

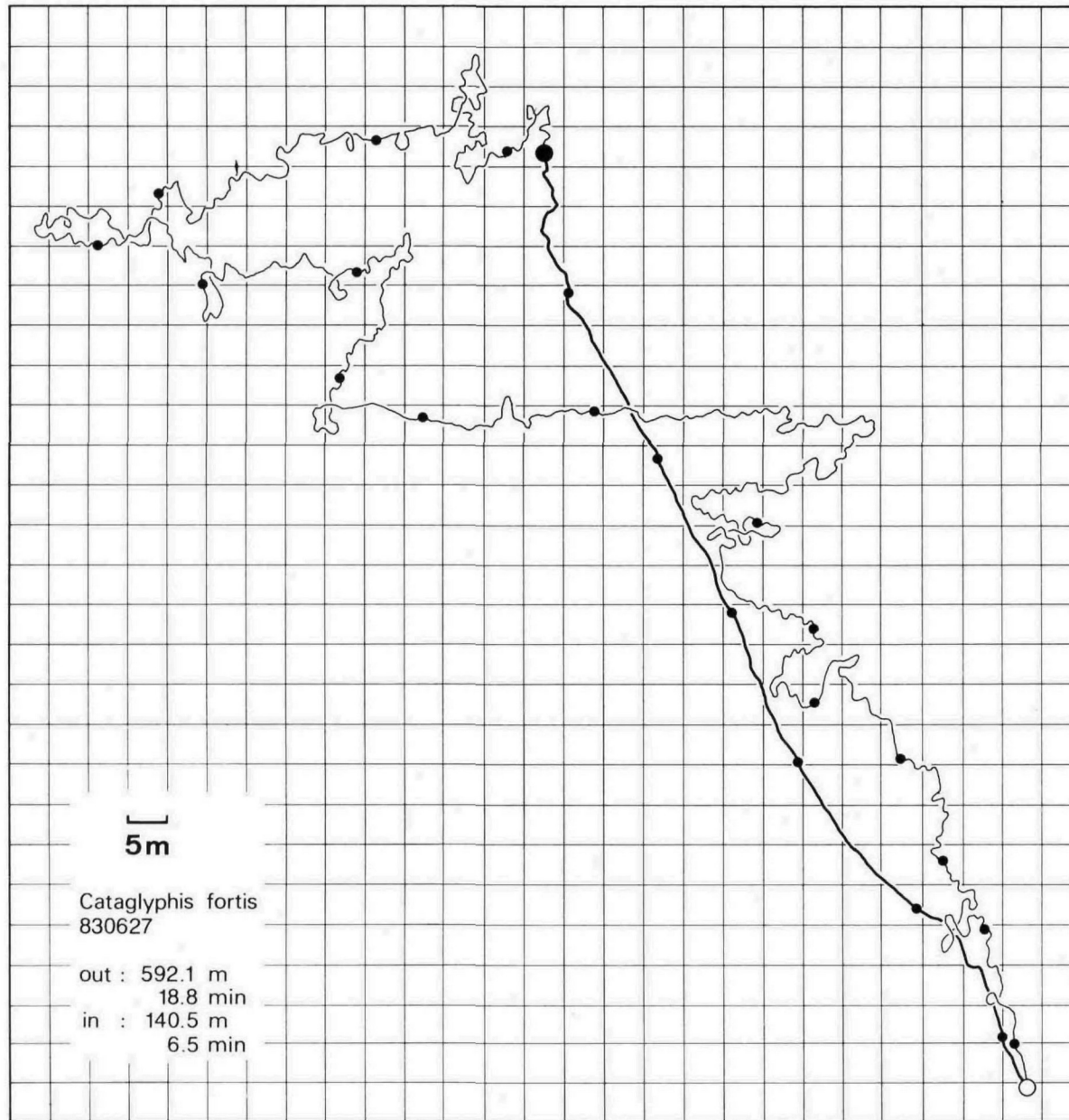
BIOENG-456

Controlling Behavior in Animals and Robots

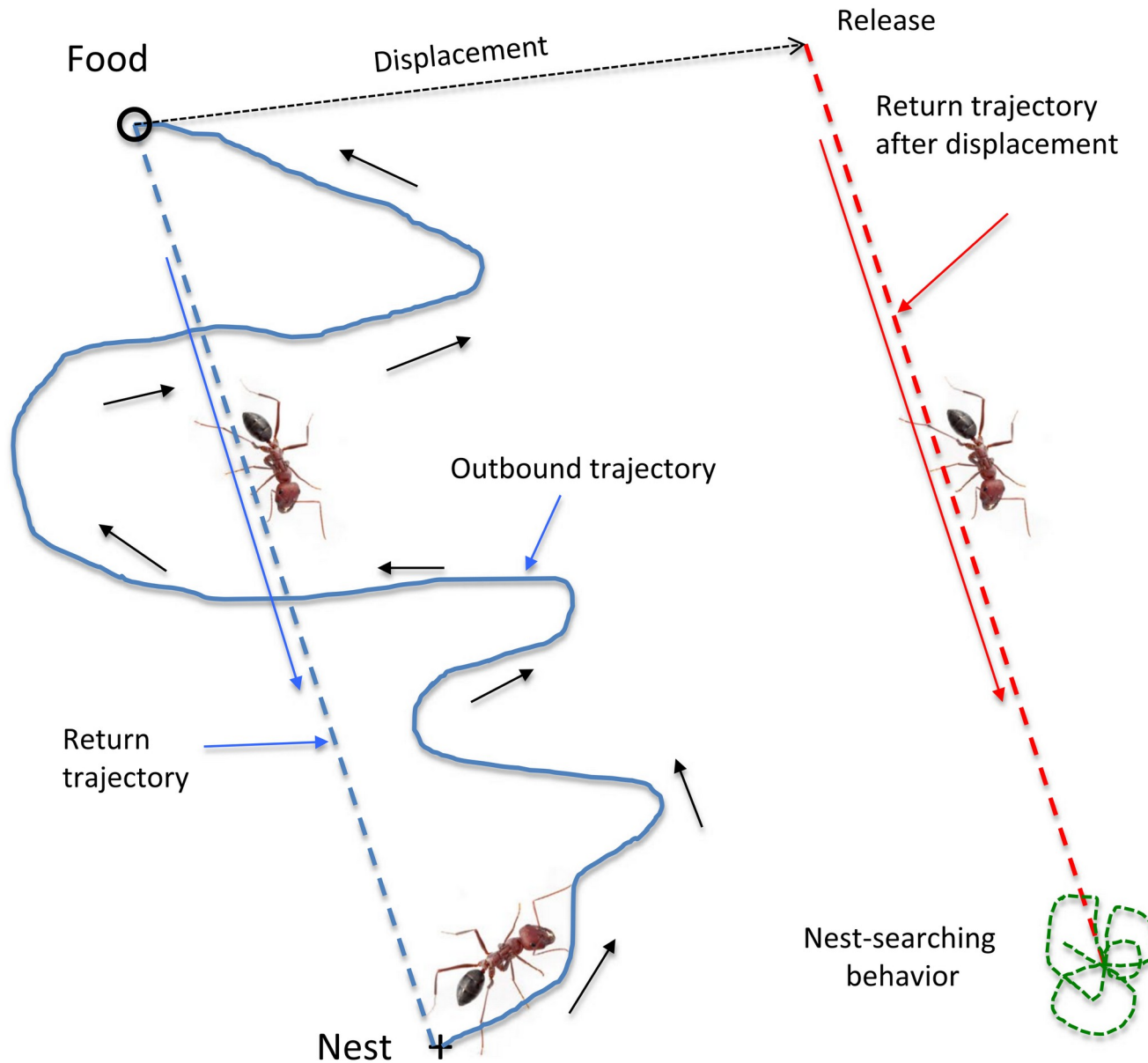
Week 6: Path integration

Which information would you need to know where you are going and how to get back to where you started?

