COMS30017
Computational Neuroscience

Week 5 / Video 2 / The Hippocampus and spatial navigation

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slides adapted from Dr. Cian O'Donnell

Intended Learning Outcomes

- Introduction to spatial navigation in hippocampus

- Sets the scene for computational models

Hippocampus and spatial navigation

- Neurons in the hippocampus and surrounding regions respond to aspects of the spatial environment:

- *Place* cells in CA3 and CA1 are active only when an animal is one particular location.

- *Grid* cells in entorhinal cortex are active when the animal is in any of a set of locations, arranged in a hexagonal grid.

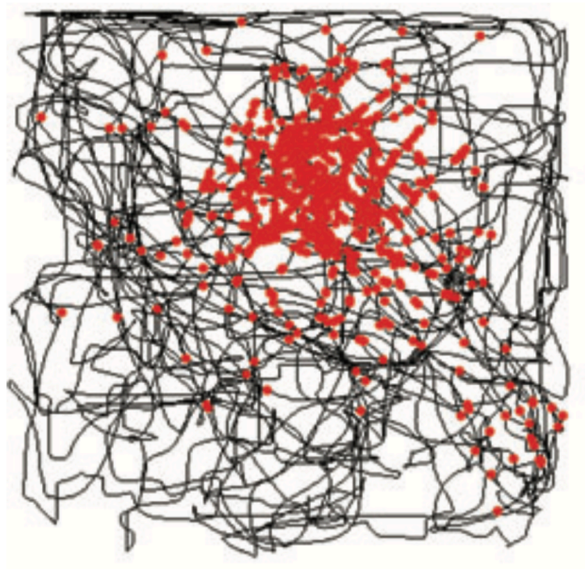
- *Head direction* cells in subiculum (and also hippocampus, entorhinal cortex, and other neighbouring structures) don't care where the animal is located, but are active only when the animal is facing a certain direction.

Place cell example video

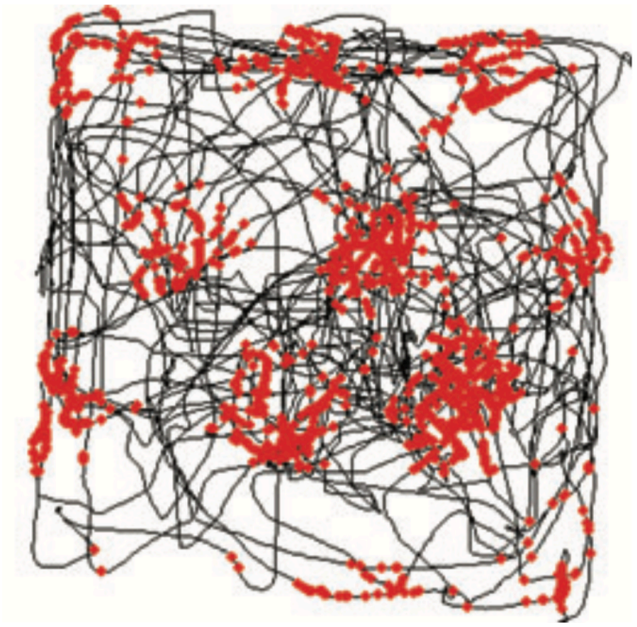
https://www.youtube.com/watch?v=lfNVv0A8QvI

