Memory & Learning

SPICE 2024

Neuroscience & Computational Psychiatry Module
Class VI

8th of July 2024

Mount Sinai

Center for Computational Psychiatry

Memory

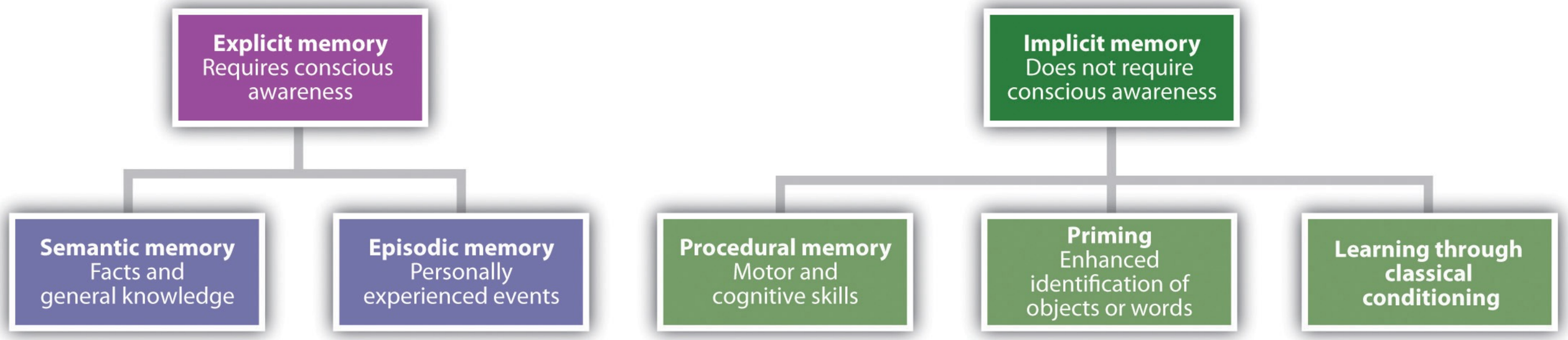
1. As types
- Explicit memory
- Implicit memory

