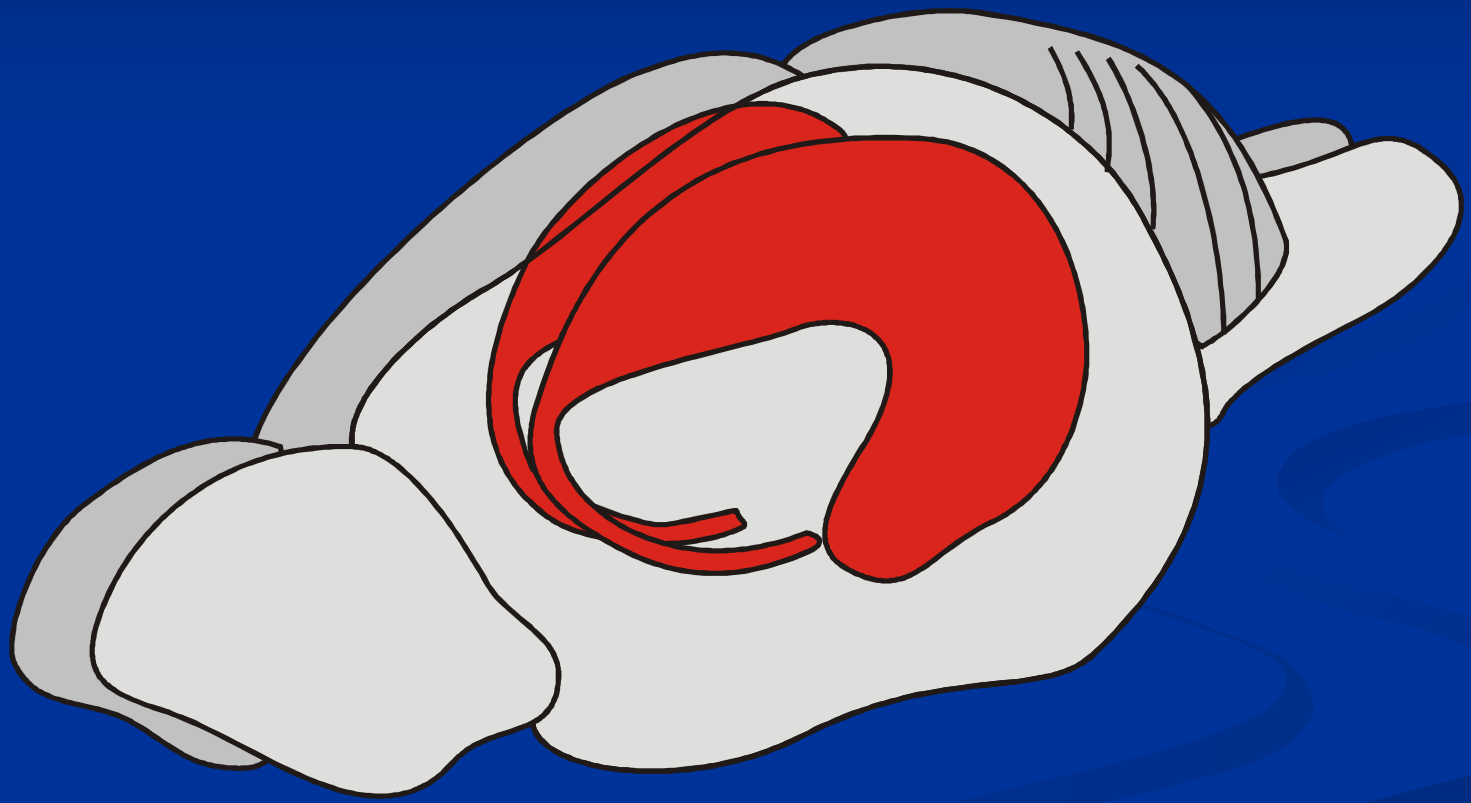
Activity of hippocampal neurons and behavior

Daniel Klement

Neurophysiology of Memory and Computational Neuroscience
Institute of Physiology
Academy of Sciences of the Czech Republic

