COMS30017
Computational Neuroscience

Week 5 / Video 1 / The Hippocampus and long-term memory

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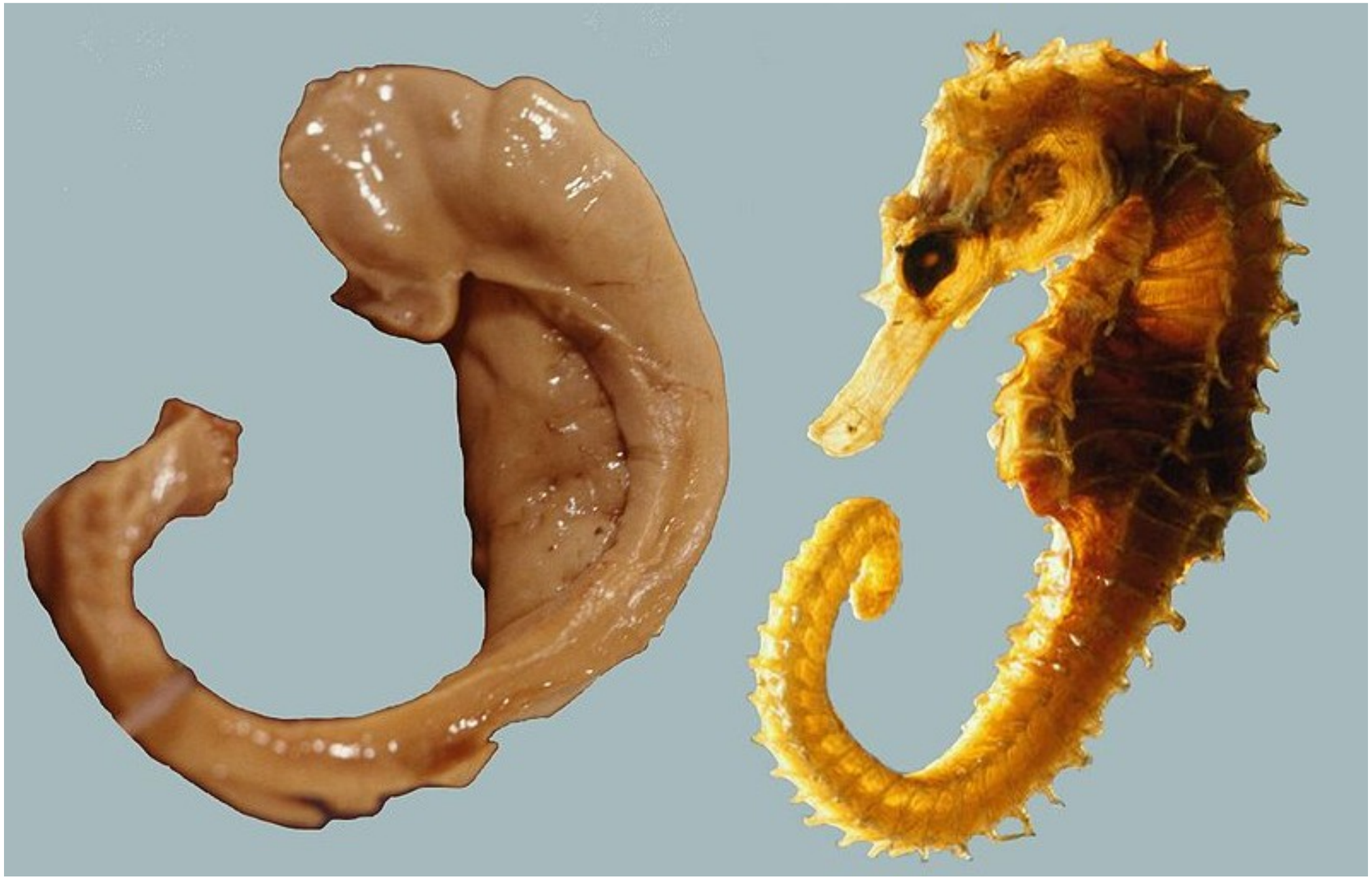
slides adapted from Dr. Cian O'Donnell