Path integration

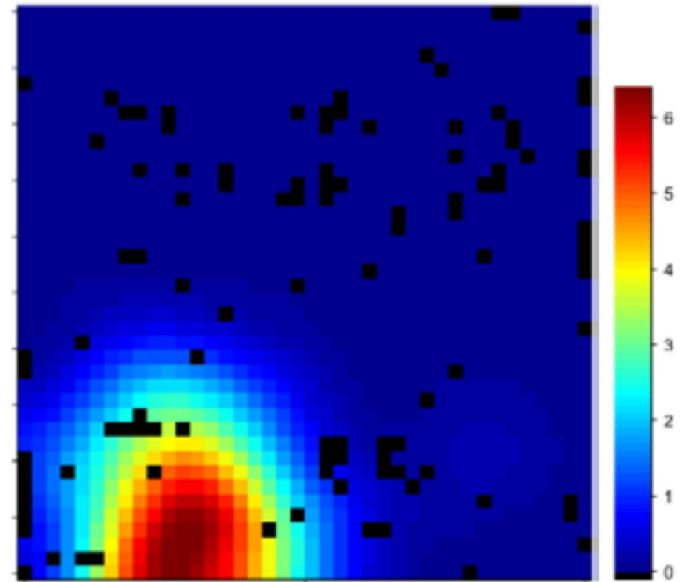
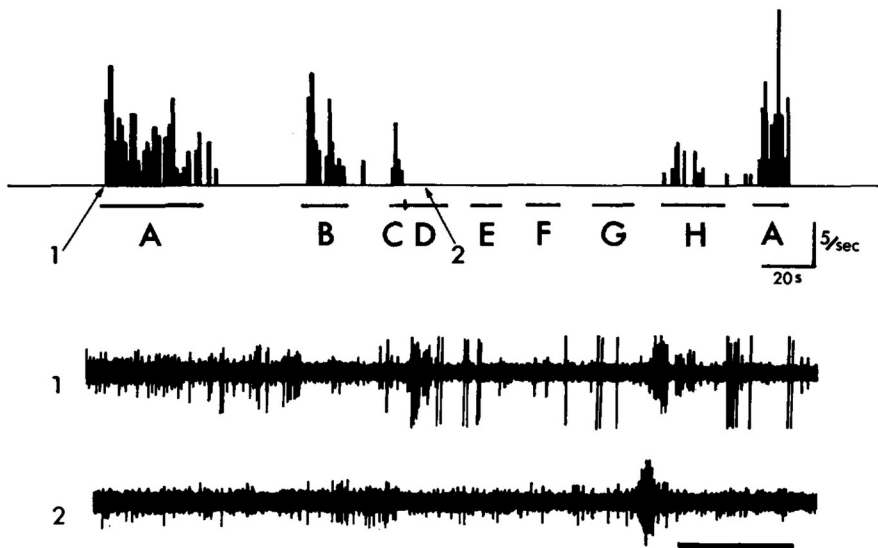
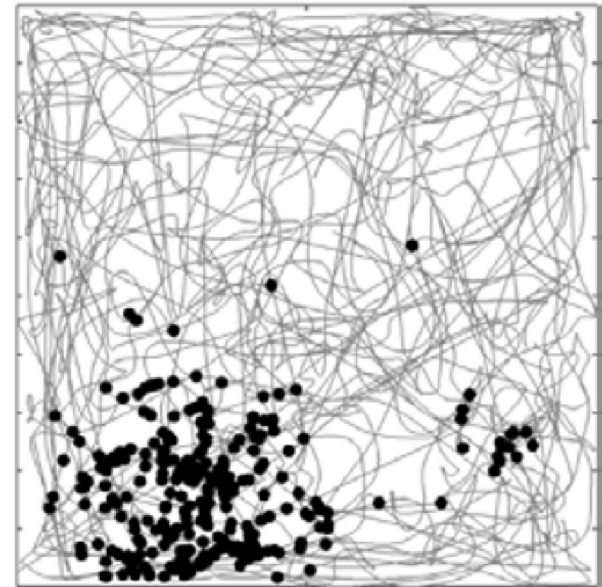
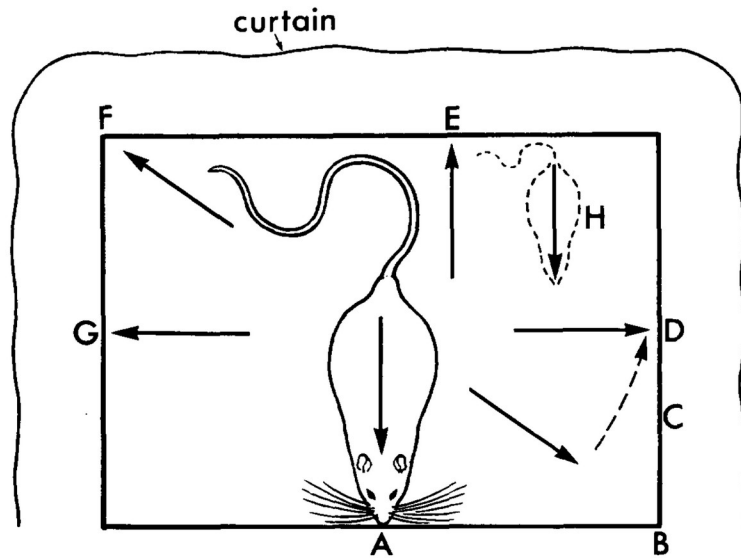


