BIOSYSTEMS II: NEUROSCIENCES

2015 Spring Semester

Lecture 32

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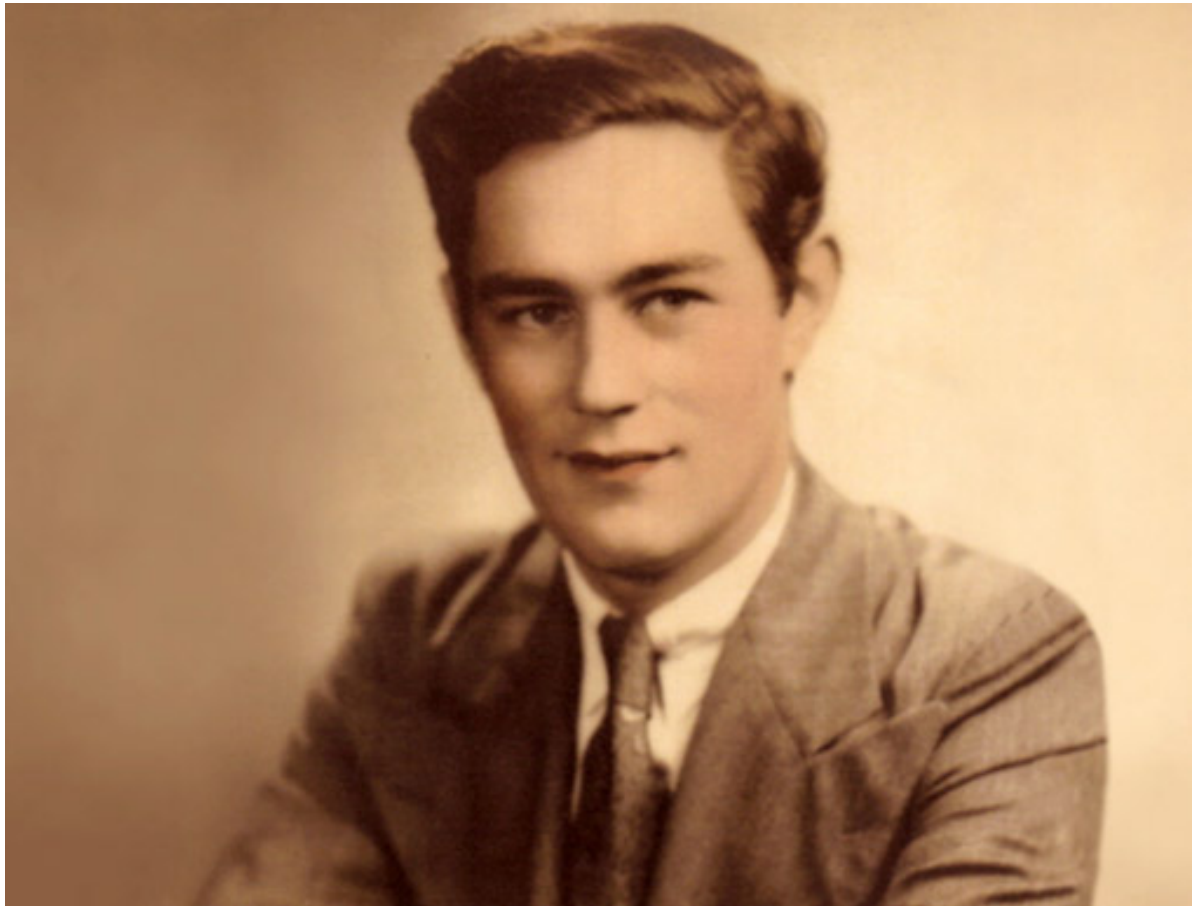
4/15/2015

Recurrent networks

- Discrete attractor networks (e.g. Hopfield network)
- Continuous attractor networks

Amnesia following hippocampal lesion

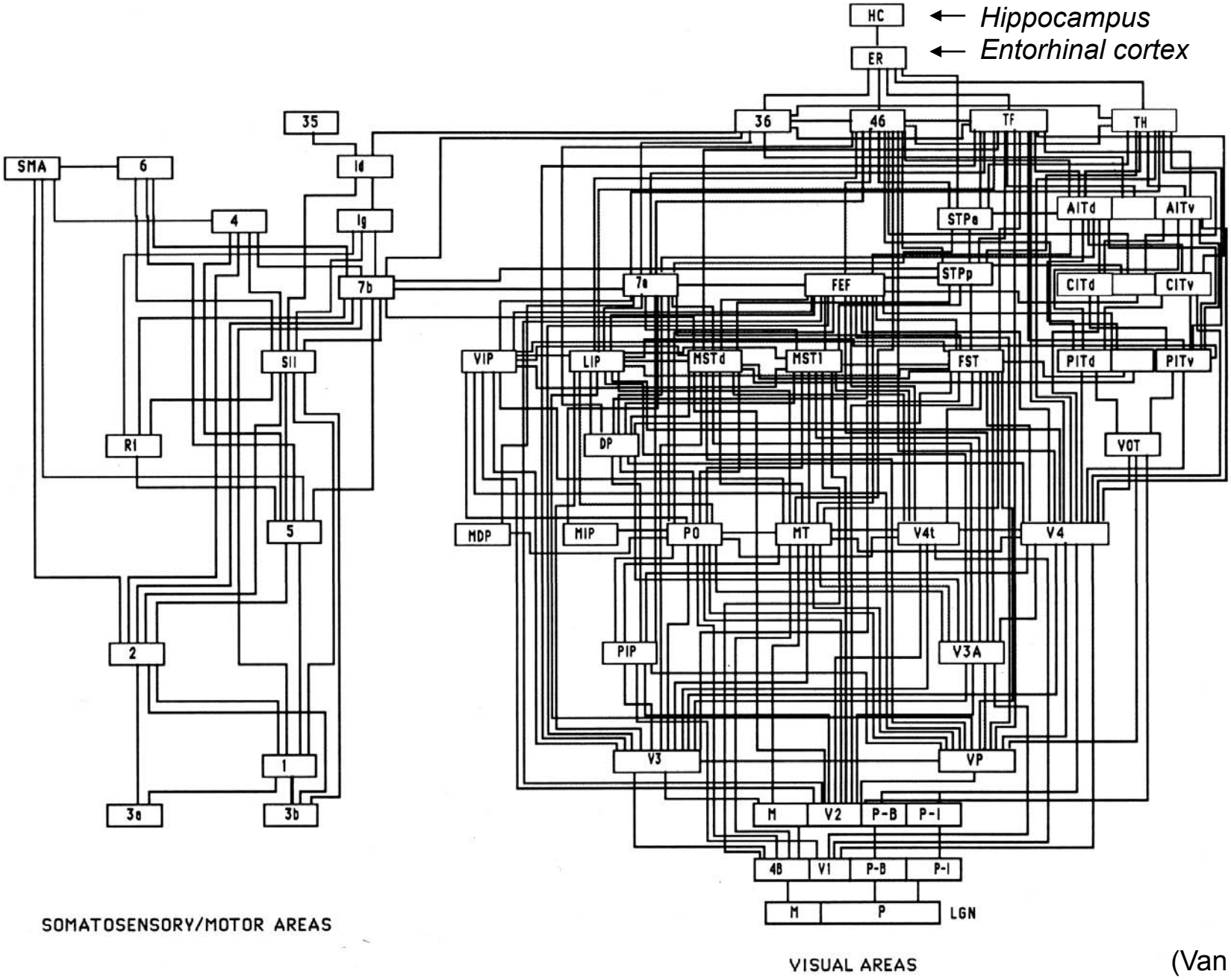
Patient H.M. (Henry Molaison, 1926 - 2008)




MEMENTO
SOME MEMORIES ARE BEST FORGOTTEN.
(Official Selection - Toronto Film Festival)
(Official Selection - Venice Film Festival)
(Official Selection - Sundance Film Festival)
GUY PEARCE CARRIE-ANNE MOSS JOE PANTOLIANO
MEMENTO
NEWMARKET
SUMMIT ENTERTAINMENT
R
RESTRICTED


ADAMSANDLER
DREWBARRYMORE
50FIRSTDATES

Anatomical Hierarchy of Macque Monkey Brain

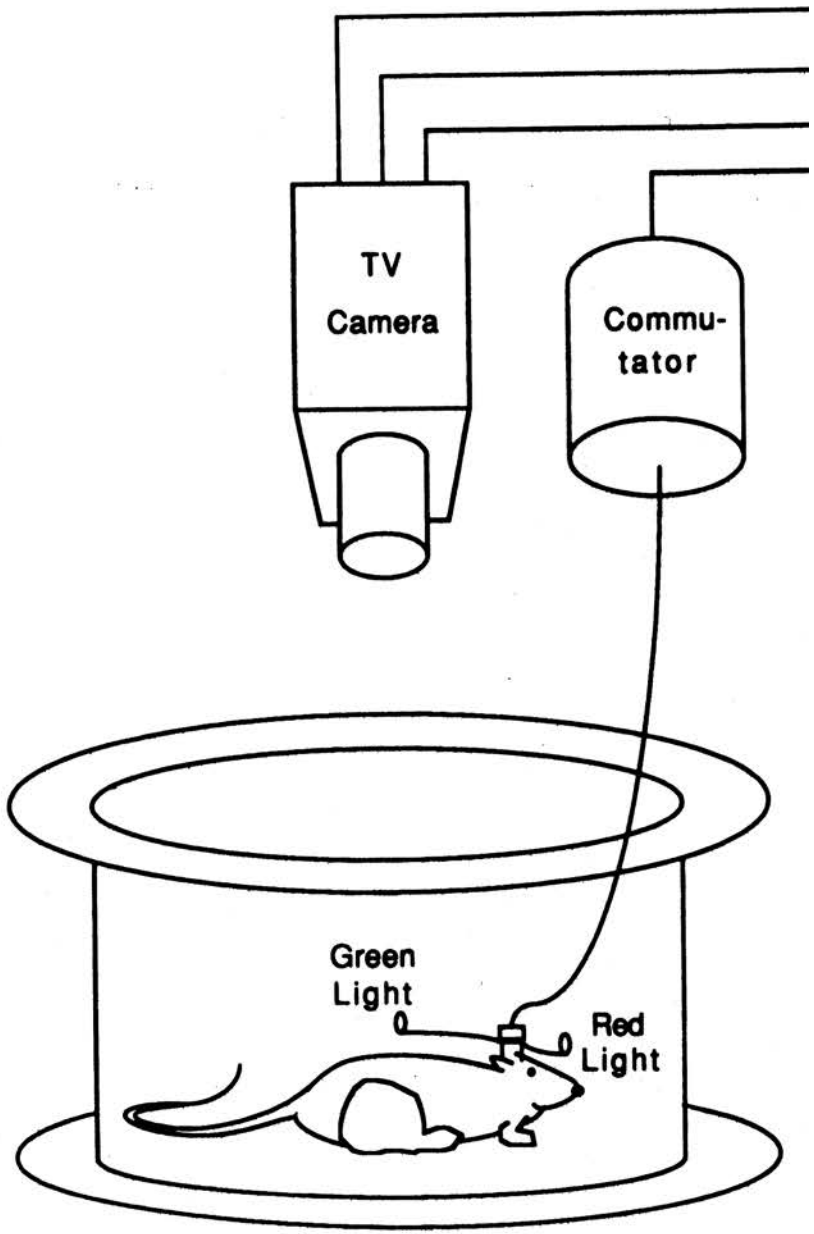


(Van Essen)

Space related cells

- **Head-direction cell**: heading direction (Papez circuit)
- **Grid cell**: periodic spatial location (entorhinal cortex)
- **Place cell**: spatial location (hippocampus)

All three representations are in world coordinate system, and they depend on both familiar landmarks and path integration by self-motion.