Rat's hippocampus



Rat's hippocampus

Hippocampal EEG

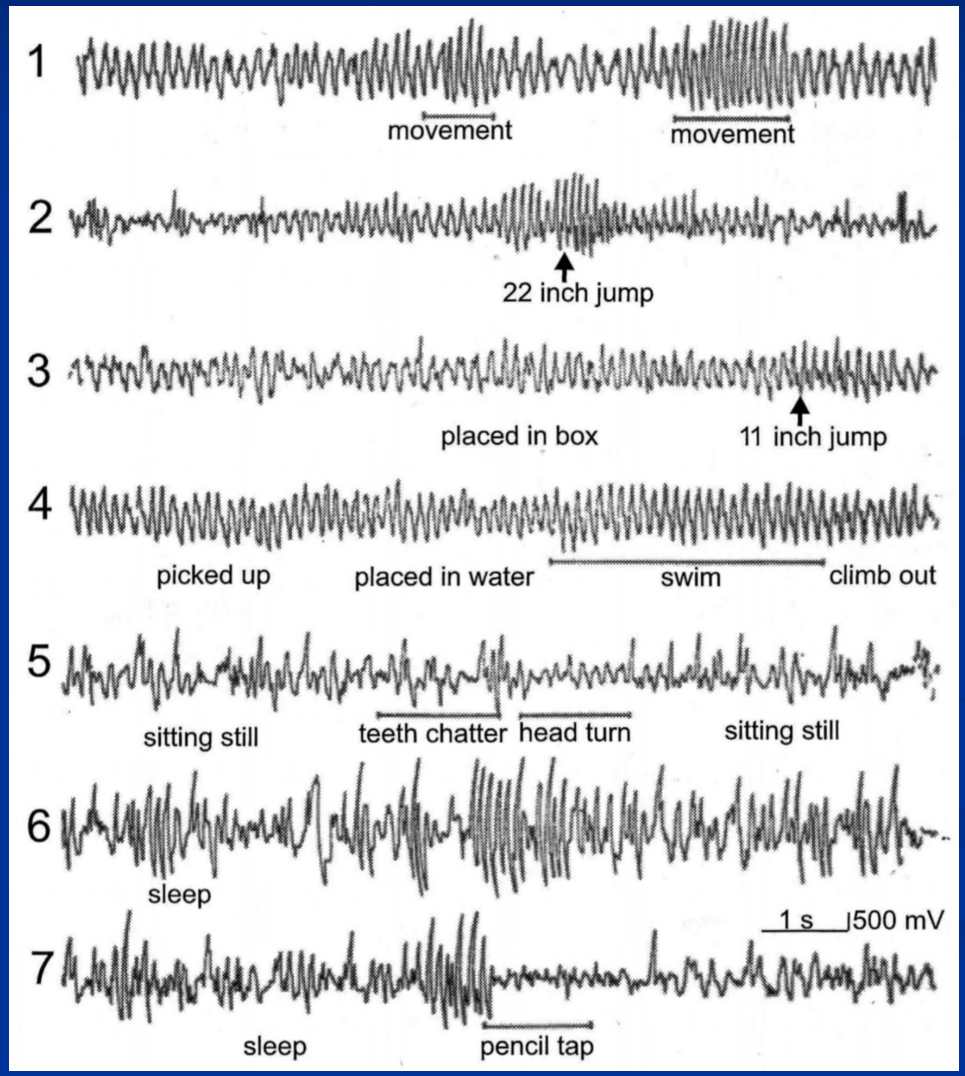
- **Theta rhythm** (RSA)
  4-12 Hz rhythmical activity
  - Type I (7-12 Hz, atropine resistant)
  - Type II (4-6 Hz, atropine sensitive)

- **LIA** (Large Irregular Activity)
  higher amplitude and lower dominant frequency compare to theta rhythm

- **SIA** (Small Irregular Activity)
  desynchronized high frequency activity with low amplitude

Example Traces of Hippocampal EEG in a Rat

Whishaw and Vanderwolf, Behav Biol 1973



Correlation of hippocampal EEG and behavior in rats

Vanderwolf CH. Electroencephalogr Clin Neurophysiol. 1969

EEG	Behavior
Theta rhythm, type I	Gross voluntary movements such as walking, running, rearing, jumping, and REM sleep
Theta rhythm, type II	Small movements such as shift of posture or isolated movements of the head or limbs
LIA	Behavioral immobility and automatic movement patterns such as scratching, washing the face, biting, and non-REM sleep
SIA	Sometimes when a drowsy or sleeping rat awakes, it ceases with the first movement of the animal

Classification of Hippocampal EEG

Andersen, Morris, Amaral, Bliss and O'Keefe, Oxford University Press 2006

Rhytmical Activity

- theta: 6–12 Hz
  - atropine resistant
  - atropine sensitive
- beta: 12–30 Hz
- gamma: 30–40 Hz, frequently with theta
- ripple: 100–200 Hz, frequently with LIA

Non-rhytmical Activity

- LIA
- SIA

Hippocampal neurons

Ranck JB Jr. Exp Neurol. 1973

Electrophysiological classification

- Theta cells (interneurons)
- Complex spike cells (pyramidal neurons)