Place cells, grid cells, head direction cells

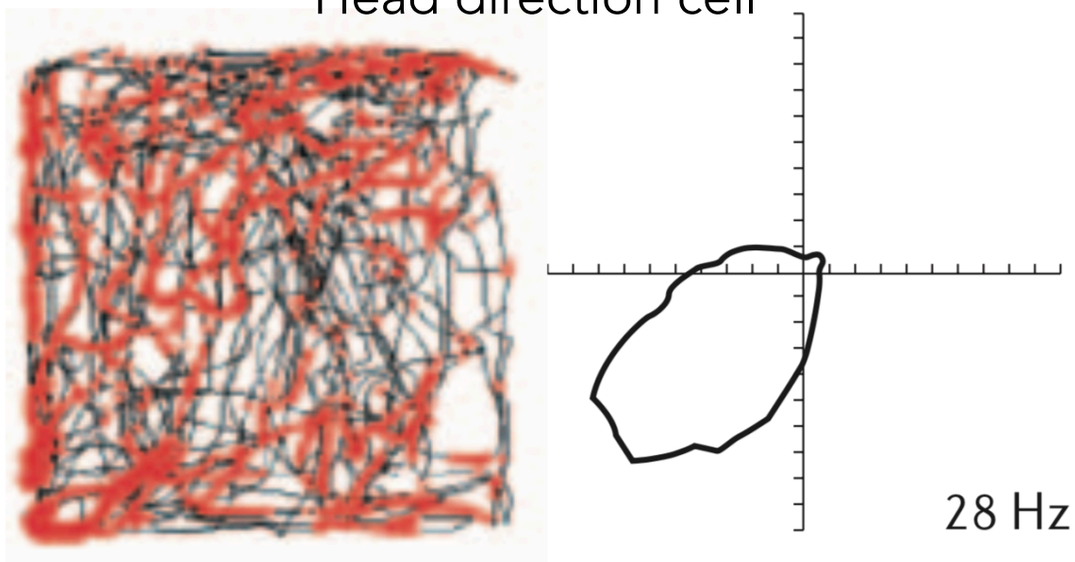
Place cell



Grid cell



Head direction cell



Hippocampal computations

For both memory and spatial navigation, the hippocampus is thought to perform two key classes of computation:

- Pattern separation vs pattern completion.

- Path integration.