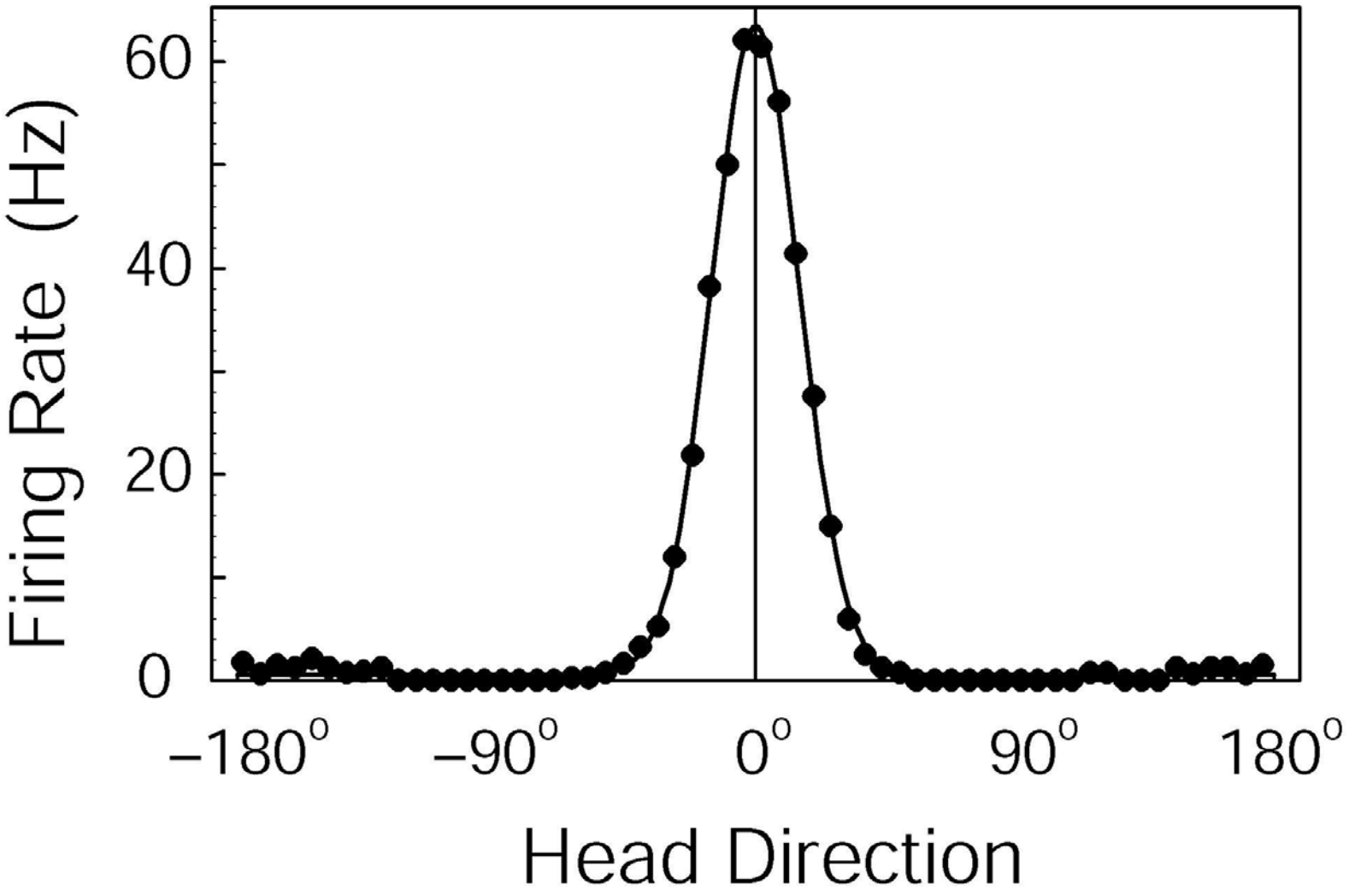


(Muller et al. 1990)

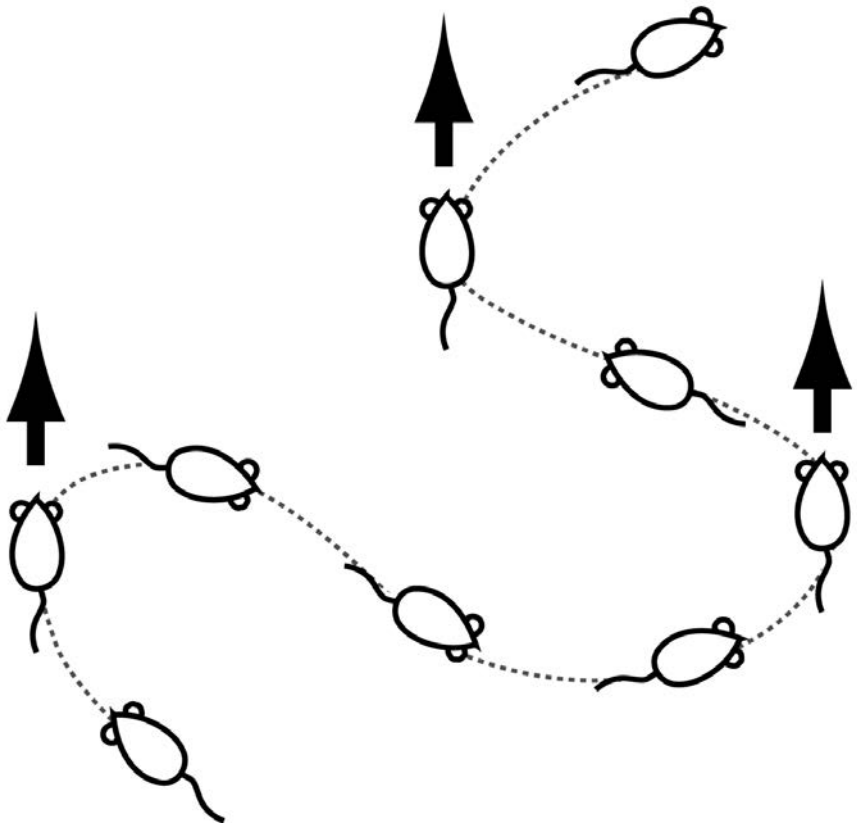
Head-Direction Cell

(J. Taube)