Path integration



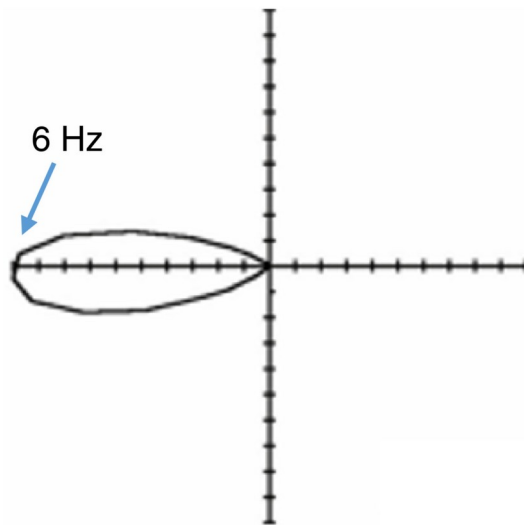
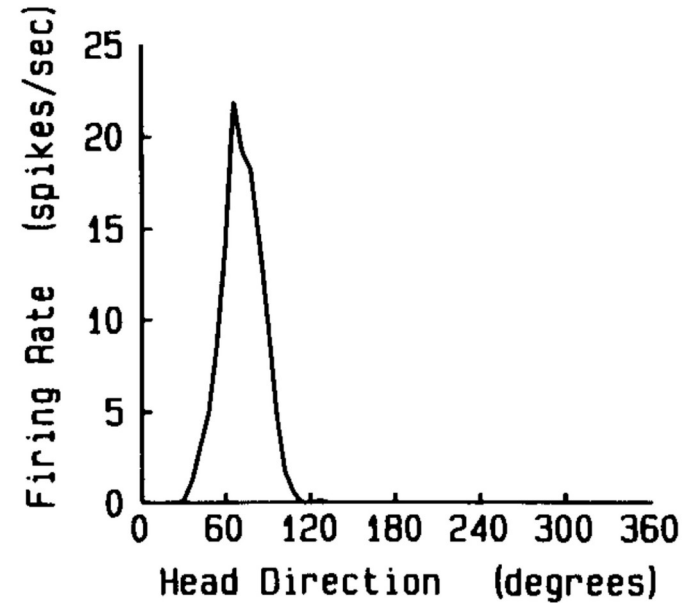
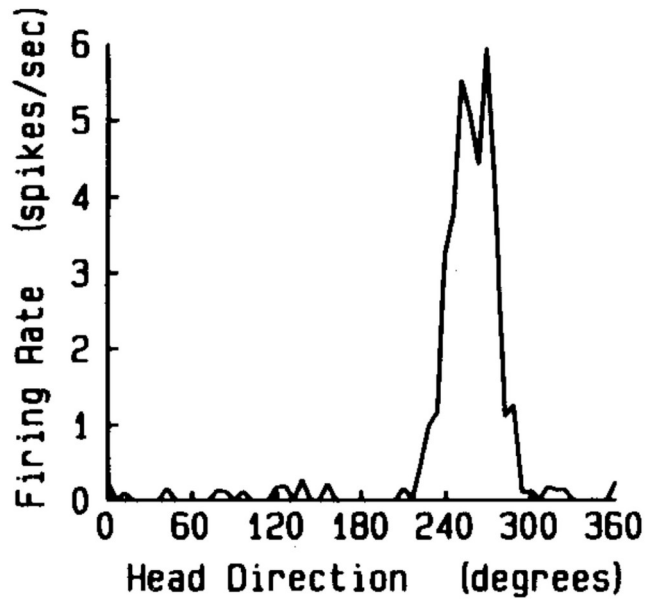
How do animal navigation systems work?