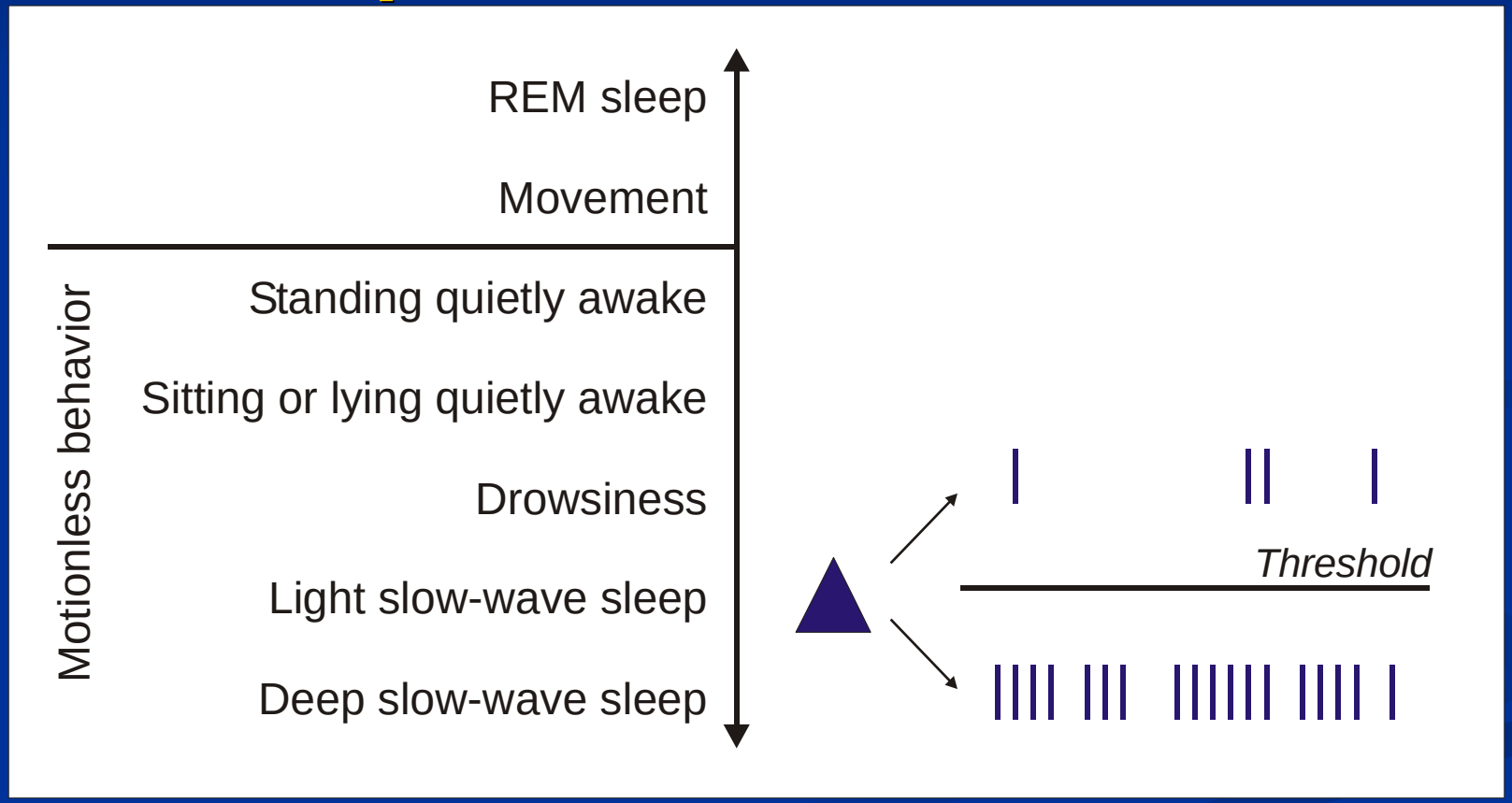
Correlation of activity of theta cells, EEG and behavior in rats

Ranck JB Jr. Exp Neurol. 1973

Activity of theta cells	EEG	Behavior
Theta mode	Theta rhythm	Voluntary movements, REM sleep
Automatic mode	LIA	Immobility, automatic movement patterns, non-REM sleep
Slow mode	often SIA, LIA otherwise	Immediately after some external stimulus while the rat was motionless