Tuning Curve of a Head-Direction Cell

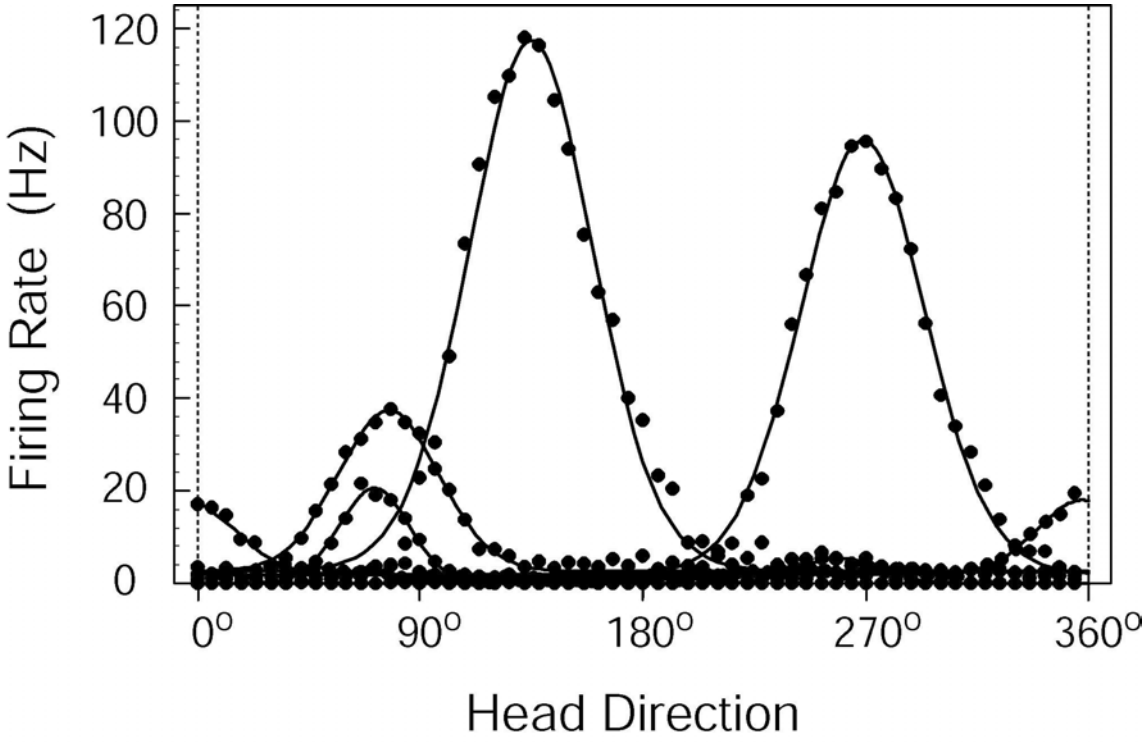


Preferred Direction of a Single Head-Direction Cell



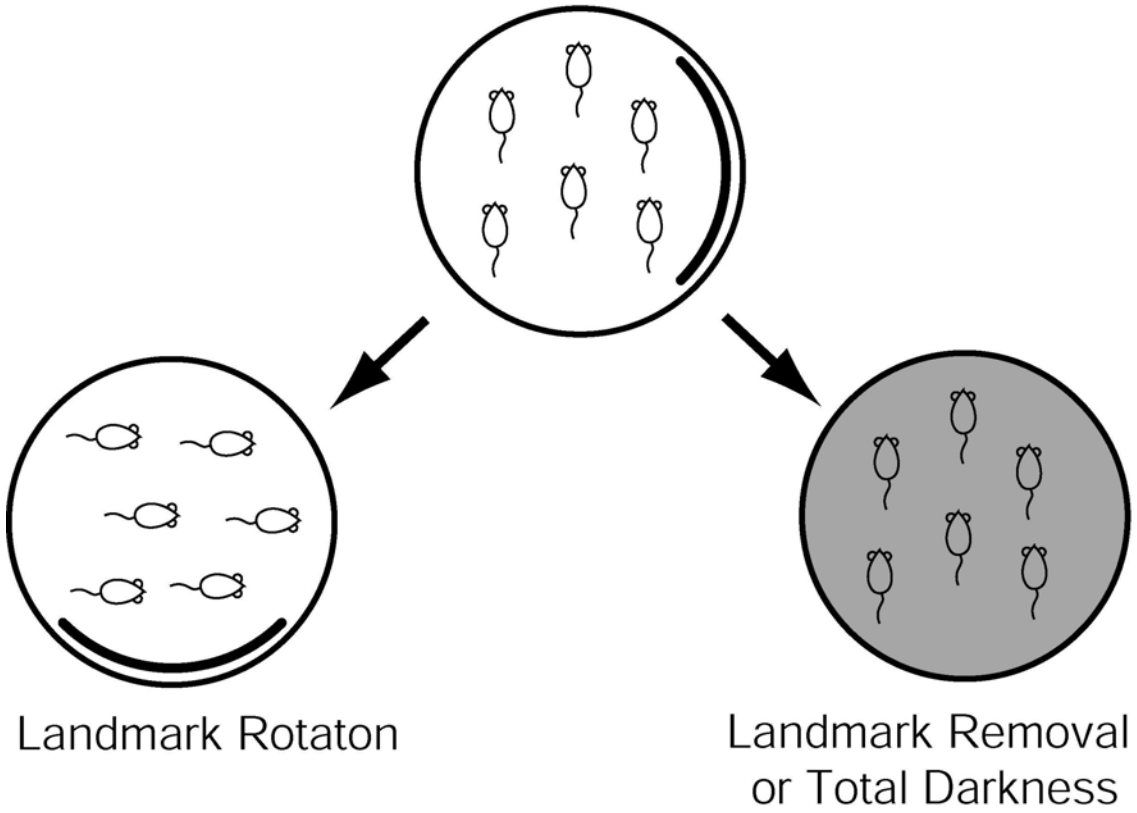
Preferred direction (indicated by arrows) is the same everywhere

Head-direction cells



- signal heading direction in world coordinate system.
- anchored to familiar landmarks (rapid learning).
- relies on self-motion (works in total darkness).
- correlated tightly with hippocampal place cells.

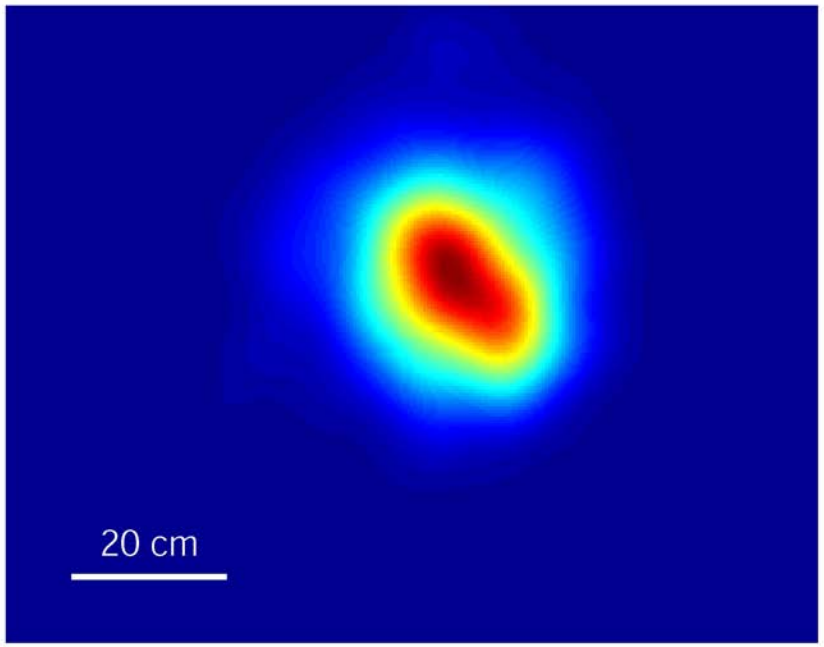
Preferred Direction of a Head-Direction Cell

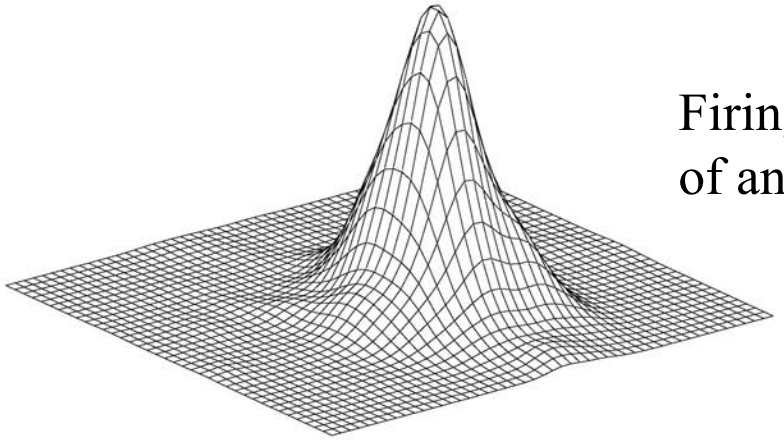


Familiar landmarks determine the preferred direction of a head-direction cell.

Without landmark, a head-direction cell may still fire normally, presumably by path integration.

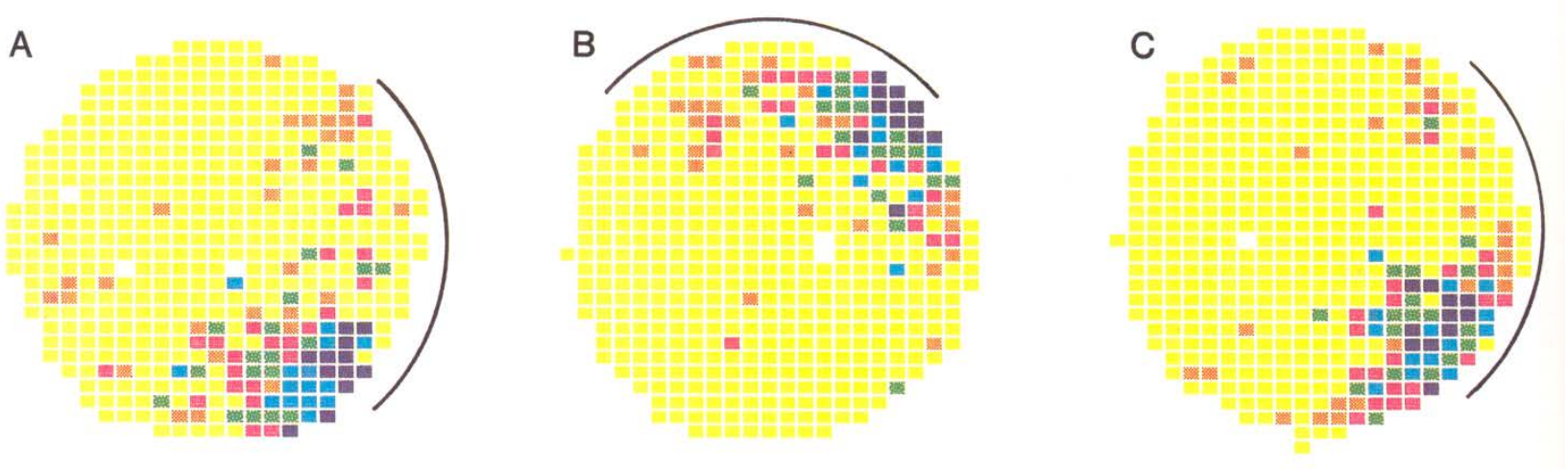
Hippocampal Place Field





Firing rate as a function of animal's position

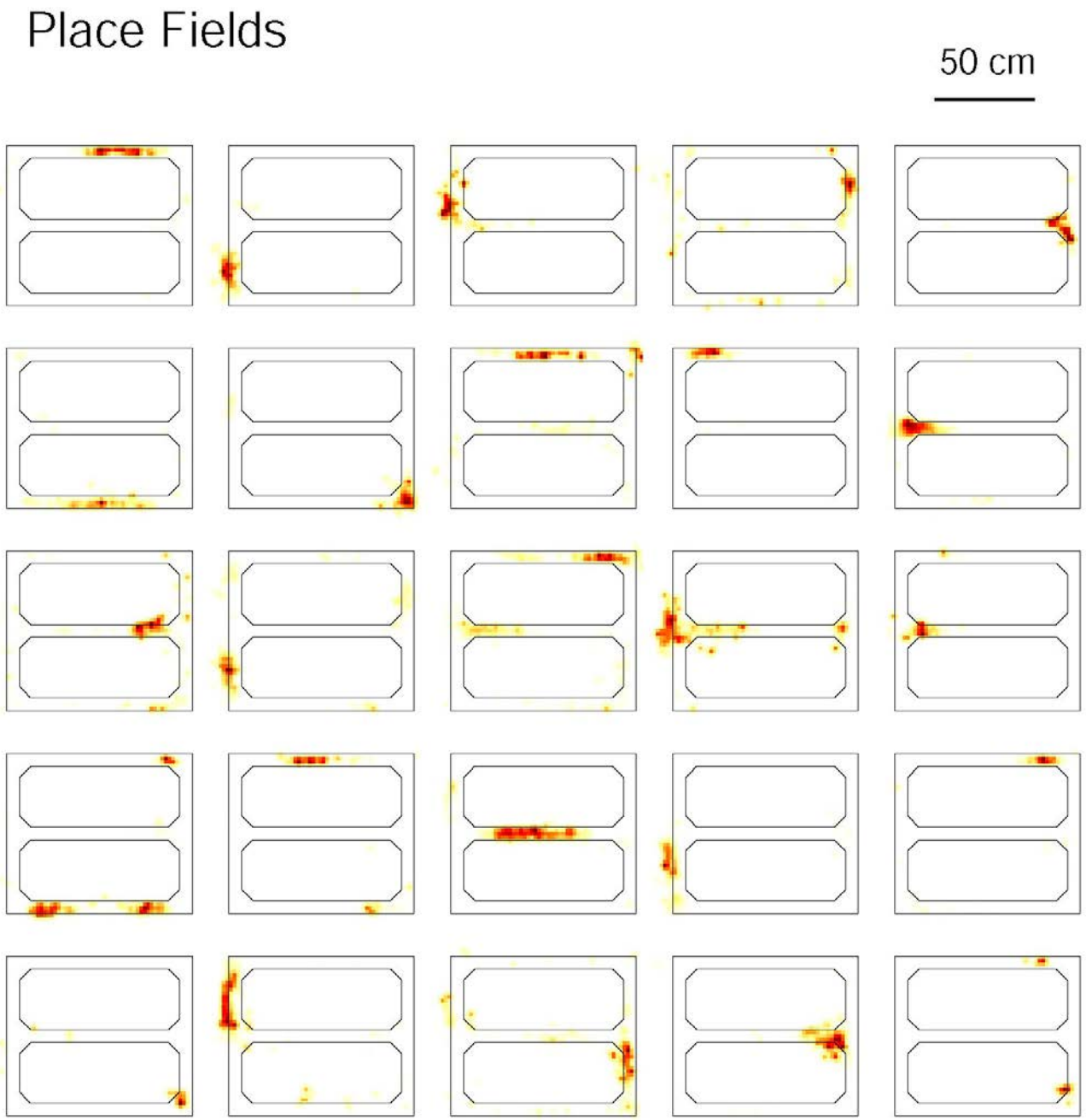
Place Field Follows Learned Visual Landmark