Place cells



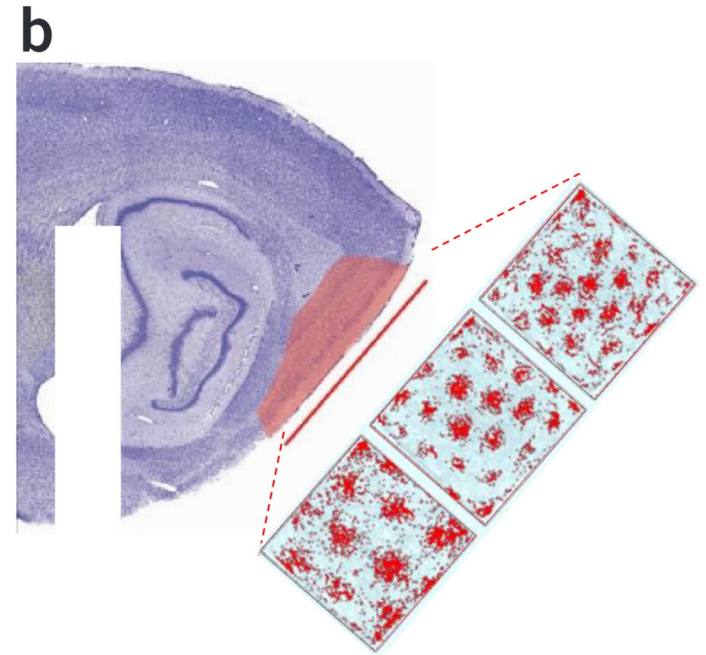
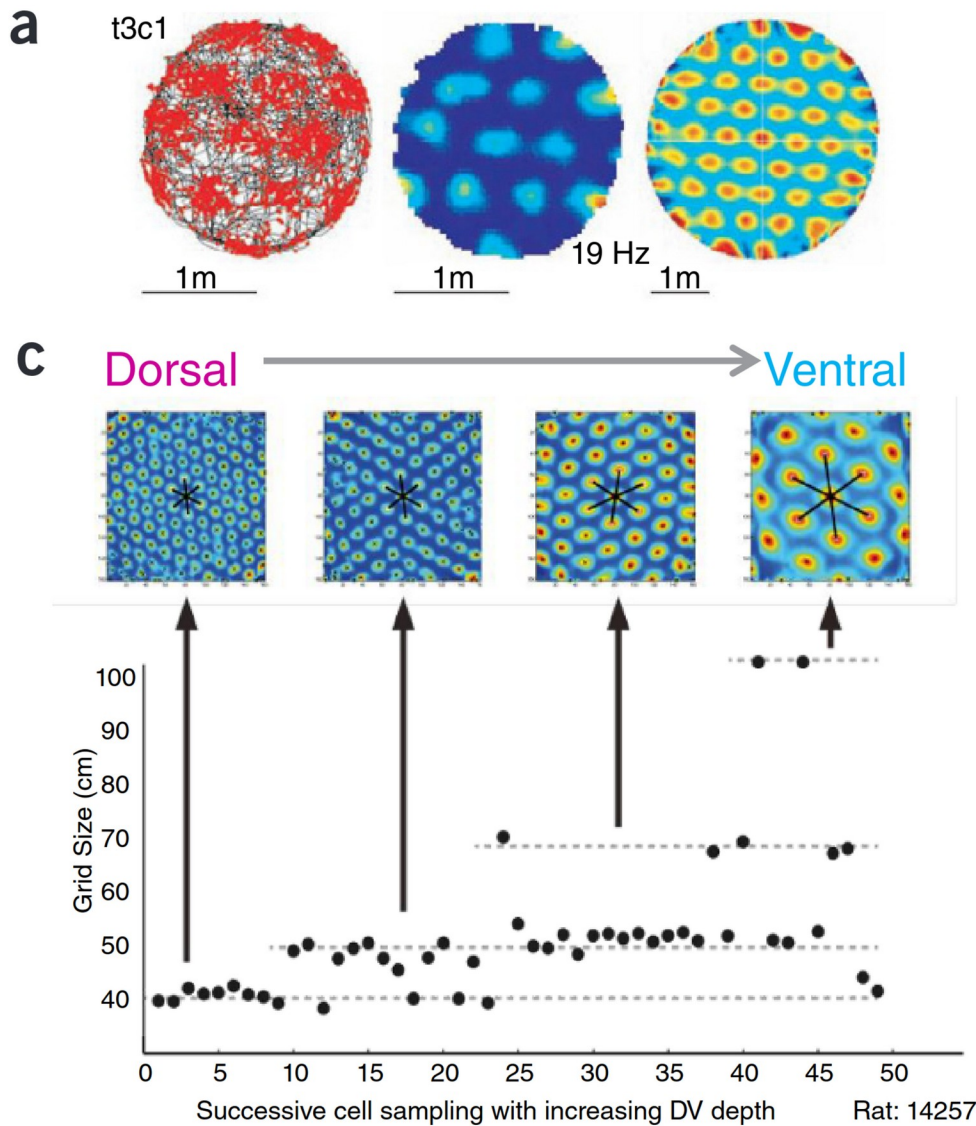
O'Keefe, J. & Dostrovsky, J. *Brain Res.* 1971
Moser et al., *Nature Neuroscience* 2017