Correlation of activity of complex spike cells and behavior in rats

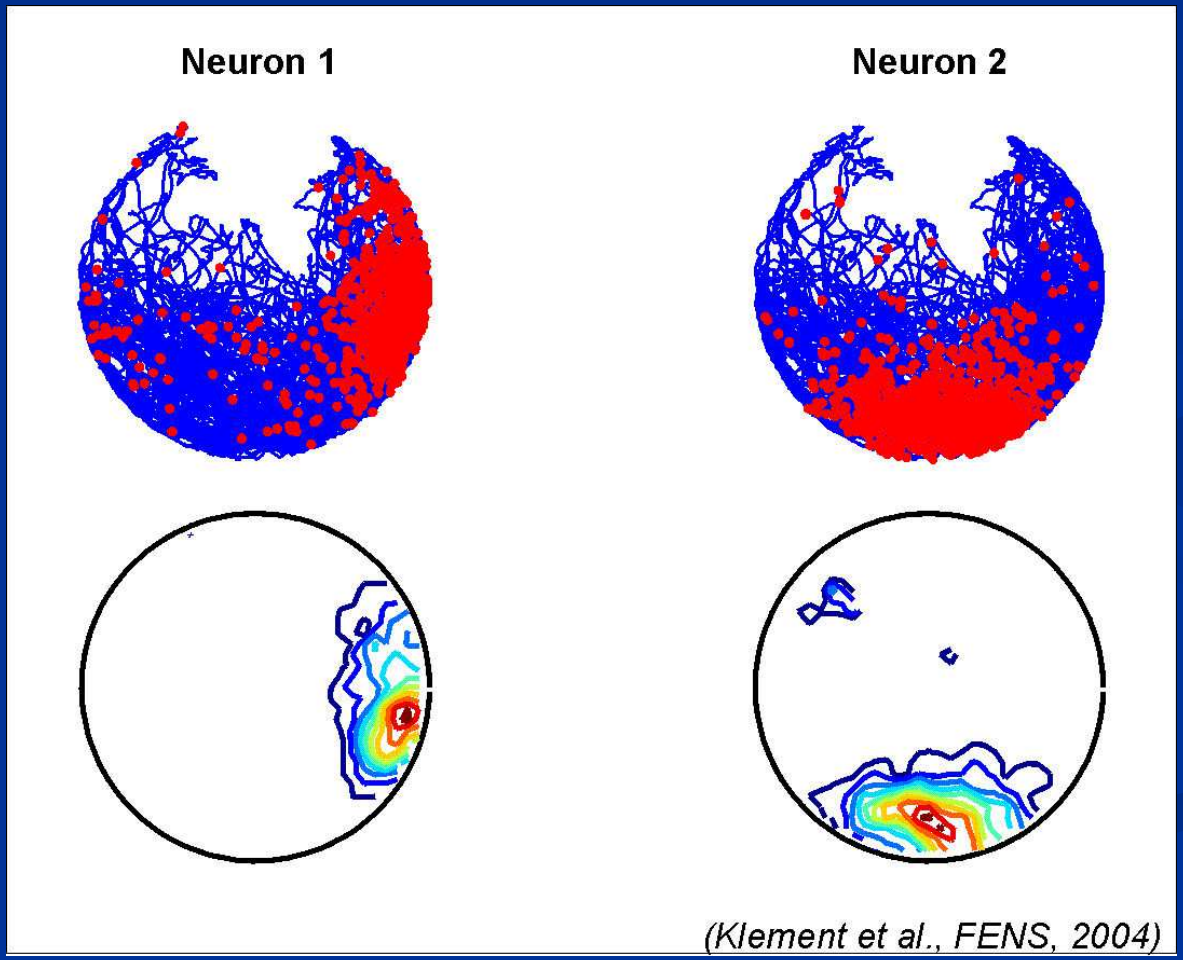
Ranck JB Jr. Exp Neurol. 1973



Ranck found behavioral correlates for all recorded complex spike cells however he did not considered spatial aspects of behavior.

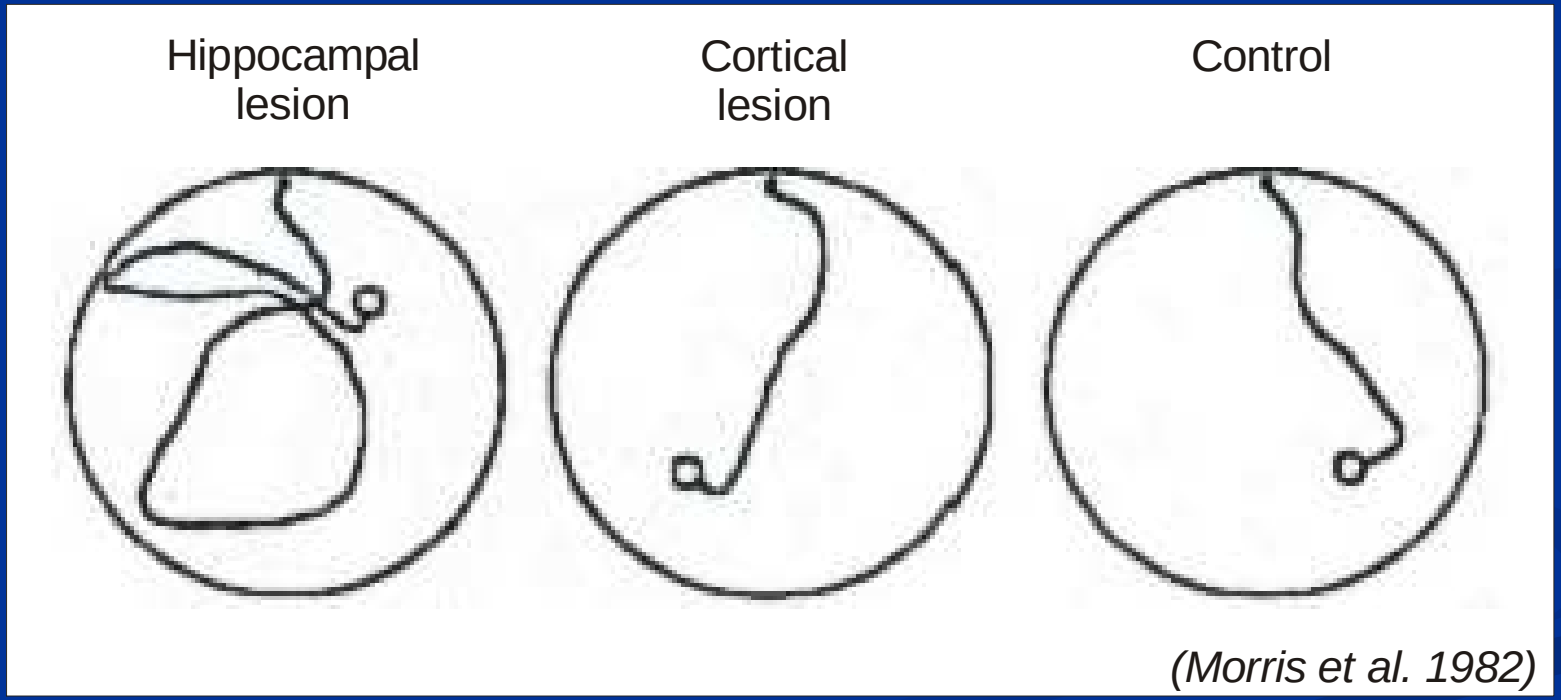
Correlation of activity of complex spike cells and behavior in rats – place cells