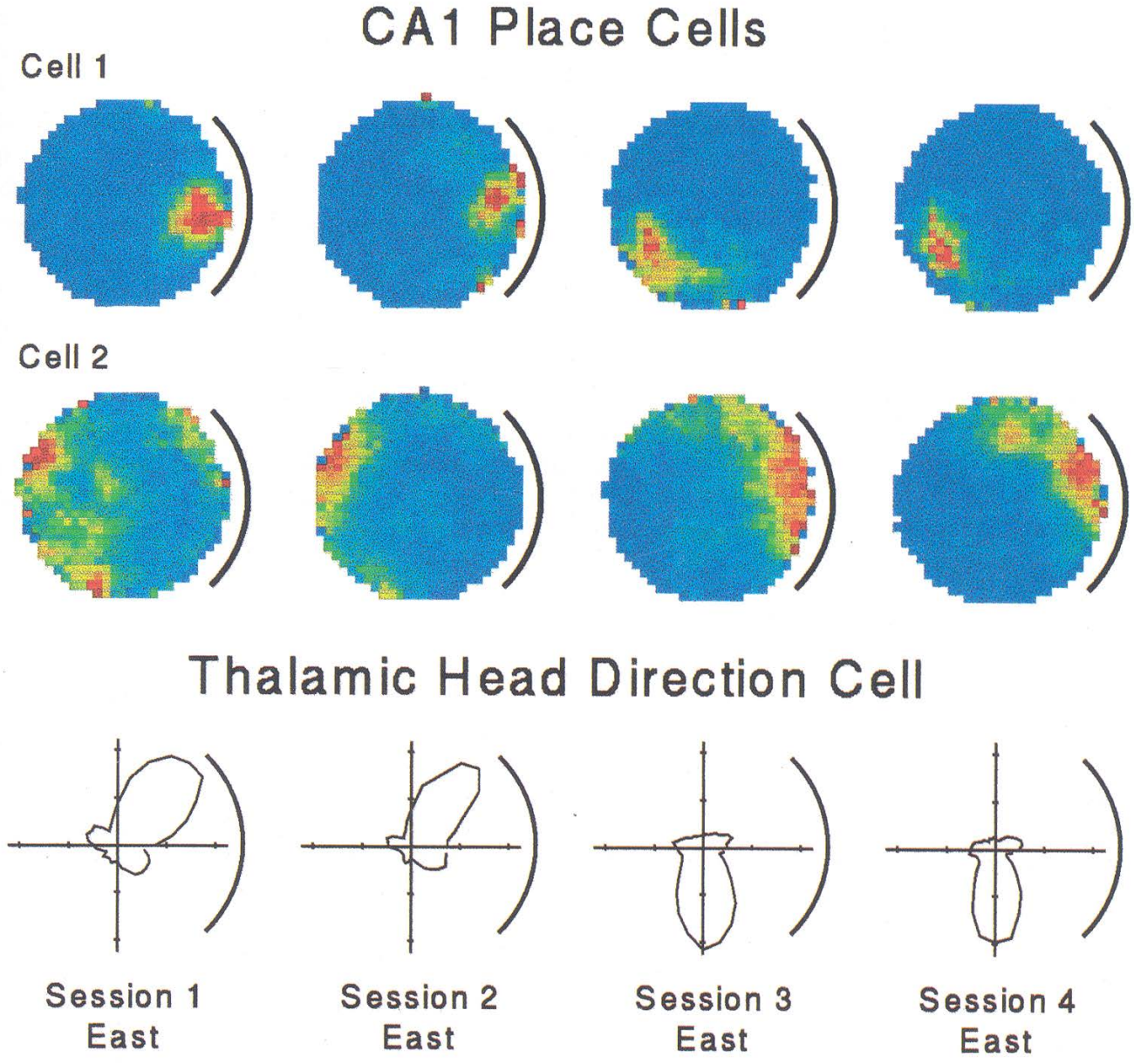
Basic properties of place cells:

- Place cell firing is determined primarily by spatial location
- Cues for spatial location come from multiple sensory modalities and self-motion
- Rapid learning of landmarks within a few minutes