Intended Learning Outcomes

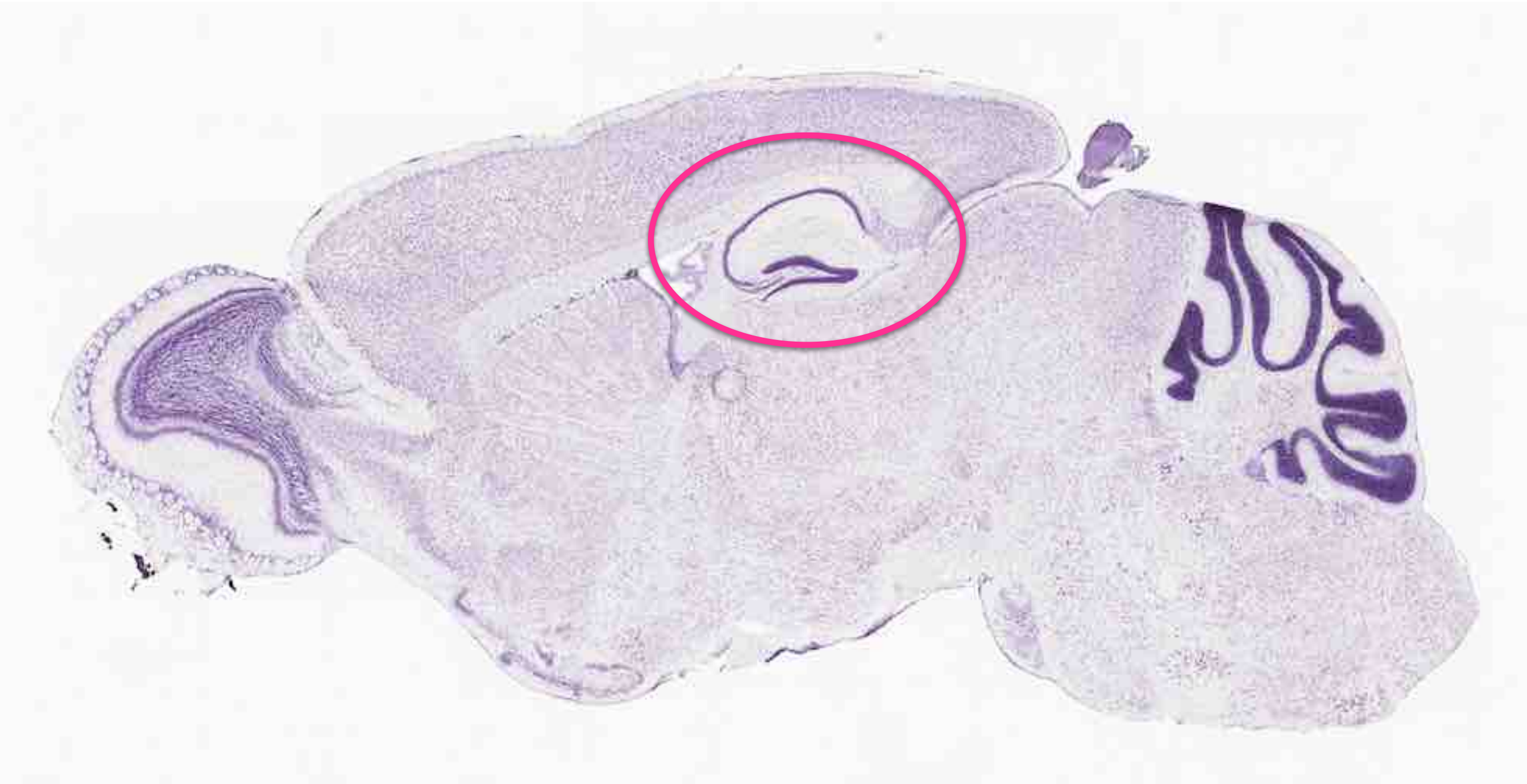
- Anatomy of the hippocampus.
- Hippocampus and long-term memory

Hippocampus, from the greek words for “horse" and “sea-monster”