2. As stages
- Sensory memory
- Short-term memory
- Long-term memory

3. As processes
- Encoding
- Storage
- Retrieval

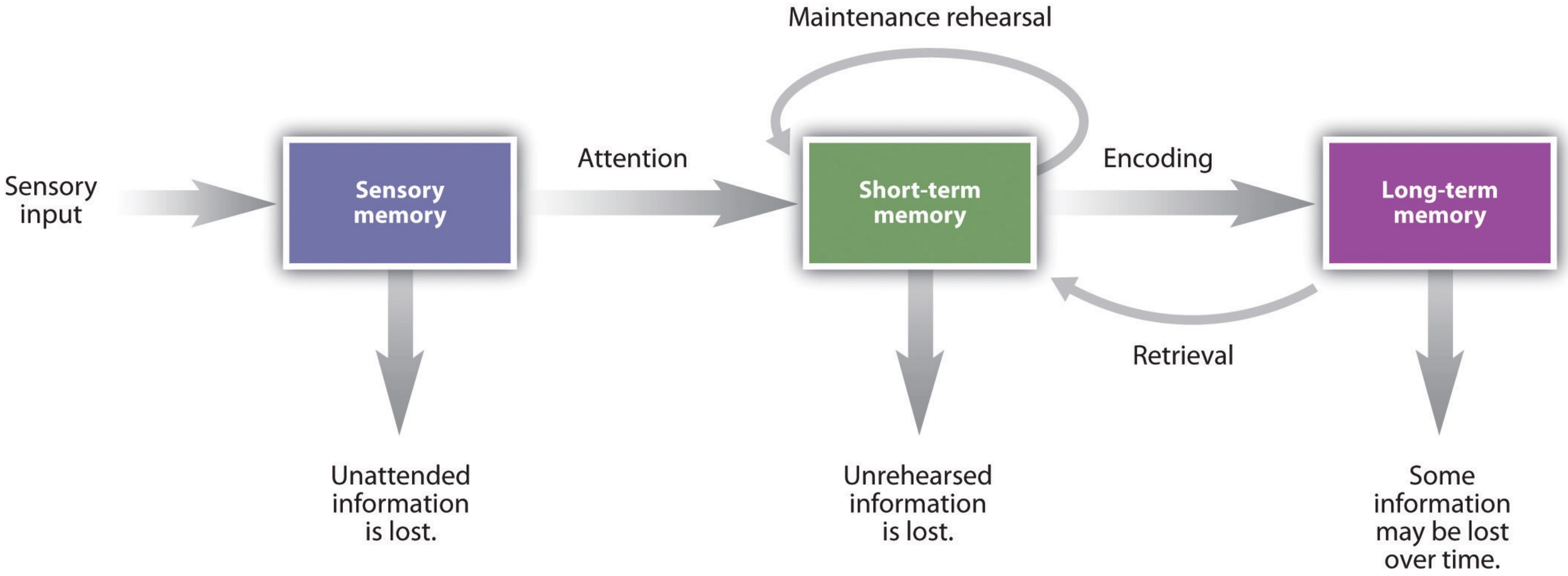
Image: Malte Mueller

Memory as types: explicit & implicit memory



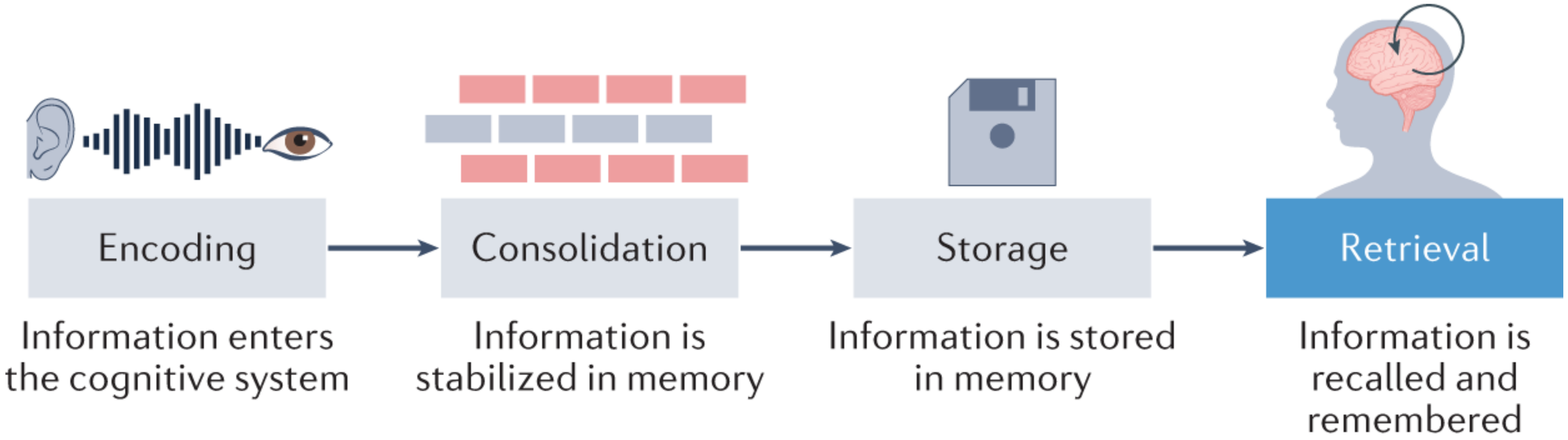
Images: Charles Stangor, 2014; BC Campus