Head-direction cells



Taube, J.S. Muller, R.U. & Ranck Jr., J.B. *J. Neurosci* 1990
Moser *et al.*, *Nature Neuroscience* 2017

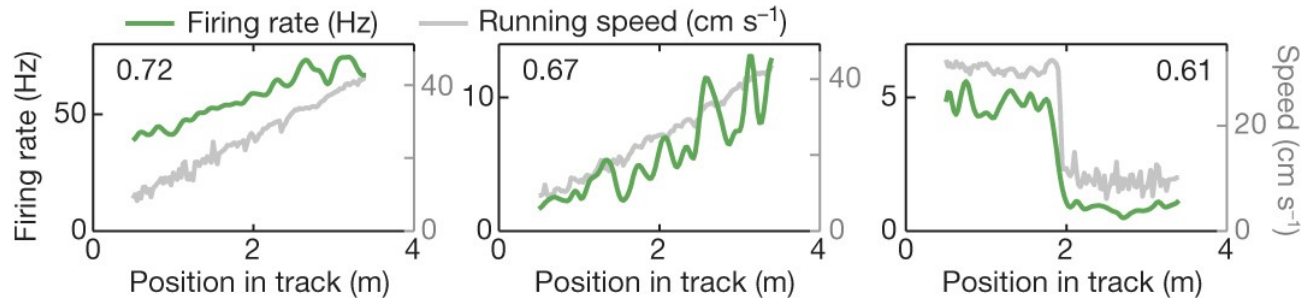
Grid cells



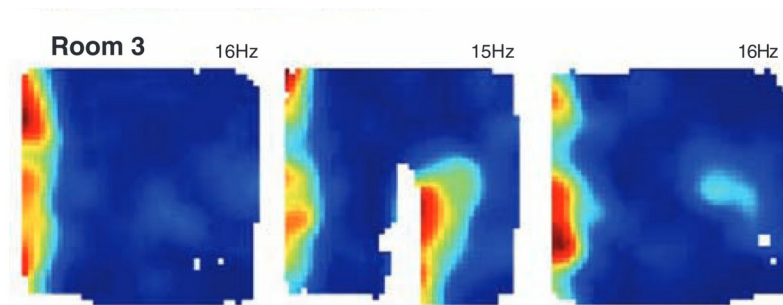
Hafting *et al.*, *Nature* 2005
 Moser *et al.*, *Nature Neuroscience* 2017