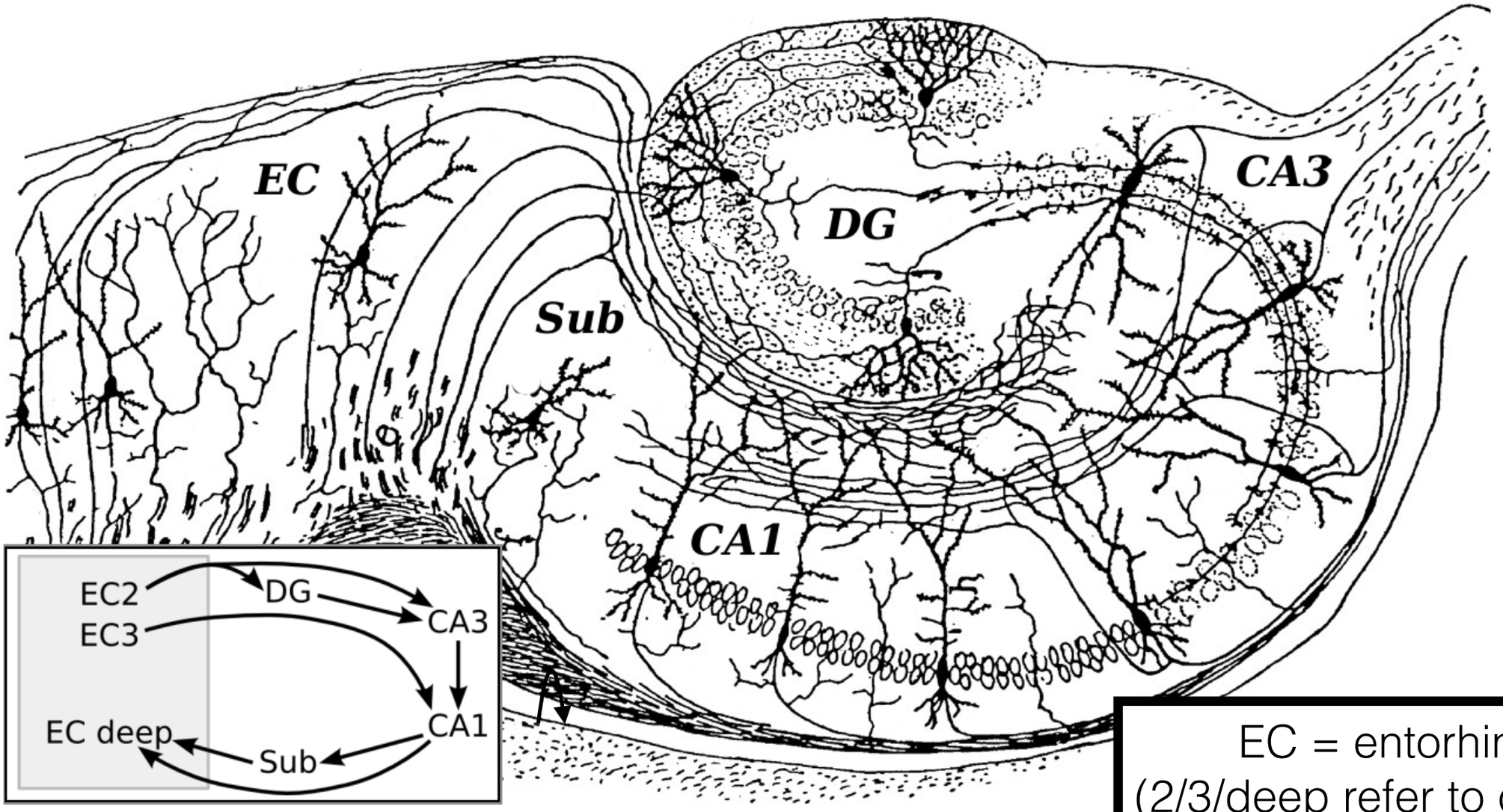
https://en.wikipedia.org/wiki/Hippocampus#/media/File:Hippocampus_and_seahorse_cropped.JPG

Anatomy of the hippocampus



https://mouse.brain-map.org

Anatomy of the hippocampus



EC = entorhinal cortex
(2/3/deep refer to cortical layers)
DG = dentate gyrus
CA = (*Cornu Ammonis,* but no on ever uses this…)

Original drawing by Ramon y Cajal (circa 1900)
https://en.wikipedia.org/wiki/Hippocampus#/media/File:CajalHippocampus_(modified).png

The tri-synaptic loop

- Information flows in a mostly feed-forward way through the hippocampus.