O'Keefe J, Dostrovsky J. Brain Res. 1971;
O'Keefe J. Exp Neurol. 1976



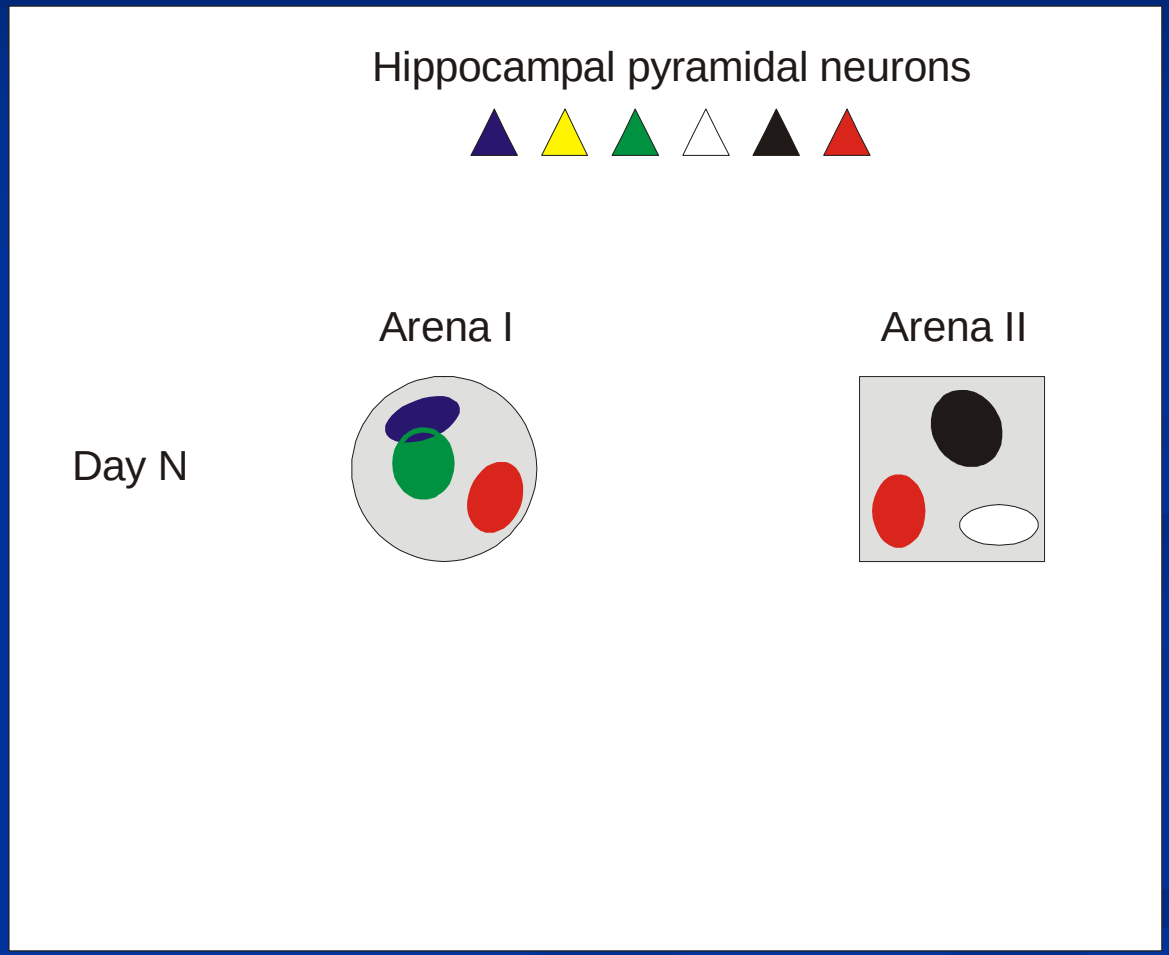
Hippocampal rats are impaired in navigation to a hidden goal