Memory as stages



Images: Charles Stangor, 2014; BC Campus

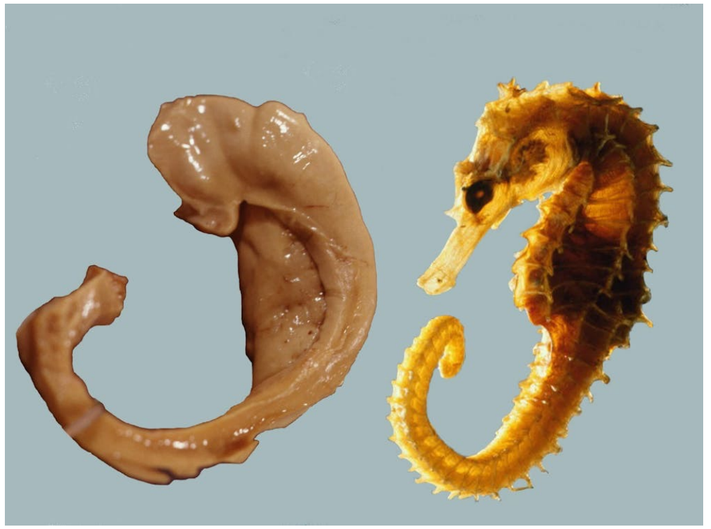
Memory as processes

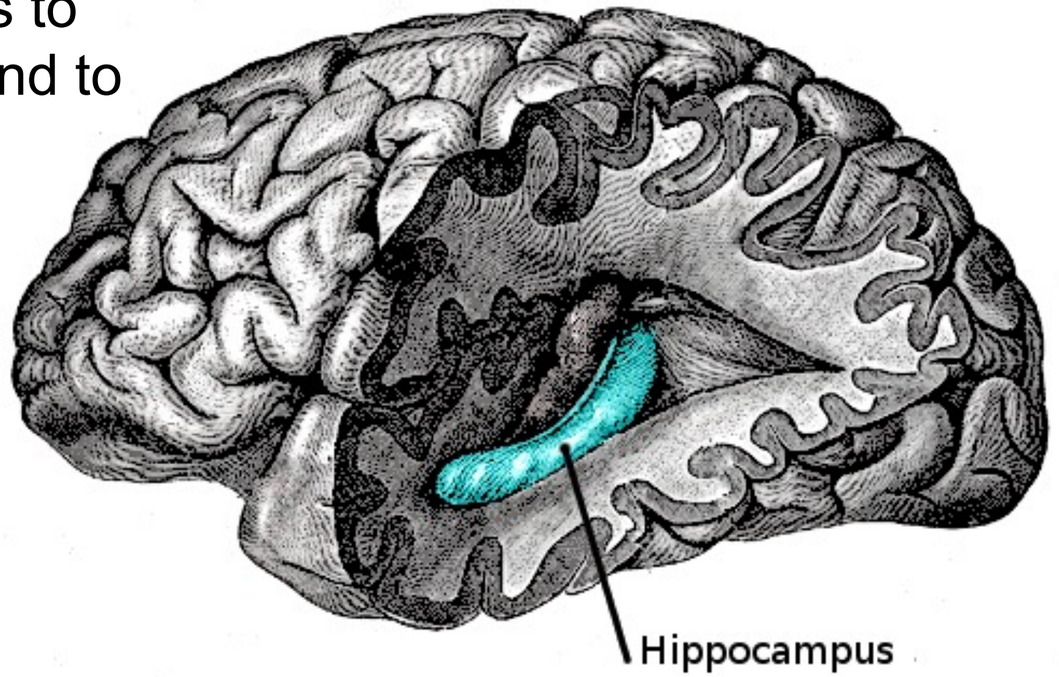


Images: Roediger & Abel, 2022

The hippocampus

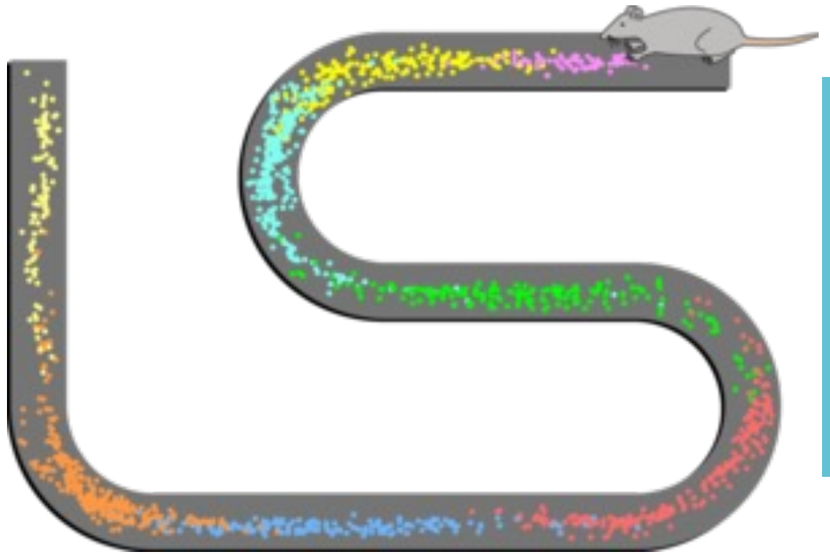
- In the middle of the brain: **medial temporal lobe**
- **Consolidates** memories
- Important for navigation
- Damage to the hippocampus leads to trouble **forming new memories** and to **navigate**