- Entorhinal cortex is sometimes described as “the gateway to the hippocampus” (most external signals to the hippocampus are routed via the EC).

- Inside the hippocampus, information propagates along the “trisynaptic loop”:
  - dentate gyrus → CA3 → CA1 → subiculum

- CA3 is the only subregion with substantial recurrent excitatory connectivity (may be mediating attractor networks).

What does the hippocampus do?

At least two main functions:

1. Long-term memory

2. Spatial navigation

1. Hippocampus and memory

Hippocampus and memory

- Patient HM (who had his hippocampus surgically removed) could not form new long-term memories, and also had time-limited retrograde amnesia.

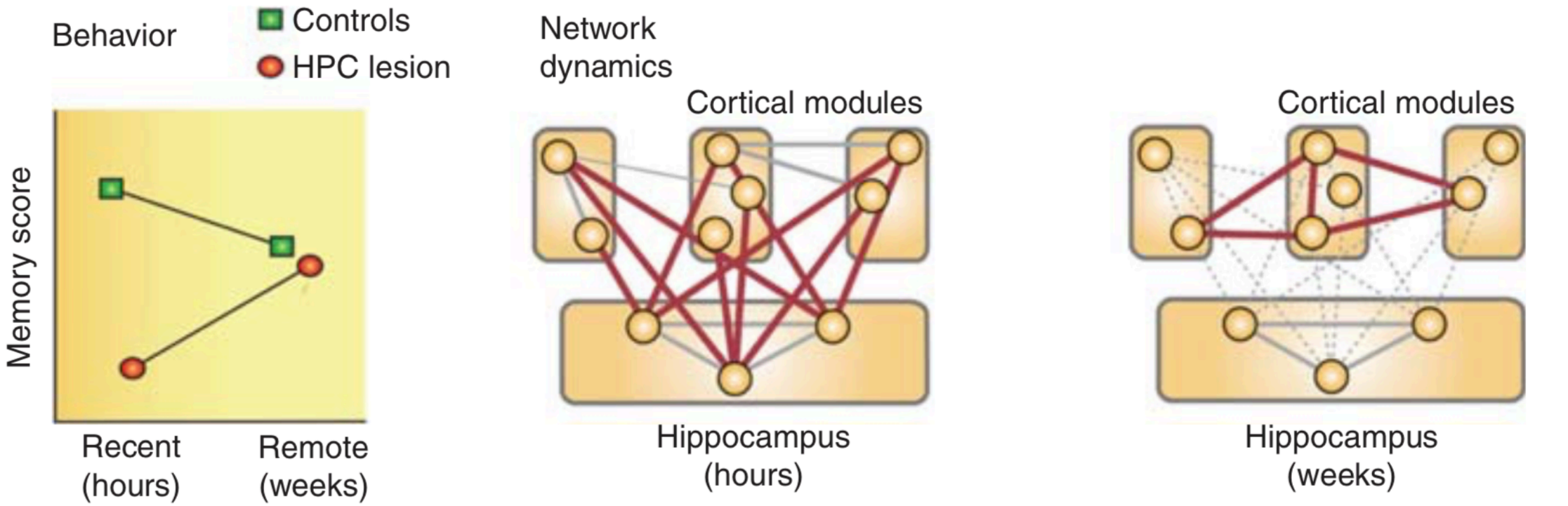
- The hippocampus is specifically needed for encoding new episodic memories, but is not necessary for other memories (e.g. procedural).

    - Episodic memories = “a conscious memory of a previous experience”

    - Procedural memories = “knowing how to do things, also known as motor skills”

- Memory encoding requires synaptic plasticity in the hippocampus.

Systems consolidation for memory



Squire et al. Cold Spring Harb Perspect Biol 7, a021766.

- New episodic memories are mainly encoded in hippocampus during the day.
- During subsequent sleep, hippocampus replays the neural activity encoding the memory and triggers learning in the cortex.
- Over time, cortex learns the memories, and they become hippocampus-independent.