Pattern separation vs pattern completion

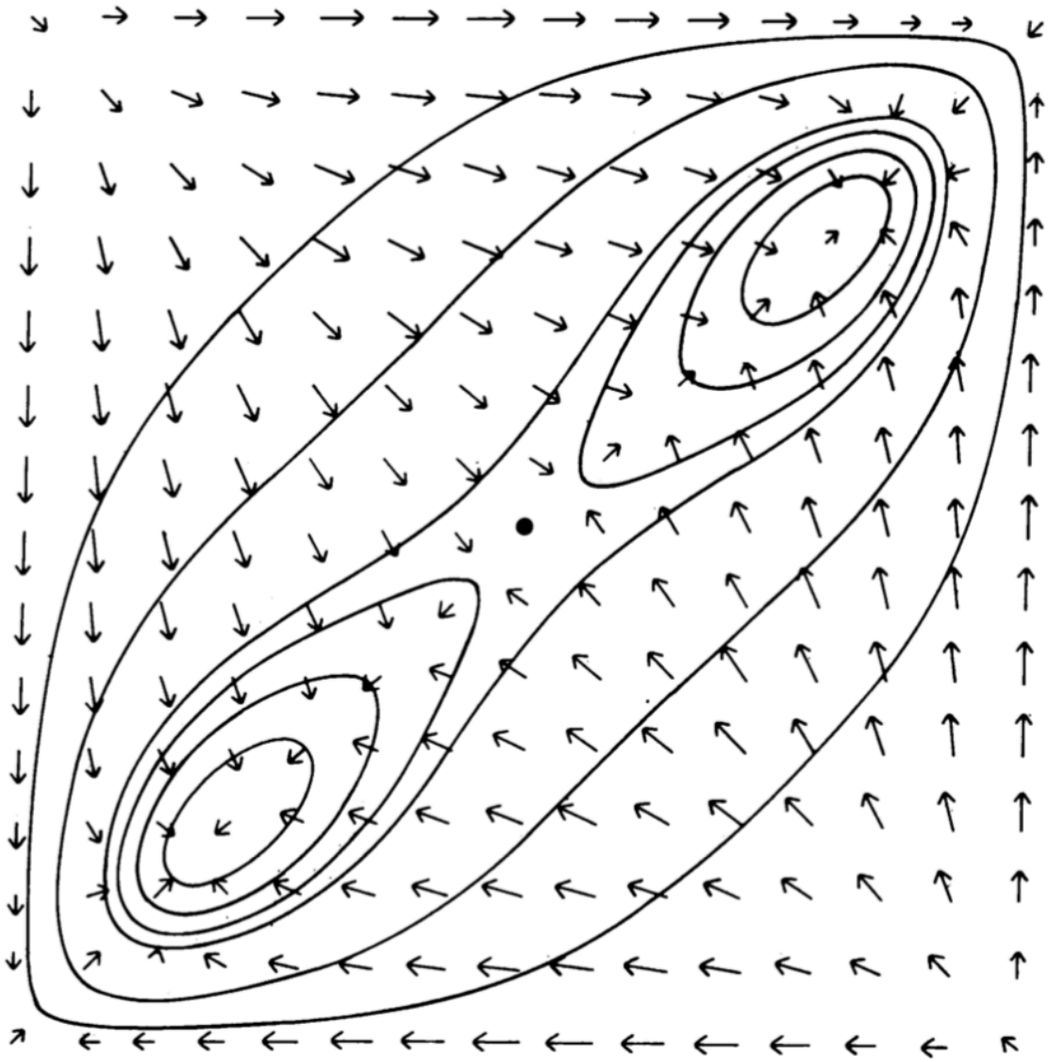
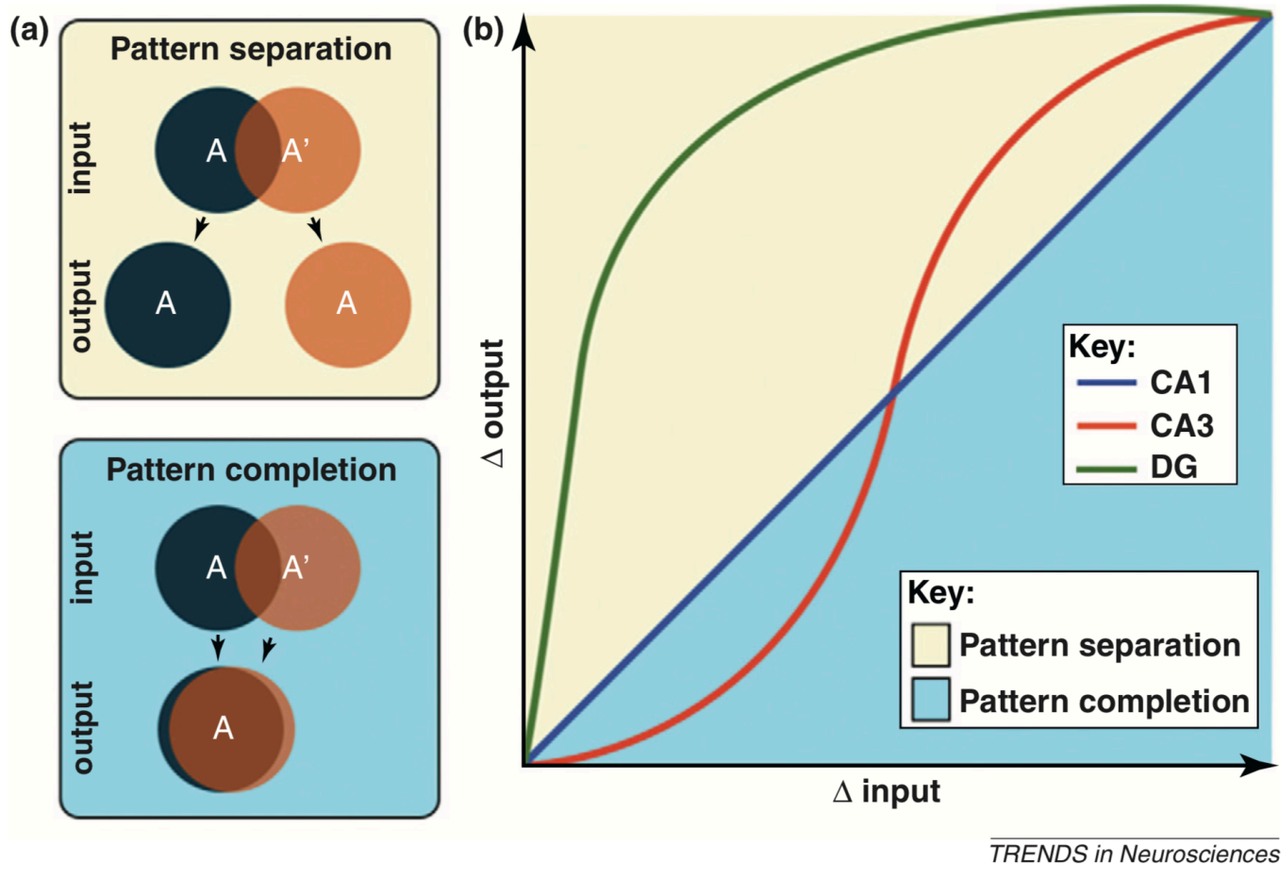


FIG. 3. An energy contour map for a two-neuron, two-stable-state system. The ordinate and abscissa are the outputs of the two neurons. Stable states are located near the lower left and upper right corners, and unstable extrema at the other two corners. The arrows show the motion of the state from Eq. **5**. This motion is not in general perpendicular to the energy contours. The system parameters are $T_{12} = T_{21} = 1$, $\lambda = 1.4$, and $g(u) = (2/\pi)\tan^{-1}(\pi\lambda u/2)$. Energy contours are 0.449, 0.156, 0.017, −0.003, −0.023, and −0.041.