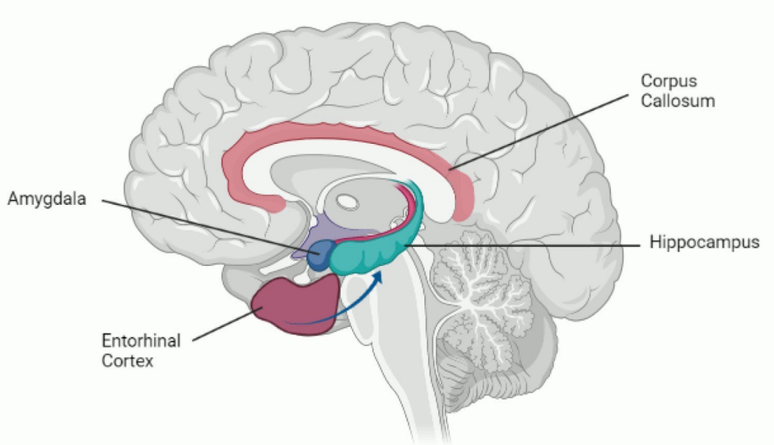




Images: Wikipedia

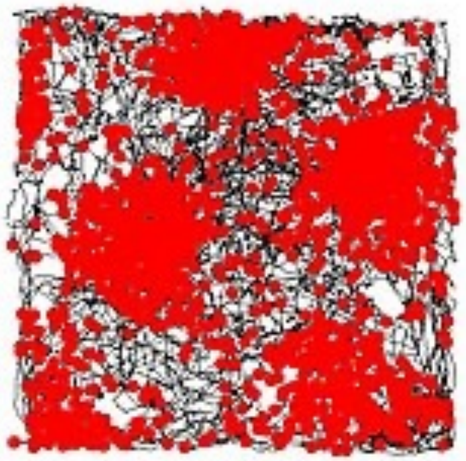
The hippocampus – place cells





Place cells: Cells that help determine spatial location and allow navigation from one place to another.

Grid cells:
Neurons within the entorhinal cortex, fire at regular intervals when navigating an open area