Hippocampus is needed for forming episodic memories

Long-term memory types

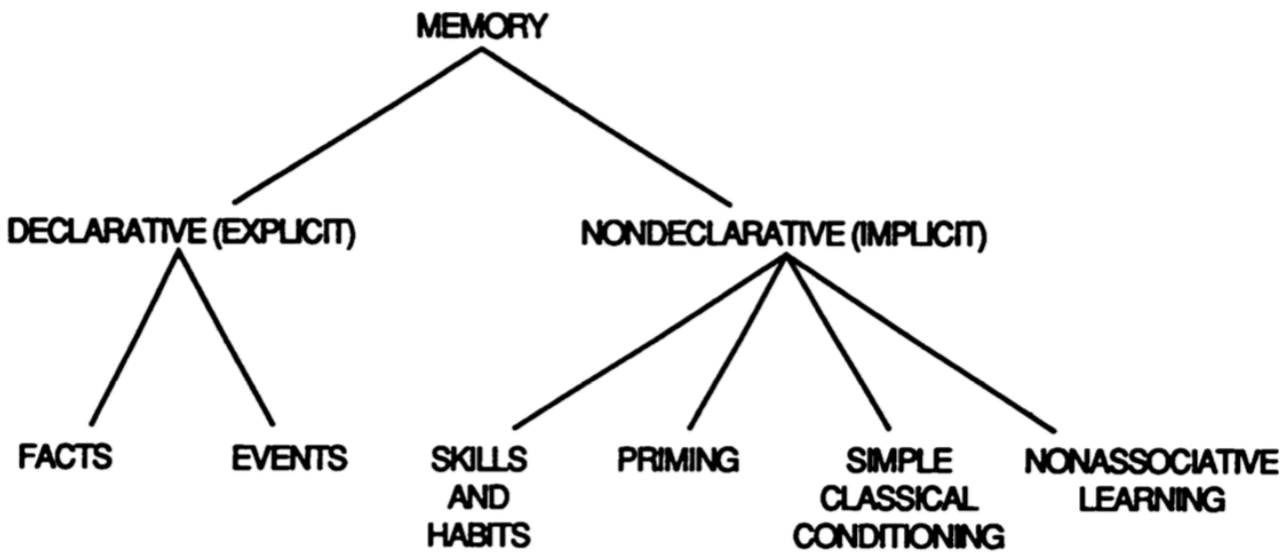
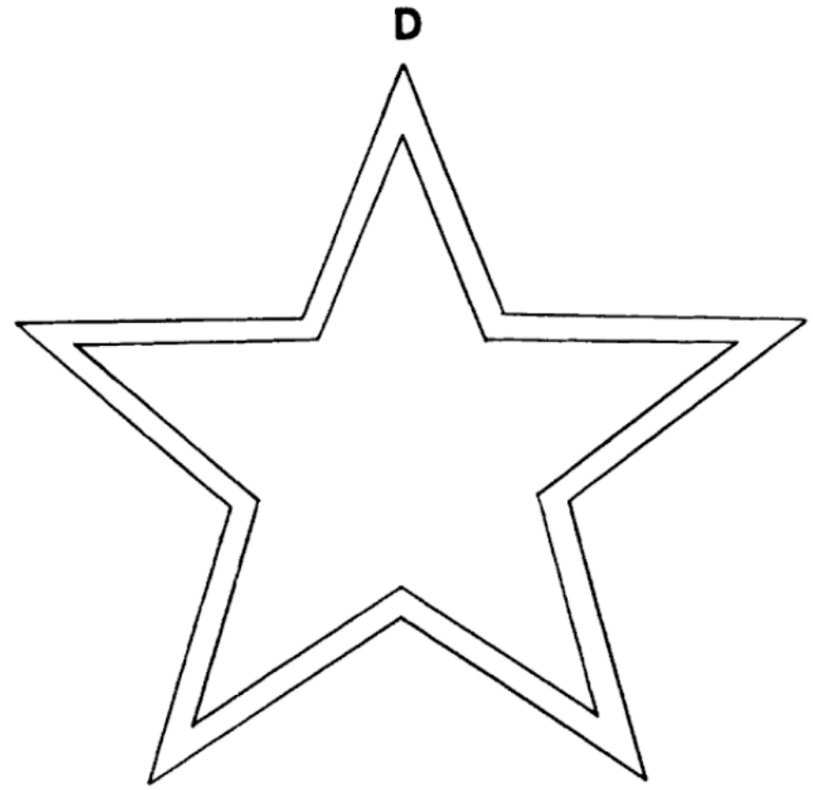


Fig. 3. Classification of memory. Declarative (explicit) memory refers to conscious recollections of facts and events and depends on the integrity of the medial temporal lobe (see text). Nondeclarative (implicit) memory refers to a collection of abilities and is independent of the medial temporal lobe (*60*). Nonassociative learning includes habituation and sensitization. In the case of nondeclarative memory, experience alters behavior nonconsciously without providing access to any memory content (*19, 20*).