Morris RG, Garrud P, Rawlins JN, O'Keefe J. Nature. 1982

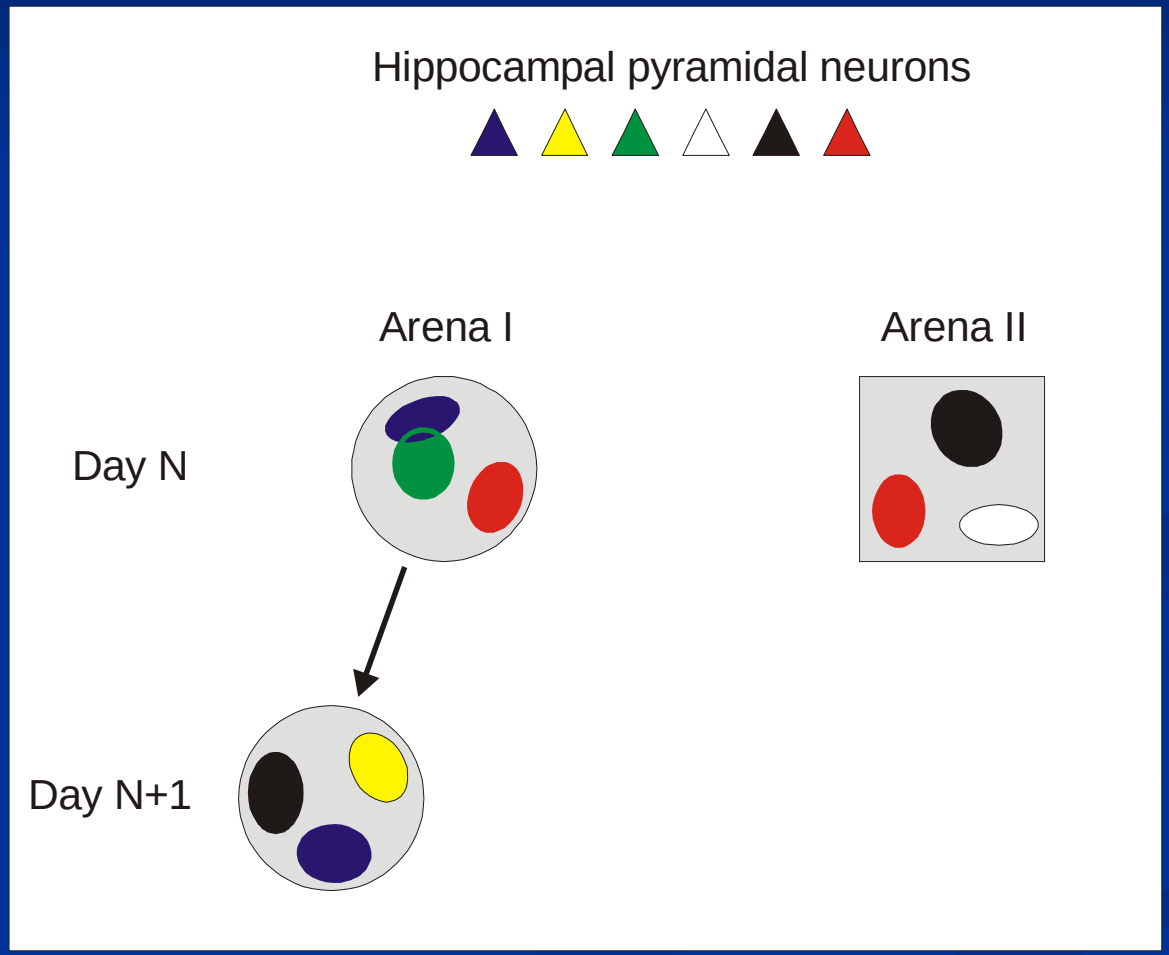


(Morris et al. 1982)

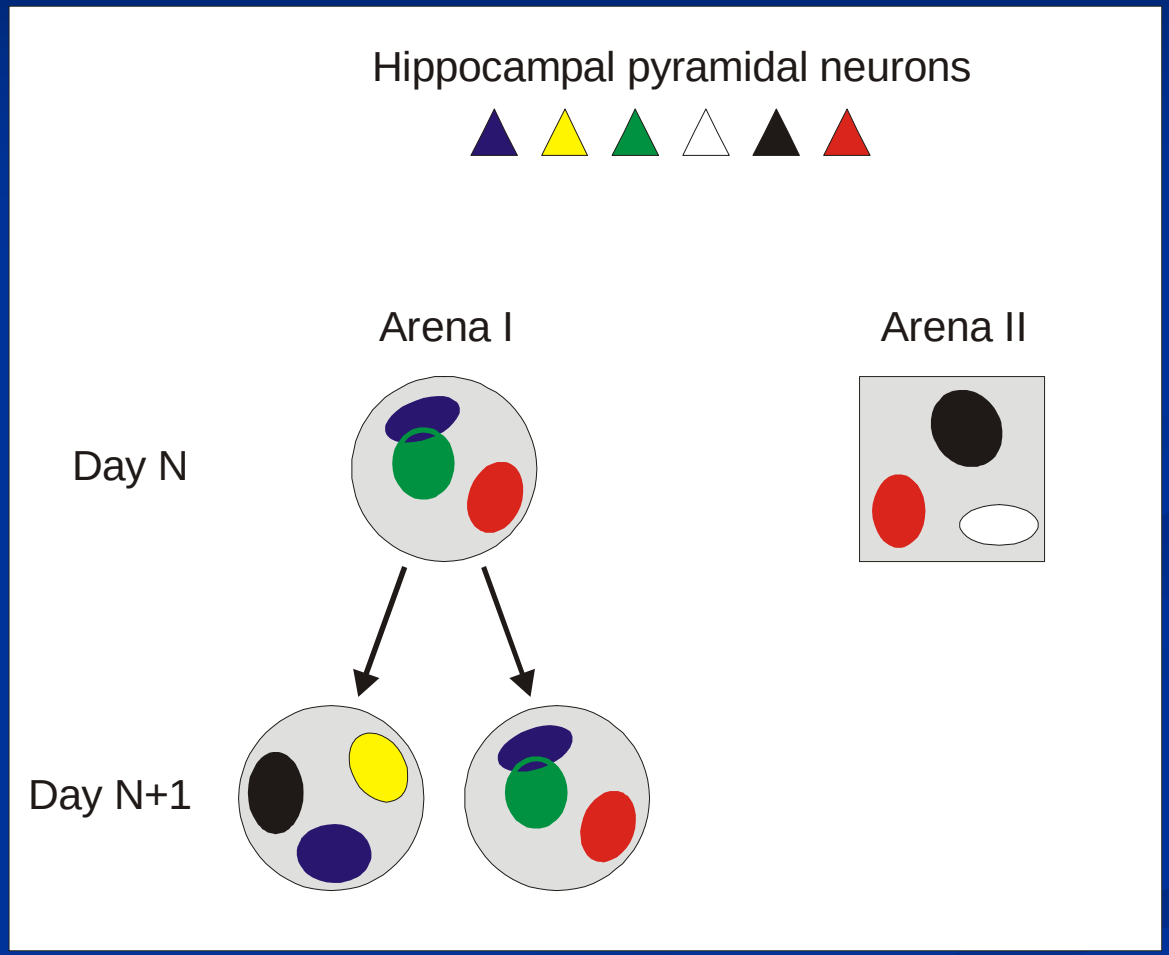
Hippocampal representation of environments