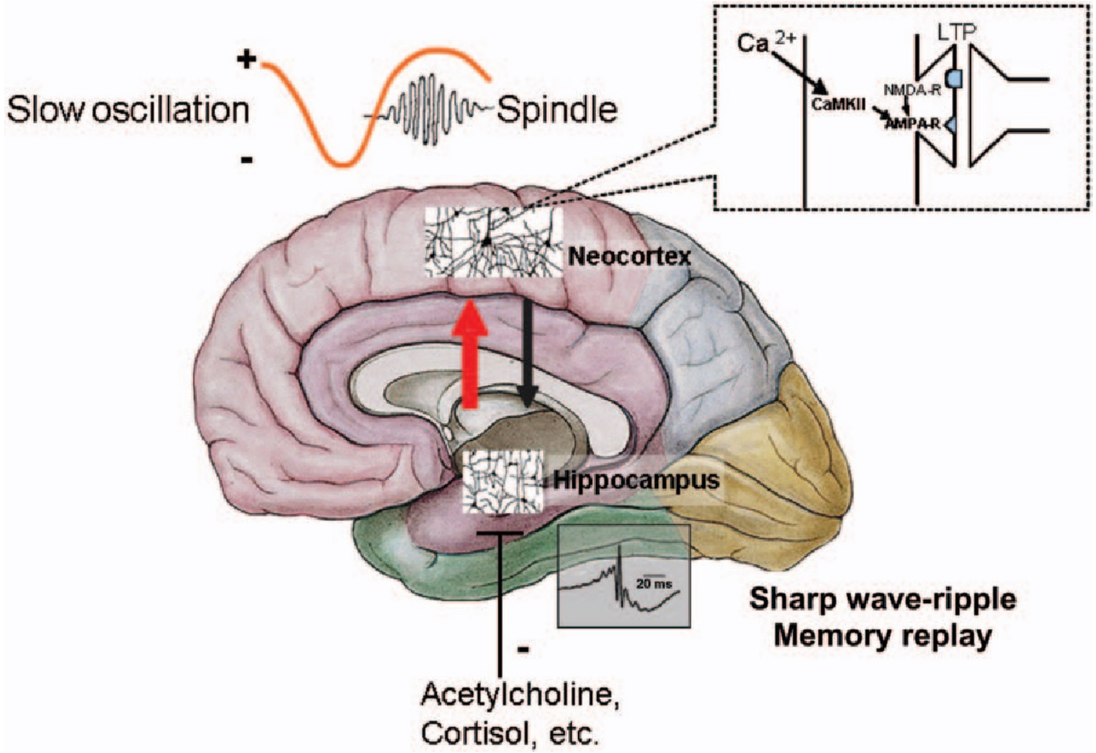


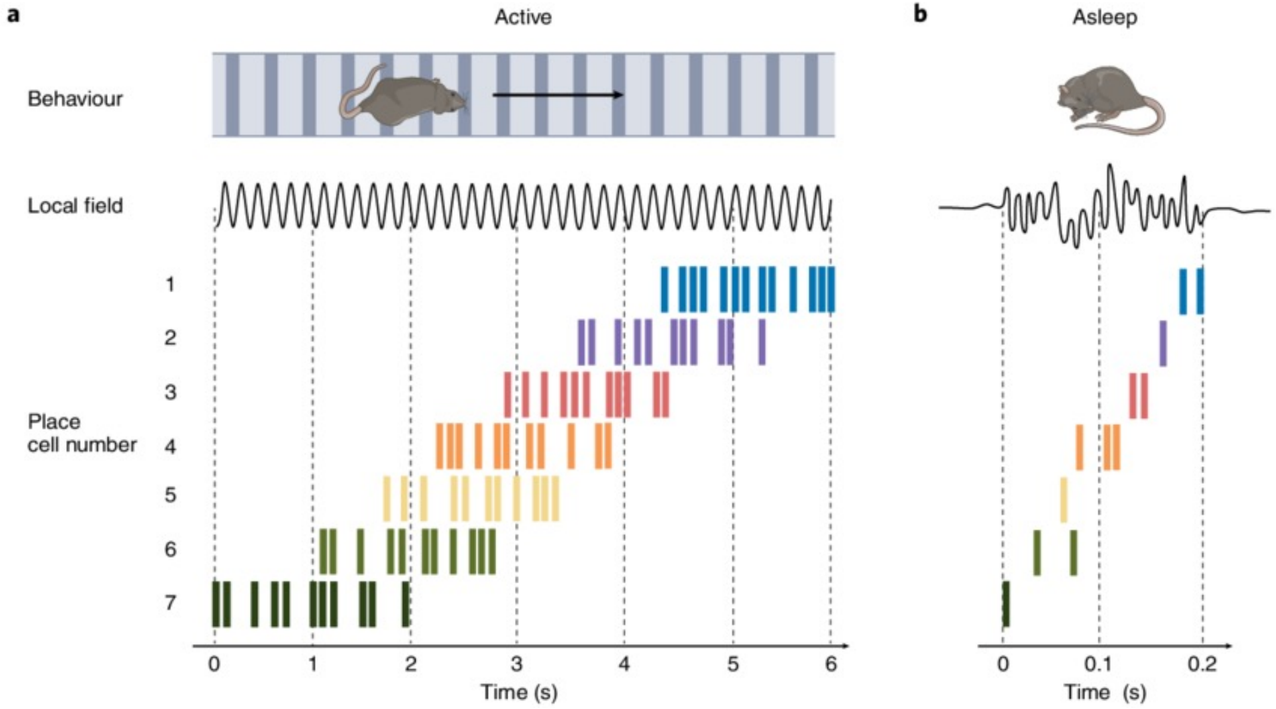
Images: Wikipedia; Brain and Life Magazine

Hippocampus

Encoding of New Memories

Memory **Consolidation**



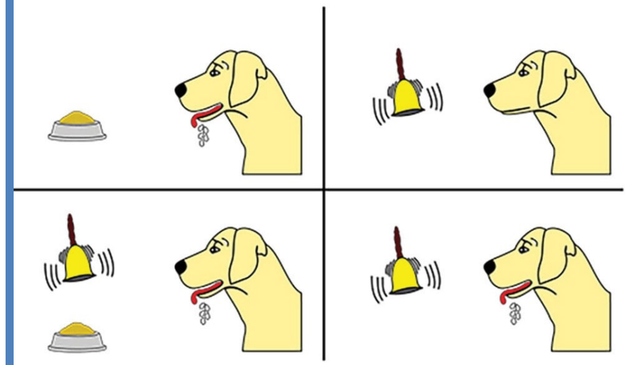


Role of **Replay** in Consolidation

- Sharp-wave ripples
- Synchronization with neocortex
- Strengthening synaptic connections