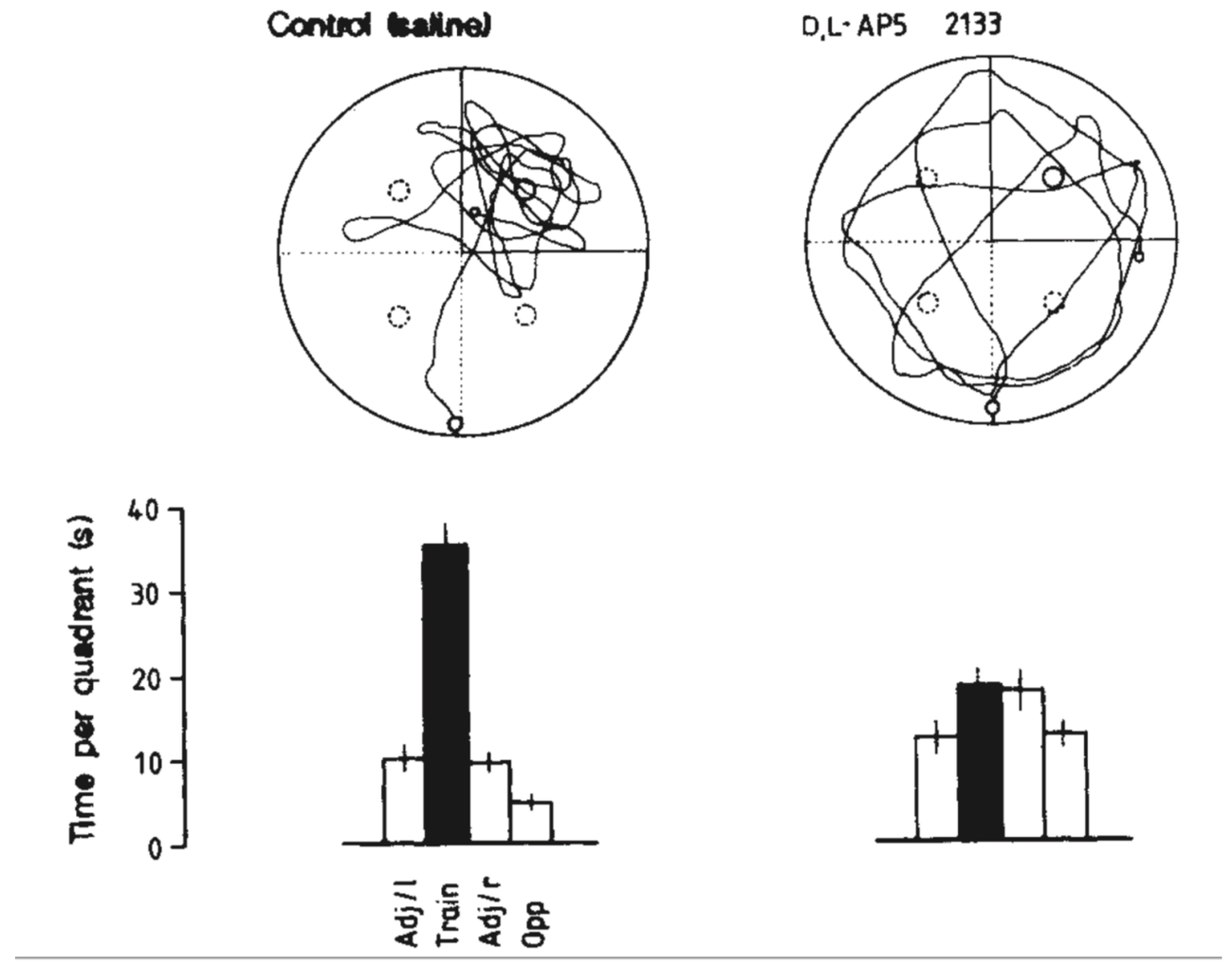
Squire & Zola-Morgan, *Science* 1991

H.M. could form new motor memories



Milner (1962)