Place cells in hippocampus


Place Fields
50 cm

Head-direction cells and place cells are tightly coupled

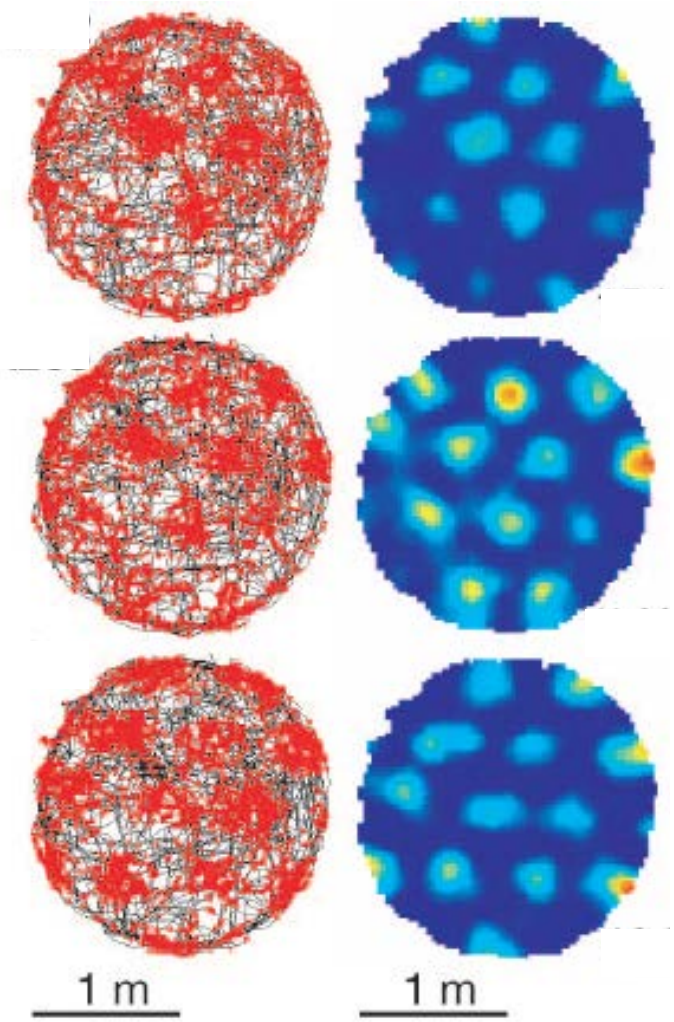


Grid cells in entorhinal cortex

Cell 1

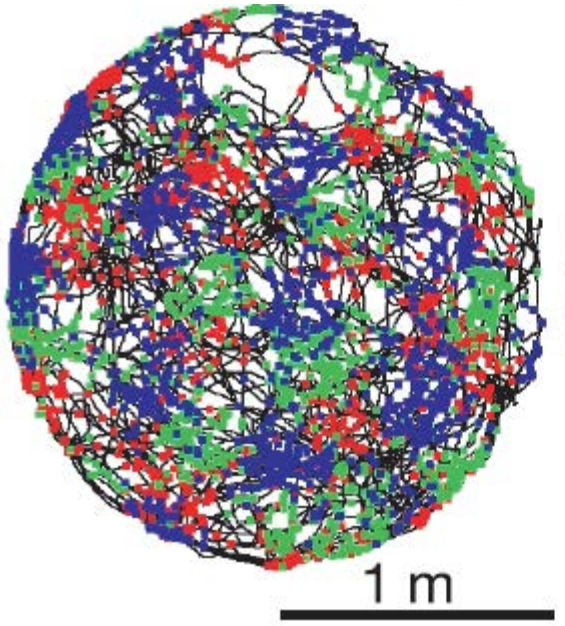
Cell 2

Cell 3



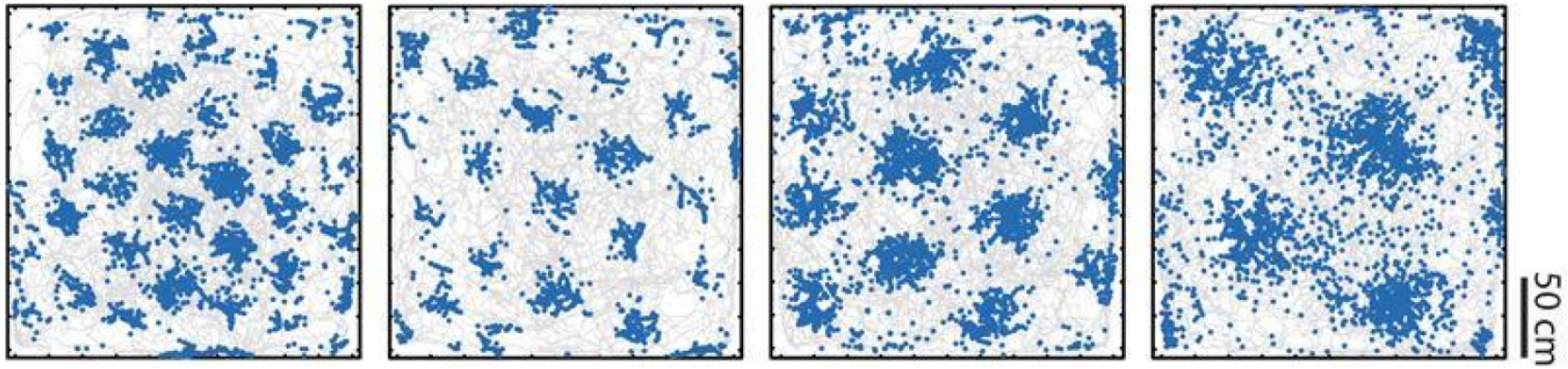
trajectories & firing

average firing rate

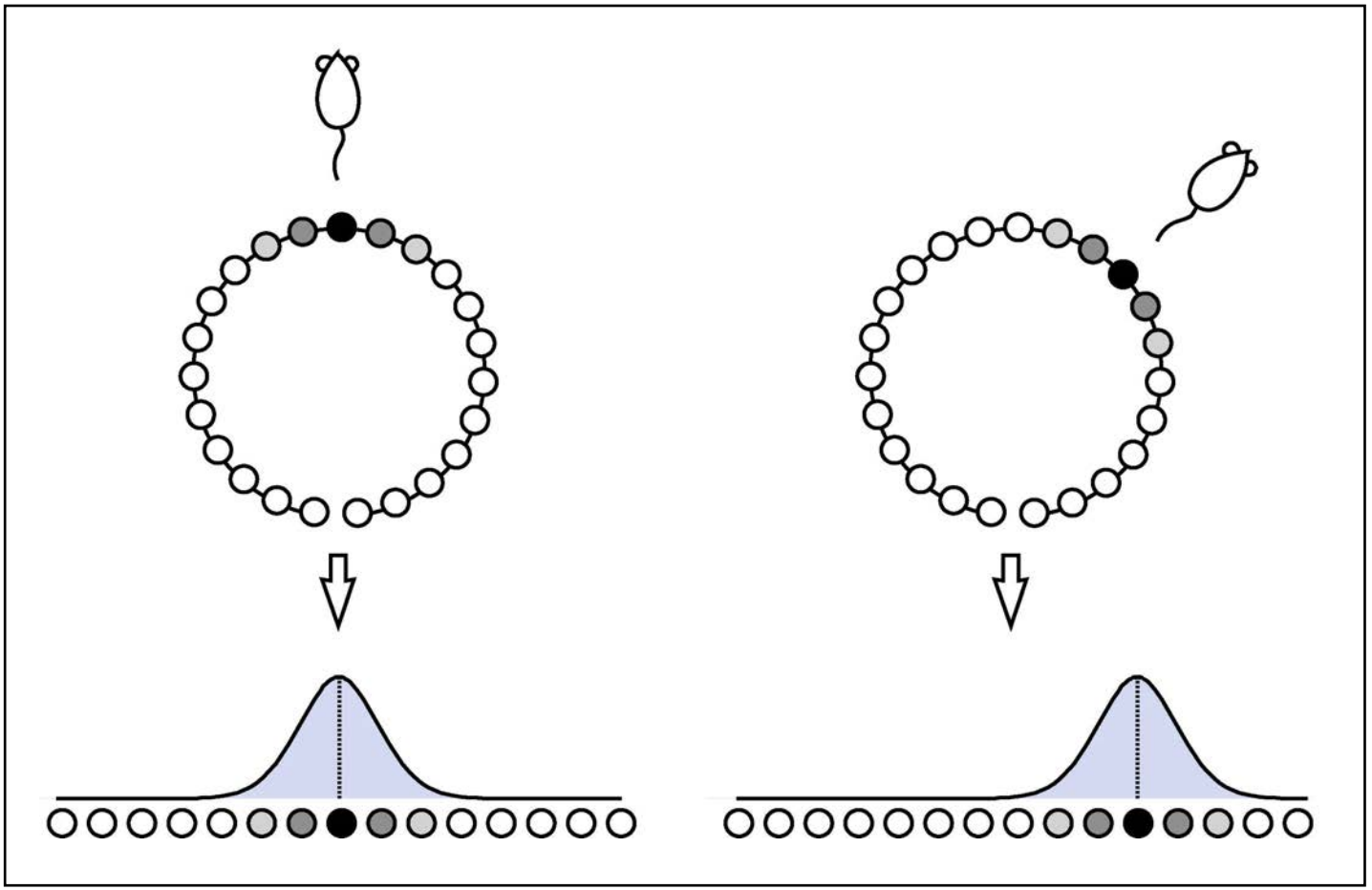


Another 3 cells: trajectories and spikes (superimposed)

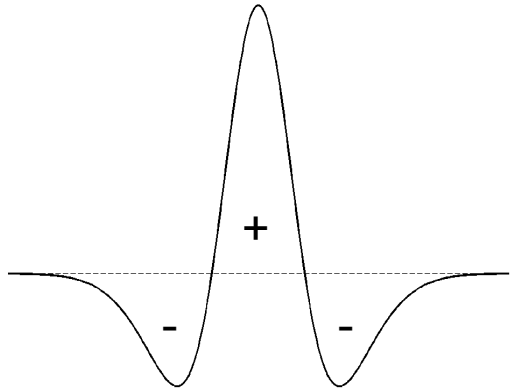
Grid cells have different spatial scales



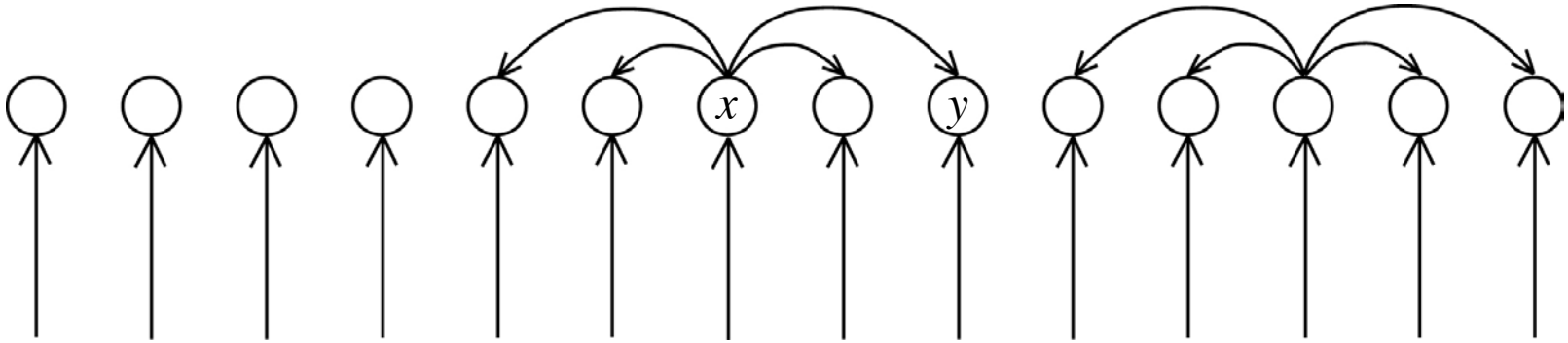
Example of continuous attractors: Ring attractor