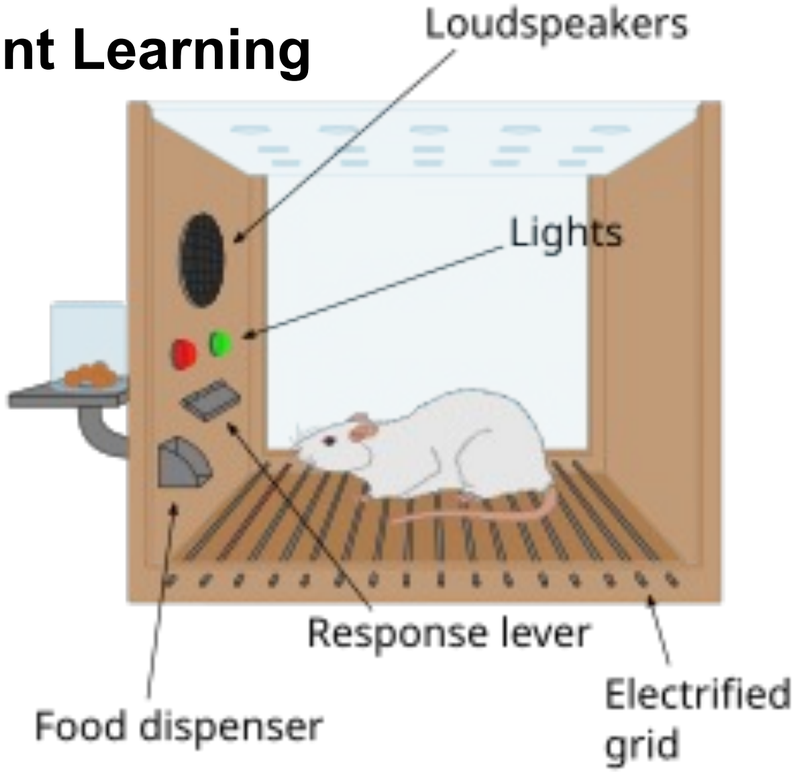
Images: Semantic Scholars; Kudithipudi et al., 2022

Learning



Conditional Learning
(classical conditioning)

Operant Learning



Operant Conditioning

Reinforcement
Increase behavior

Positive
Add appetitive stimulus following correct behavior
Giving a treat when a dog sits

Negative
Remove noxious stimuli following correct behavior
Turning off an alarm clock by pushing the snooze button

Active Avoidance
Behavior avoids noxious stimulus
Studying to avoid getting a bad grade

Punishment
Decrease behavior

Positive
Add noxious stimuli following behavior
Spanking a child for cursing

Negative
Remove appetitive stimulus following behavior
Sending a child to his room for cursing

Images: Structual Learning; Wikimedia

Rescola-Wagner Model

$$\Delta V = \alpha\beta(\lambda - V)$$

Prediction Error or PE

- ΔV: Change in associative strength.
- α: Learning rate for the CS (bell).
- β: Learning rate for the US (food).
- λ: Maximum associative strength (actual strength of the US).
- V: Current associative strength (prediction of the US by the CS).

Dopaminergic prediction errors (PEs)

- Prediction error: $\lambda - V = 1 - 0.2 = 0.8$.
- Change in associative strength: $\Delta V = 0.5 \times 0.5 \times 0.8 = 0.2$.