Hippocampal representation of environments

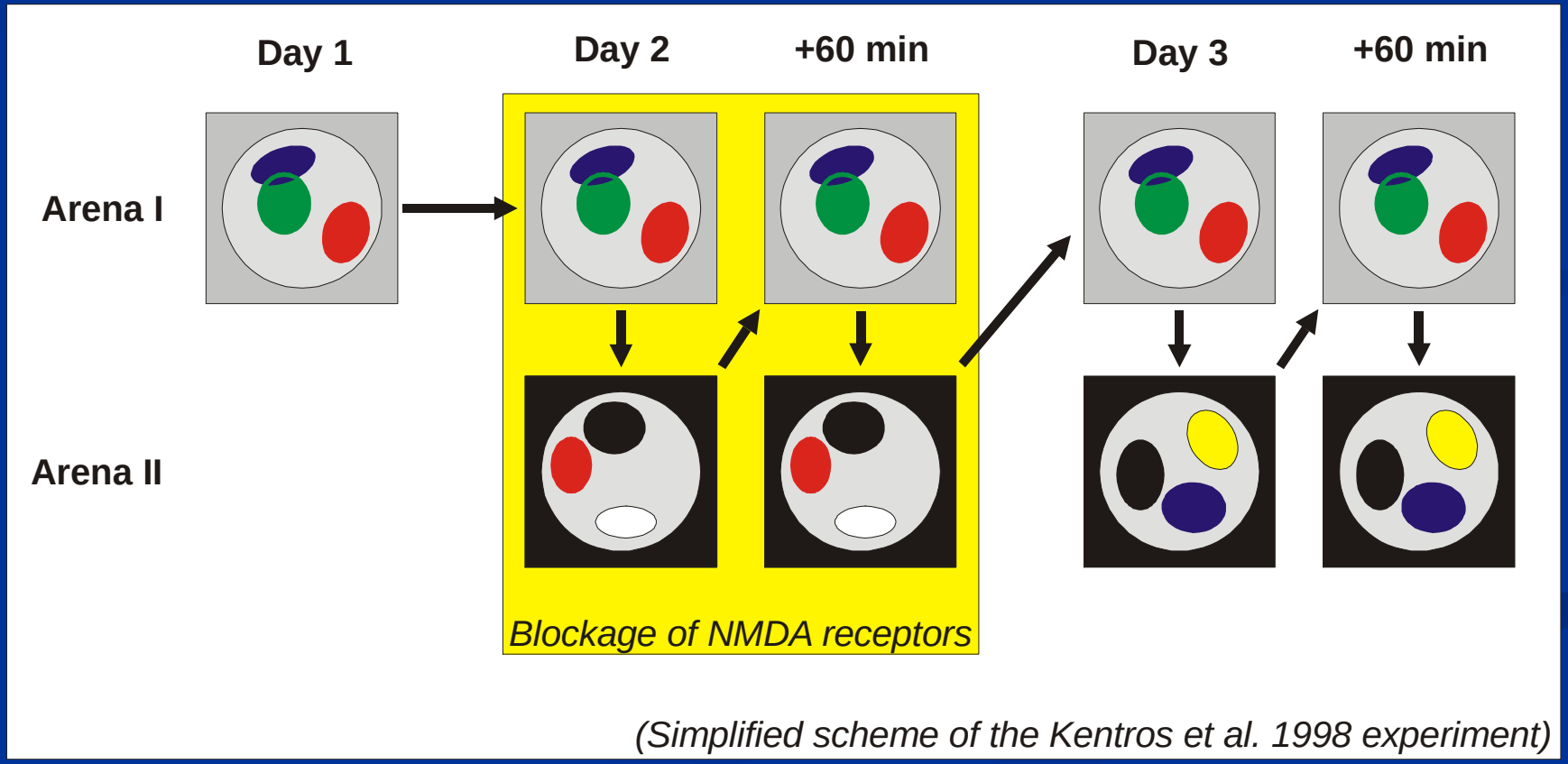


Hippocampal representation of environments



NMDA-receptor-dependent synaptic plasticity and stability of place fields

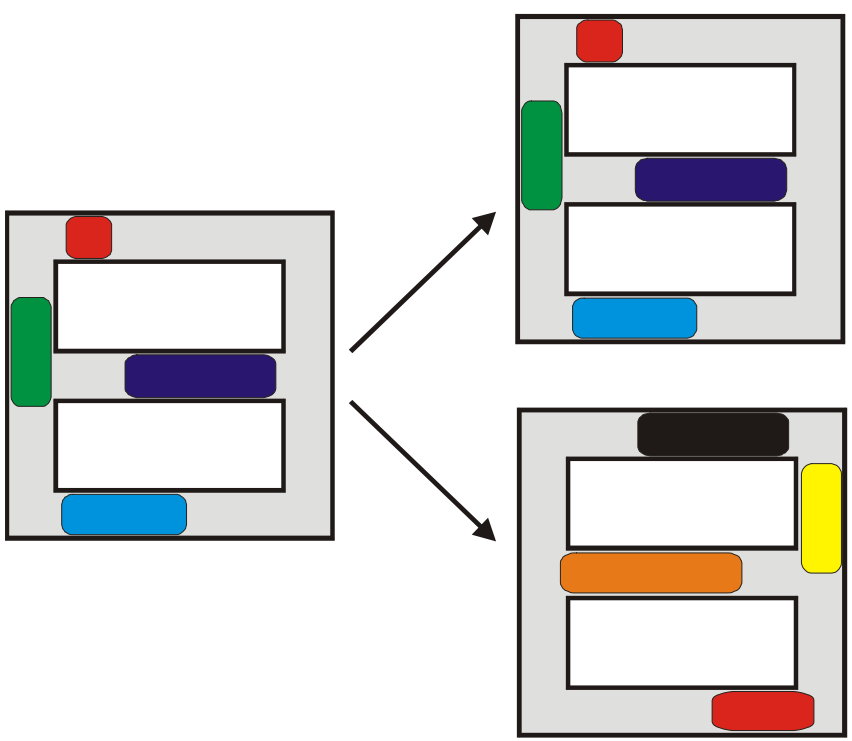
Kentros C, Hargreaves E, Hawkins RD, Kandel ER, Shapiro M, Muller RV. Science. 1998