Recurrent network: center-surround lateral connections



Recurrent weight distribution $W(y-x)$

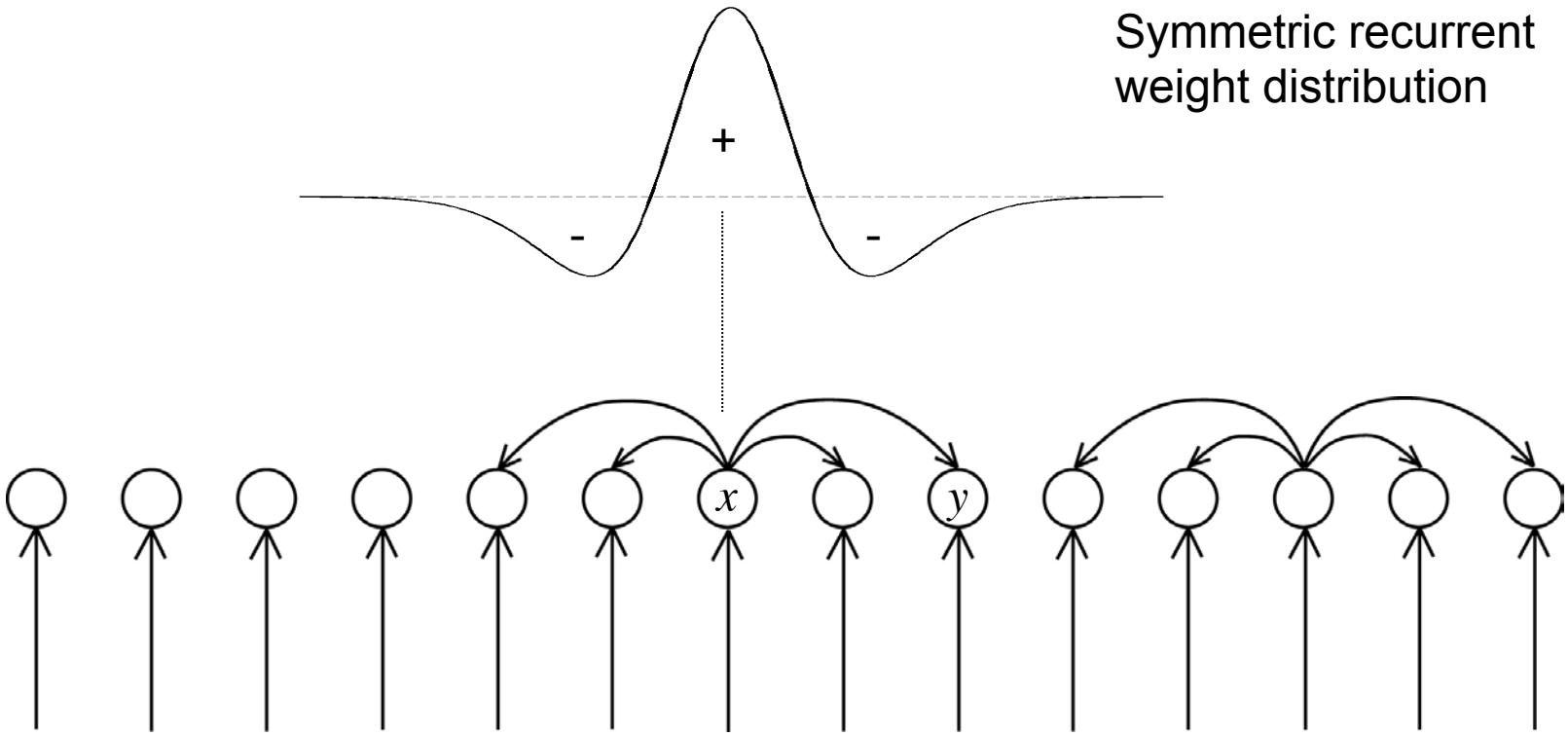


External input $I(x,t)$

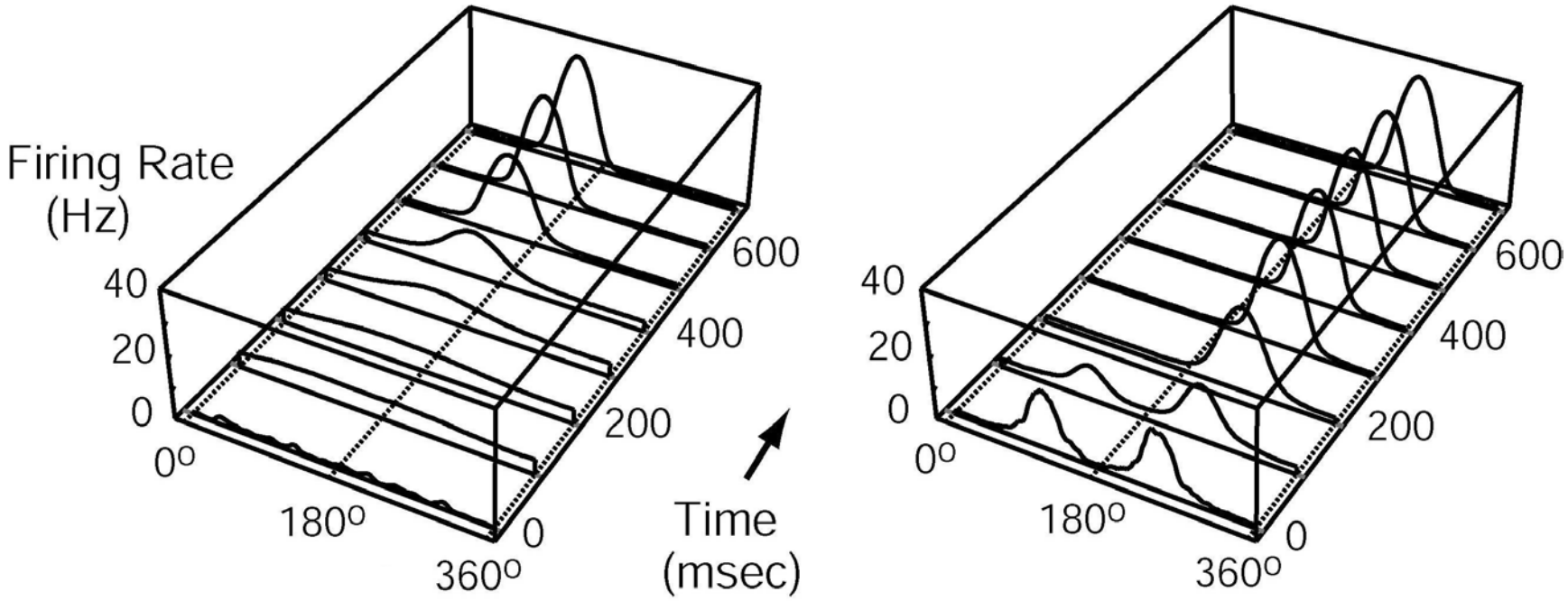
$$\frac{\partial S(x,t)}{\partial t} = -S(x,t) + \sum_{y} W(y-x) g\Big(S(y,t)\Big) + I(x,t)$$

where $S(x,t)$ is the activity of the neuron at location x and time t and $g(\,)$ is gain function.

Recurrent network with symmetric lateral connections

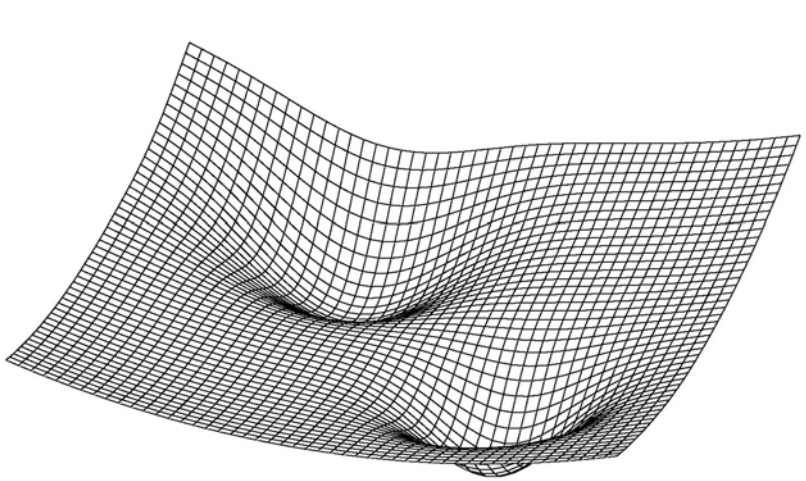


Snapshots of the activity of a symmetric recurrent network starting from different initial states



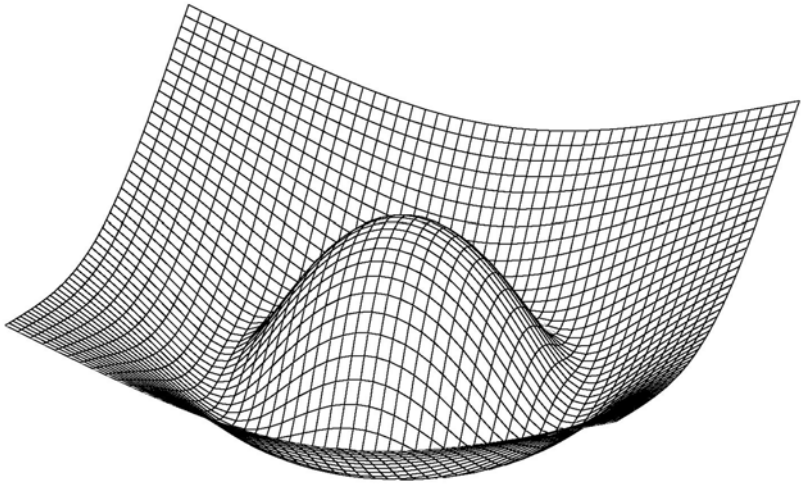
Liapunov function (energy) of network state

Point Attractors



Discrete memory states
in a Hopfield network

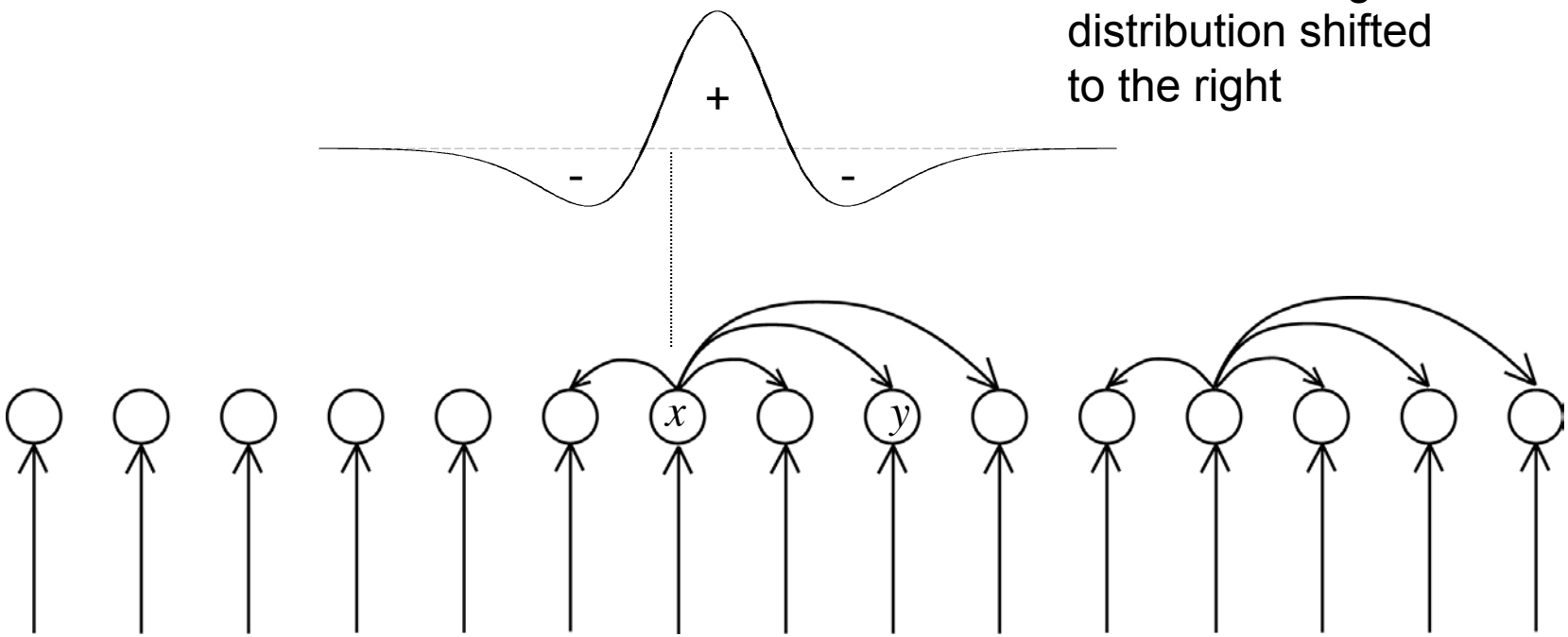
Continuous Attractor



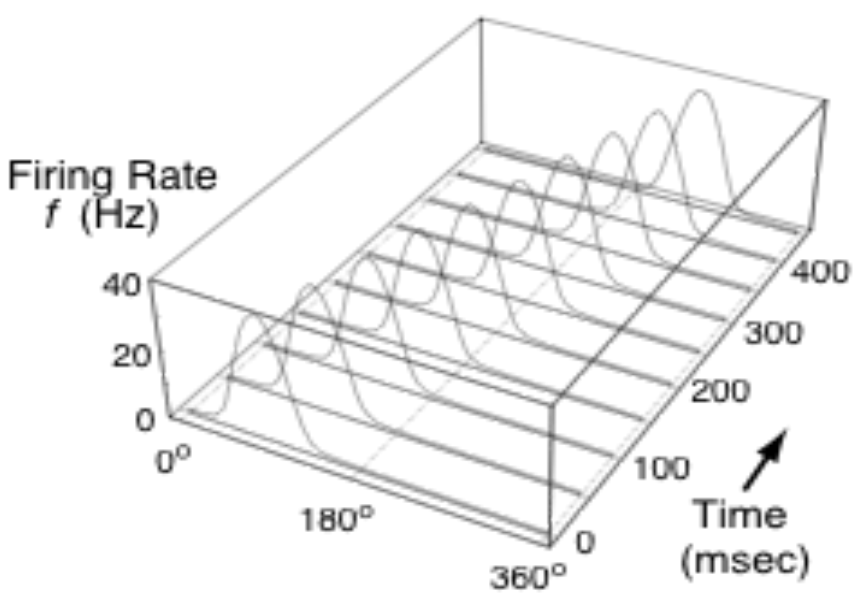
A continuum of stable states
(here a ring)