Hopfield, *PNAS* 1984

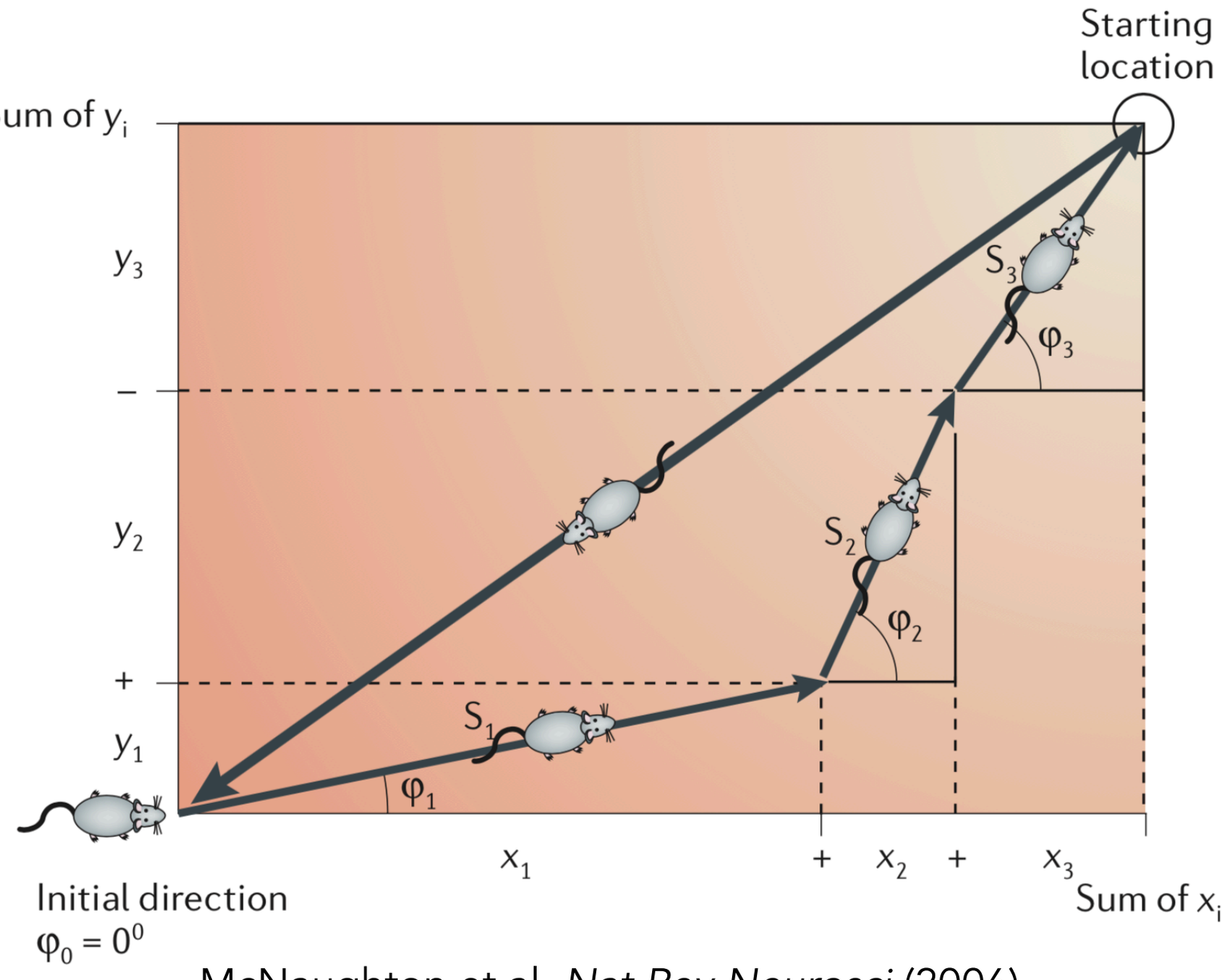


Yassa & Stark, *Trends Neurosci* (2011)

- Dentate gyrus is thought to do pattern separation.
- CA3 is thought to do pattern completion.

Path integration

Path integration is the idea that an animal can keep a running internal estimate of its spatial location by integrating its direction and velocity signals.



McNaughton et al, *Nat Rev Neurosci* (2006)

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