(Simplified scheme of the Kentros et al. 1998 experiment)

Aging and stability of place fields

Barnes CA, Suster MS, Shen J, McNaughton BL. Nature. 1997



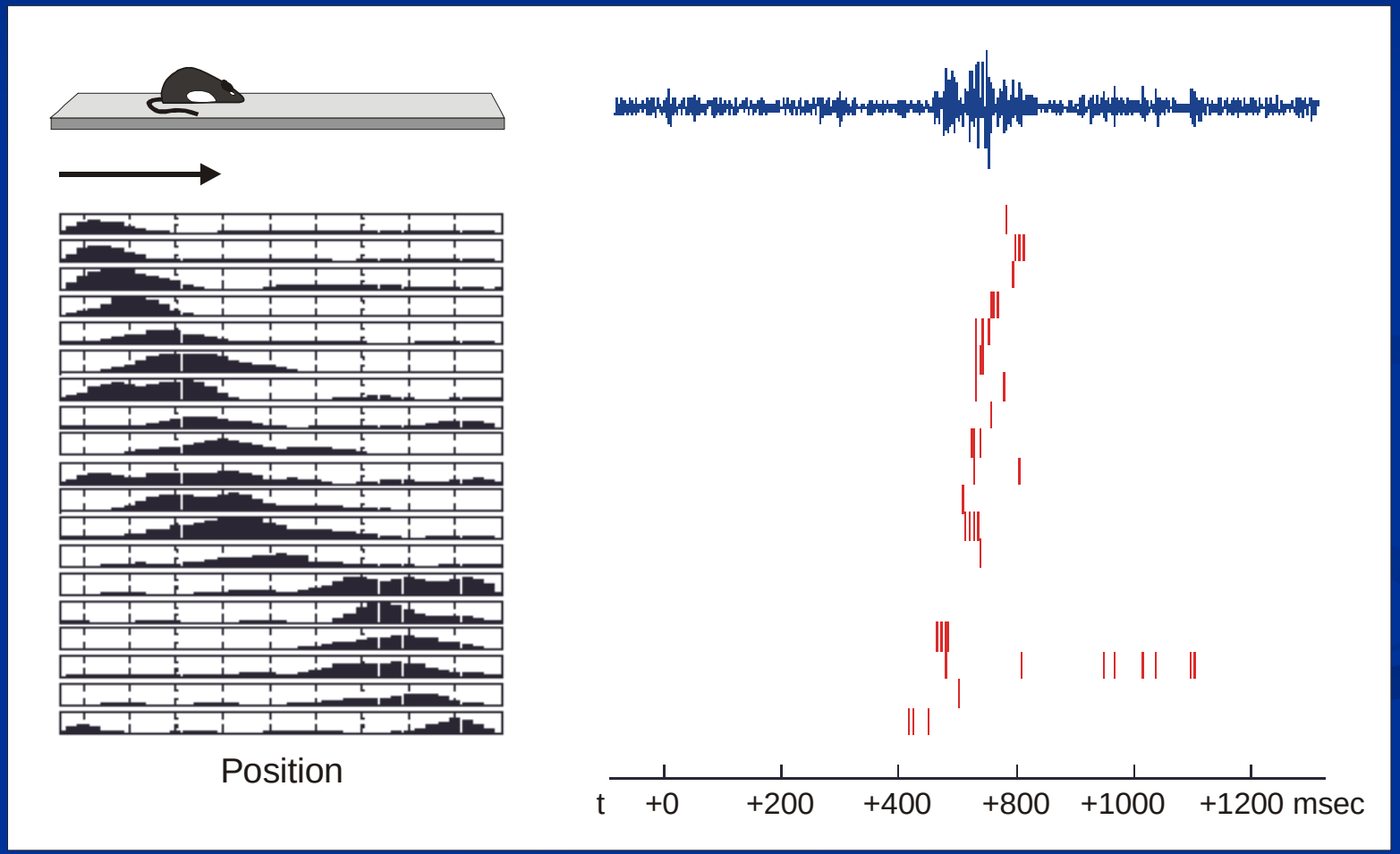
	Young rats	Old rats
Stable place fields	100%	70%
Remapped place fields	0%	30%

(Simplified scheme of the Barnes et al. 1997 experiment)

Attractor dynamics of hippocampal neural network

Reverse replay of behavioral sequences in hippocampal place cells during the awake state

Foster DJ and Wilson MA. Nature. 2006



Replay of behavioral sequences of hippocampal place cells during sleep

Lee AK and Mattew MA. Neuron. 2002 – **Slow-wave sleep**

Temporal sequences of neuronal activity reflecting behavioral experience are replayed in brief burst (~100 ms) during slow wave sleep, the behavioral sequence is compressed approximately 20-times.

Louie K and Wilson MA. Neuron. 2001 – **REM sleep**

Temporal sequences of neuronal activity reflecting tens of seconds to minutes of behavioral experience are replayed during REM episodes at an equivalent time scale.