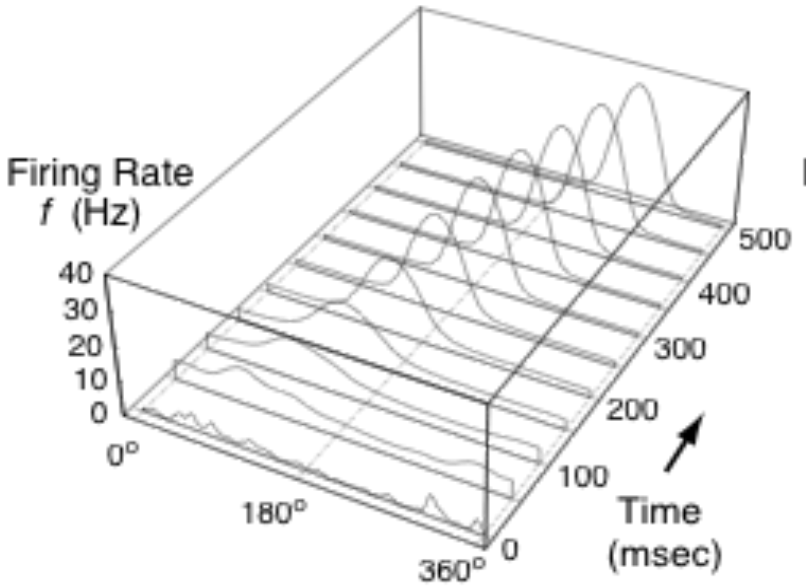
Asymmetric lateral connections

Recurrent weight distribution shifted to the right

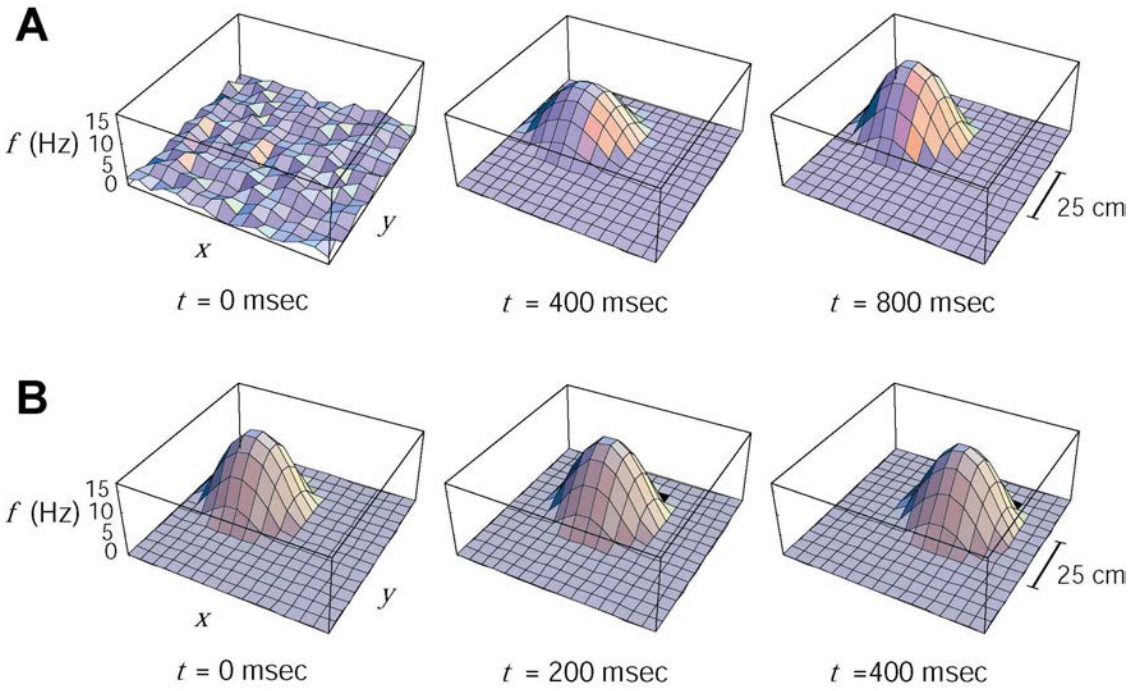


Snapshots of the activity of an asymmetric recurrent network starting from different initial states

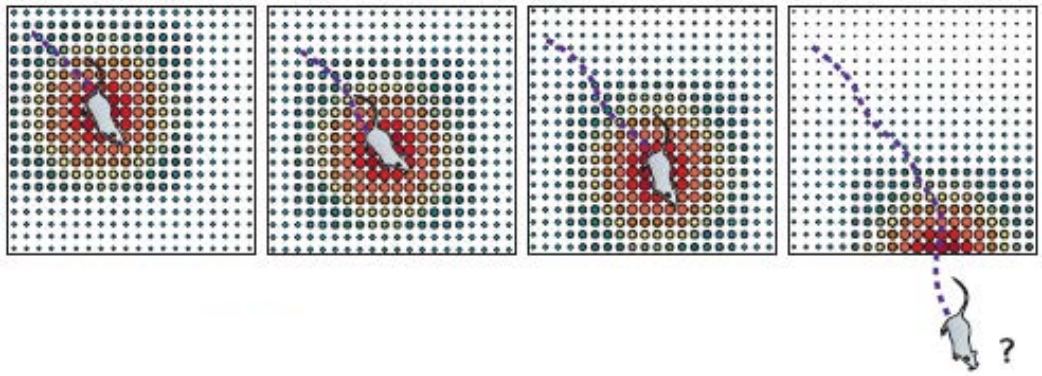




Place cell activity as plane attractor

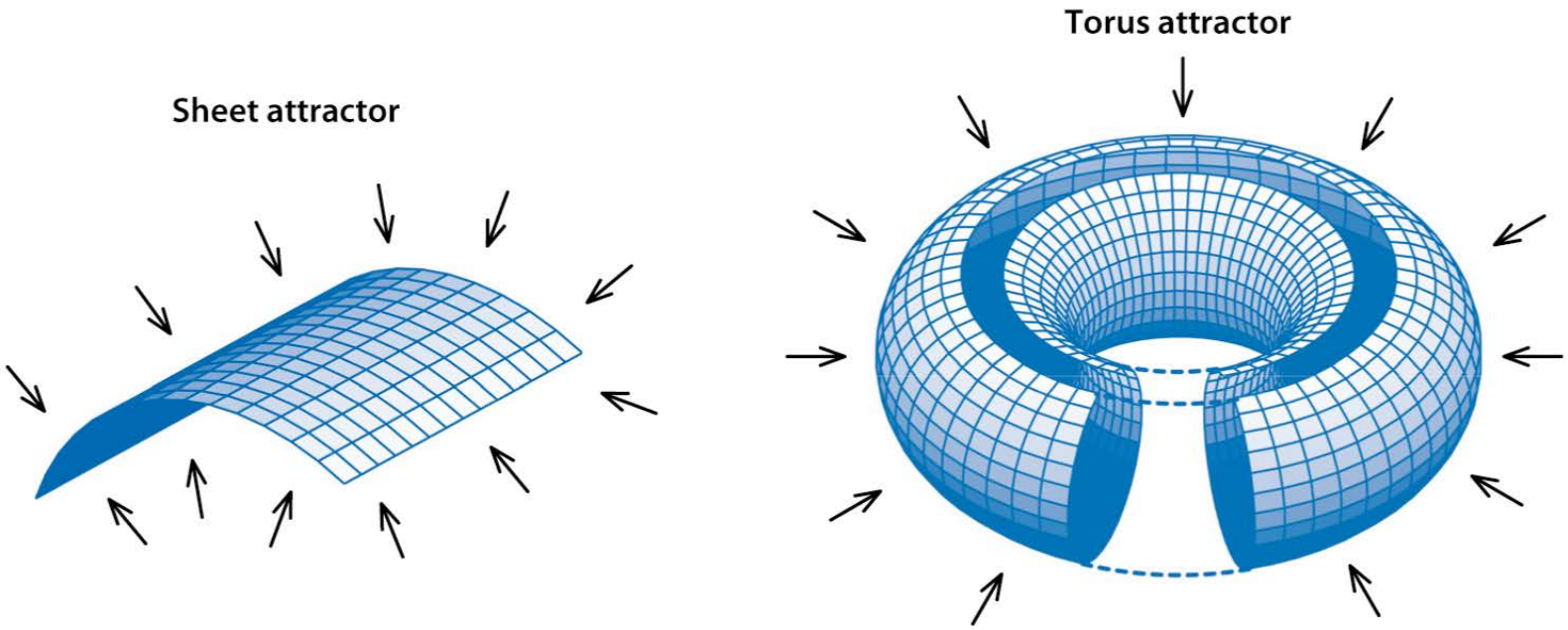


(Zhang)



(McNaughton)

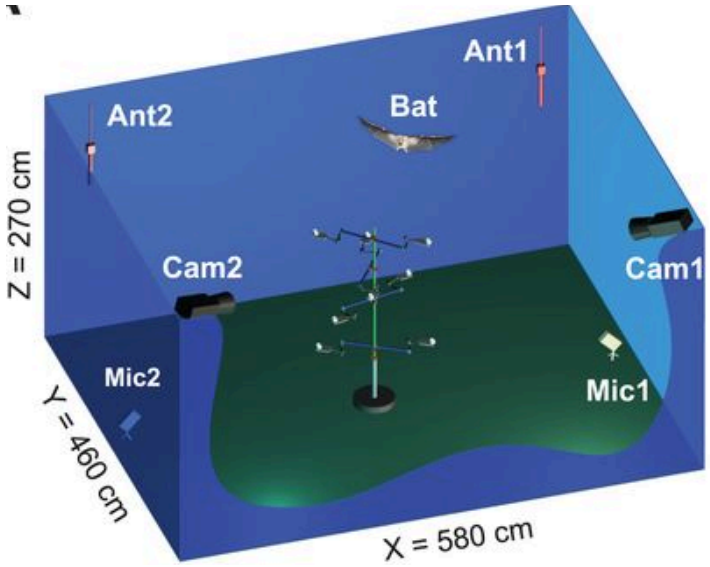
Grid cell activity as torus attractor?