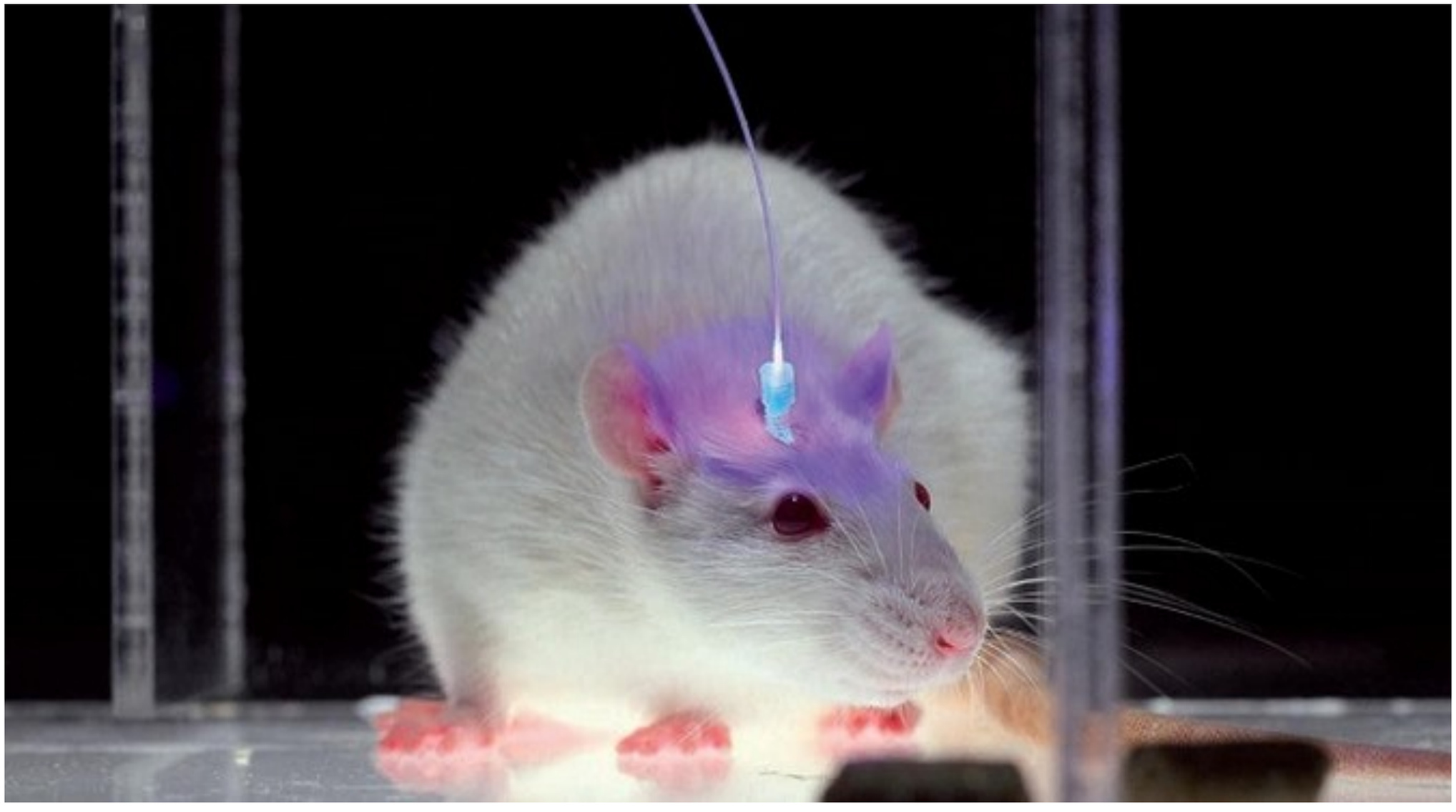
Synaptic plasticity in the hippocampus is needed for learning



Morris et al, *Nature* 1986

- A drug that blocks NMDA receptors blocks both synaptic plasticity and performance on a spatial learning task (left side is data from control animals, right side data from animals with drug).

False memories (the Inception experiment)



Tonegawa group (MIT) and Mayford group (UC San Diego); e.g. (Liu *et al*. 2012 Nature)

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