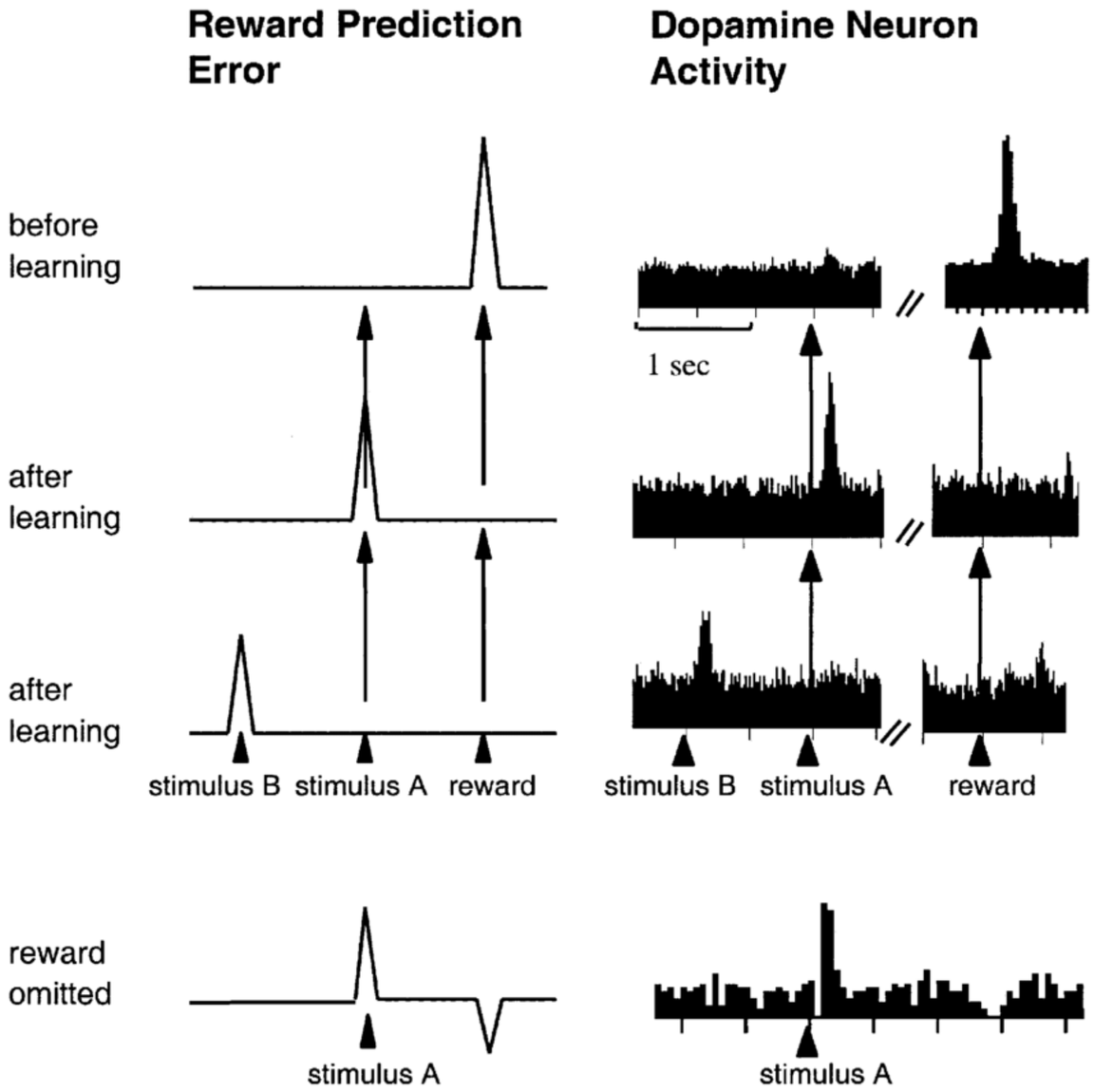


Image: Suri, 2022

Model-based and model-free reinforcement learning (RL)

Model-Free Reinforcement Learning: Relies on updating values based on prediction errors without a cognitive map of the environment.
Prediction Errors: Differences between expected and received outcomes.

- **Value Functions**: Representation of the expected reward of actions or states.
- **Habit Formation**: Behavior becomes automatic with repeated actions.

Important Brain Areas:

- **Dorsal Striatum**: Involved in habit formation and procedural learning.
- **Dopaminergic System**: Ventral tegmental area (VTA) and substantia nigra for reward prediction.

Model-Based Reinforcement Learning: Involves building a cognitive map of the environment and planning based on anticipated future states.

- **Cognitive Map**: Internal representation of the environment and relationships between states.
- **Planning**: Evaluating possible future actions and outcomes before making decisions.
- **Flexible Adaptation**: Ability to adjust behavior based on new information and changing circumstances.

Important Brain Areas:

- **Prefrontal Cortex (PFC)**: Dorsolateral PFC for planning and decision-making.
- **Hippocampus**: Spatial navigation and memory formation.
- **Anterior Cingulate Cortex (ACC)**: Monitoring outcomes and adjusting behavior.

Thank you!

Any Questions?

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Next Class:

Tuesday the 9th of July

9:30am-10:30am

Characterizing a psychiatric symptom dimension related to deficits in goal-directed control

Claire M Gillan ✉, Michal Kosinski, Robert Whelan, Elizabeth A Phelps, Nathaniel D Daw

New York University, United States; University of Cambridge, United Kingdom; Stanford University, United States; University College Dublin, Ireland; Nathan Kline Institute, United States; Princeton University, United States