occurs without our conscious awareness or intention.
- For example, exposing someone to the word "yellow" will evoke a faster response to the word "banana" than it would to unrelated words like "television." Because yellow and banana are more closely linked in memory, people respond faster when the second word banana is presented.
- Priming can work with stimuli that are related in a variety of ways. For example, priming effects can occur with perceptually, linguistically, or conceptually related stimuli.

Semantic, associative and conceptual priming

- **Semantic priming** involves words that are associated in a logical way. The earlier example of responding to the word "banana" more rapidly after being primed with the word "yellow" is an example of semantic priming.
- **Associative priming** involves using two stimuli that are normally associated with one another. For example, "cat" and "mouse" are two words that are often linked with one another in memory, so the appearance of one of the words can prime the subject to respond more rapidly when the second word appears.
- **Conceptual priming** involves a stimulus and response that are conceptually related. Words such as "seat" and "chair" are likely to show priming effects because they are in the same conceptual category.

Perceptual, repetition and negative priming

- **Perceptual priming** involves stimuli that have similar forms. For example, the word "goat" will evoke a faster response when it is preceded by the word "boat" because the two words are perceptually similar.
- **Repetition priming** occurs when a stimulus and response are repeatedly paired. Because of this, subjects become more likely to respond in a certain way more quickly each time the stimulus appears.
- Positive and negative priming describes how priming influences processing speed. Positive priming makes processing faster and speeds up memory retrieval. **Negative priming** is a slow down in response speed and an increase in error rate when responding to an object that **had to be ignored** previously.

Priming web: example

- The lines in this web indicate associations that an individual might have. **Solid** lines denote **associative** priming while **dashed** lines denote a **perceptual** one.