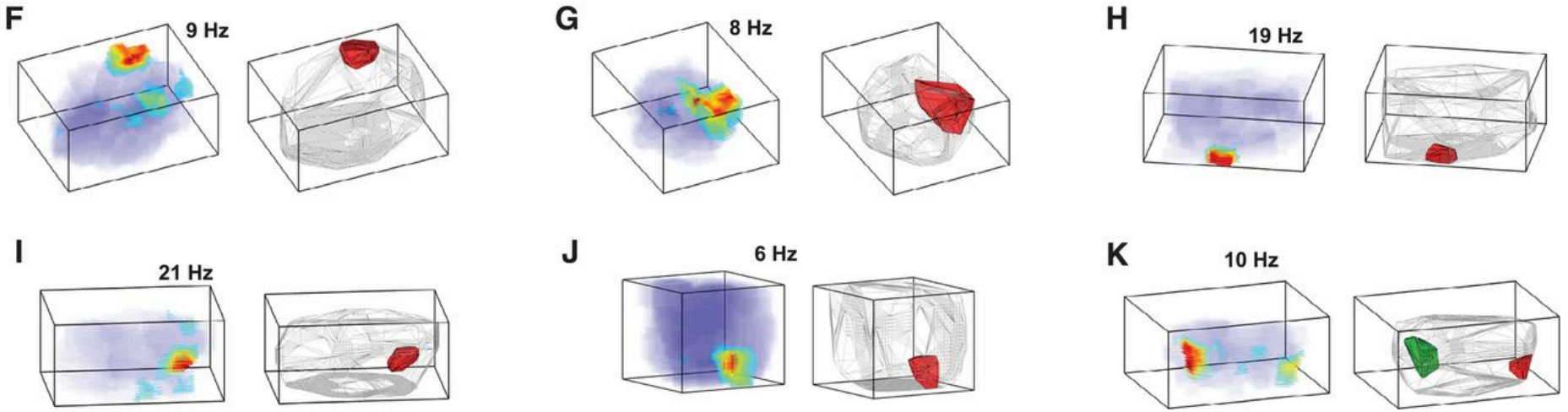


Comparison of different animals

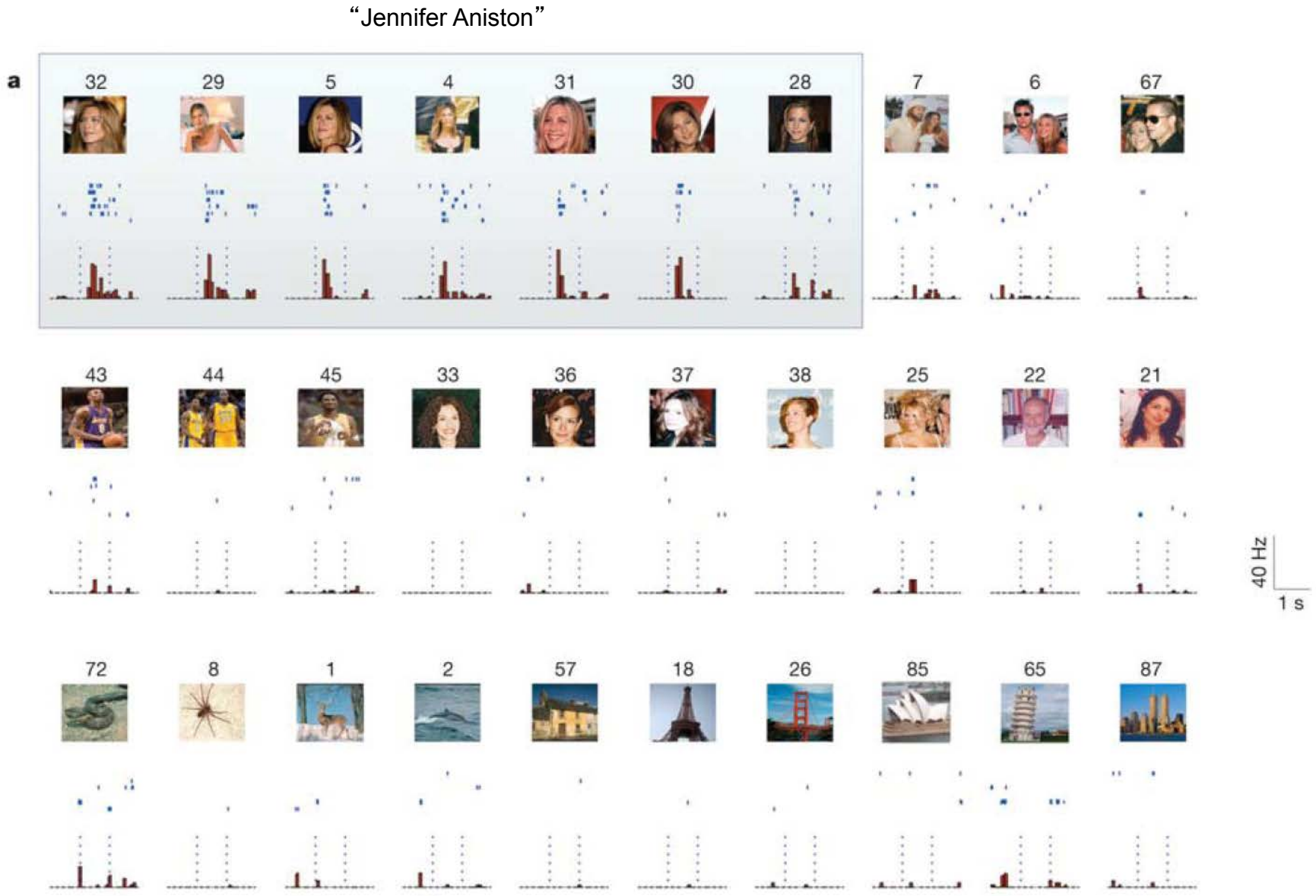
- Rat & Mouse: head-direction cell, grid cell, and place cell
- Bat: place cell in 3D space
- Monkey & Human may have head-direction cell, grid cell, and place cell as well. Evidence for “grandmother cell”.

Three-dimensional place cells in the hippocampus of flying bat

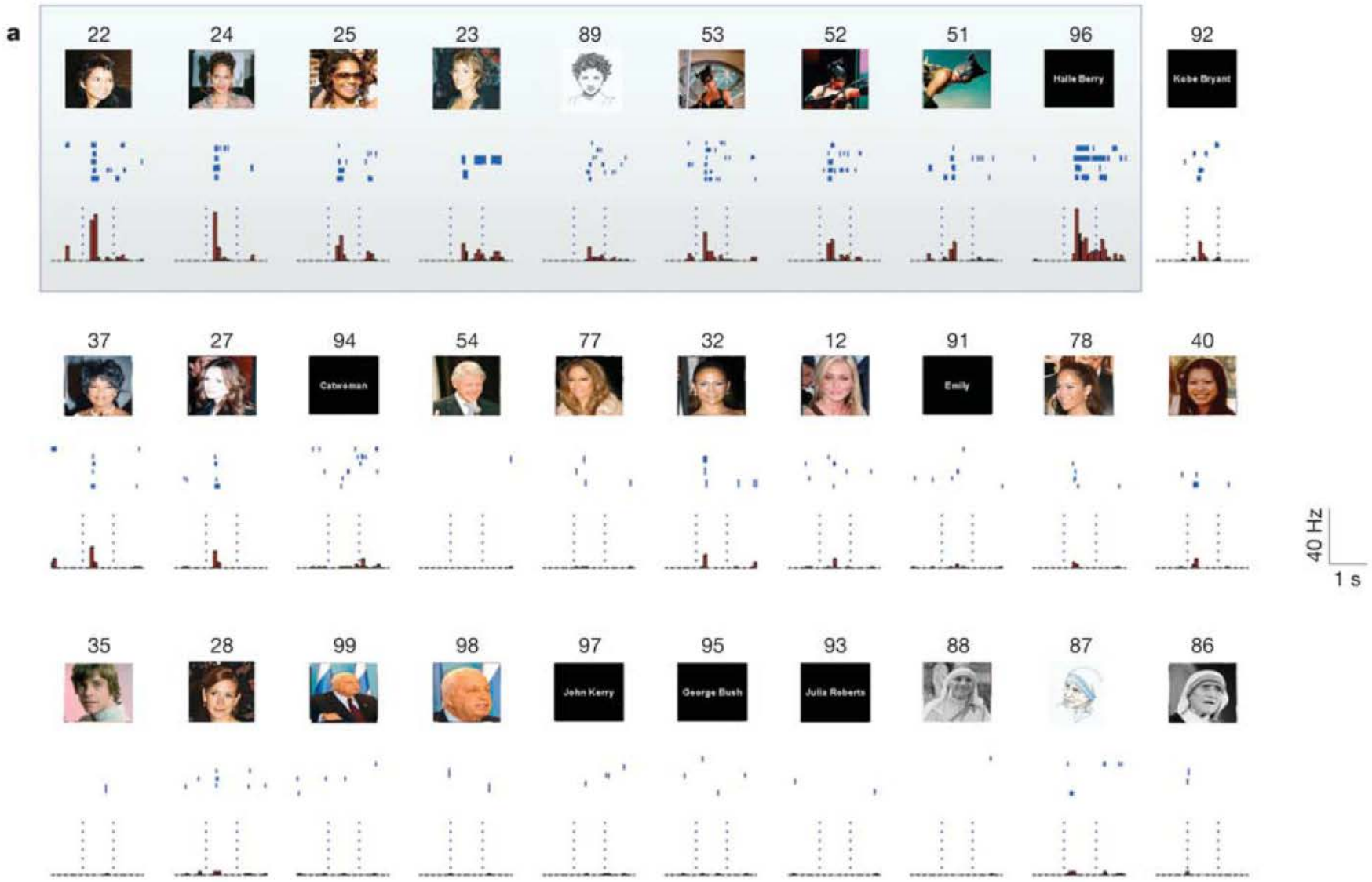




Response of a single neuron in human hippocampal region



“Halle Berry”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Halle Berry
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Kobe Bryant
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Catwoman
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Emily
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John Kerry
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George Bush
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Julia Roberts
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“Sydney Opera”