A zoo of cell types

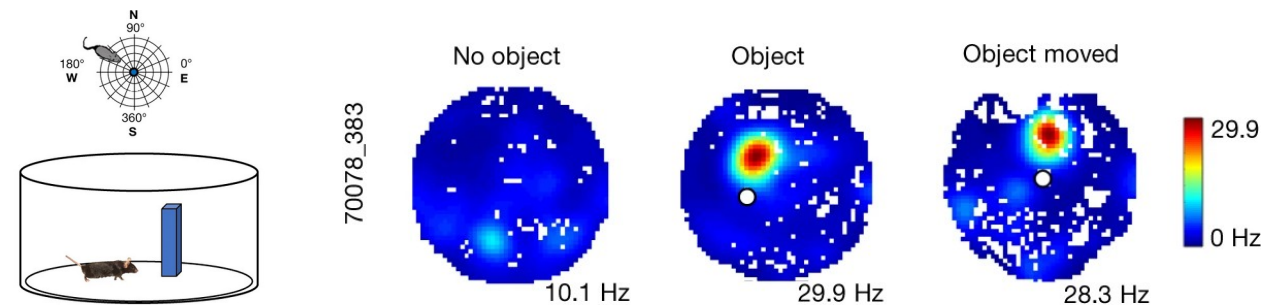
Speed
cells



Boundary
cells



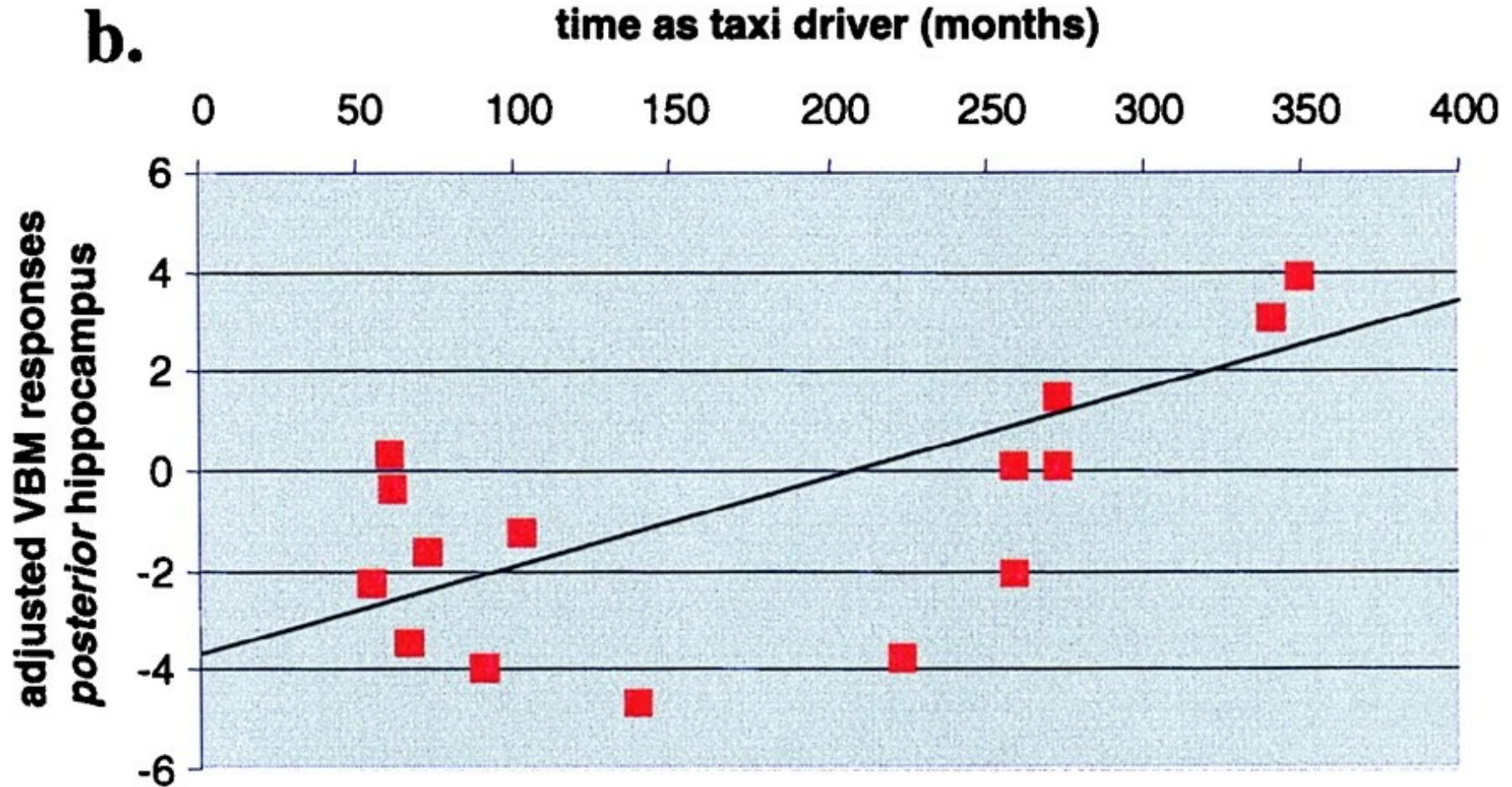
Object
vector
cells



Emilio K. *et al.*, *Nature* 2015
Solstad T. *et al.*, *Science* 2008
Høydal Ø. *et al.*, *Nature* 2019

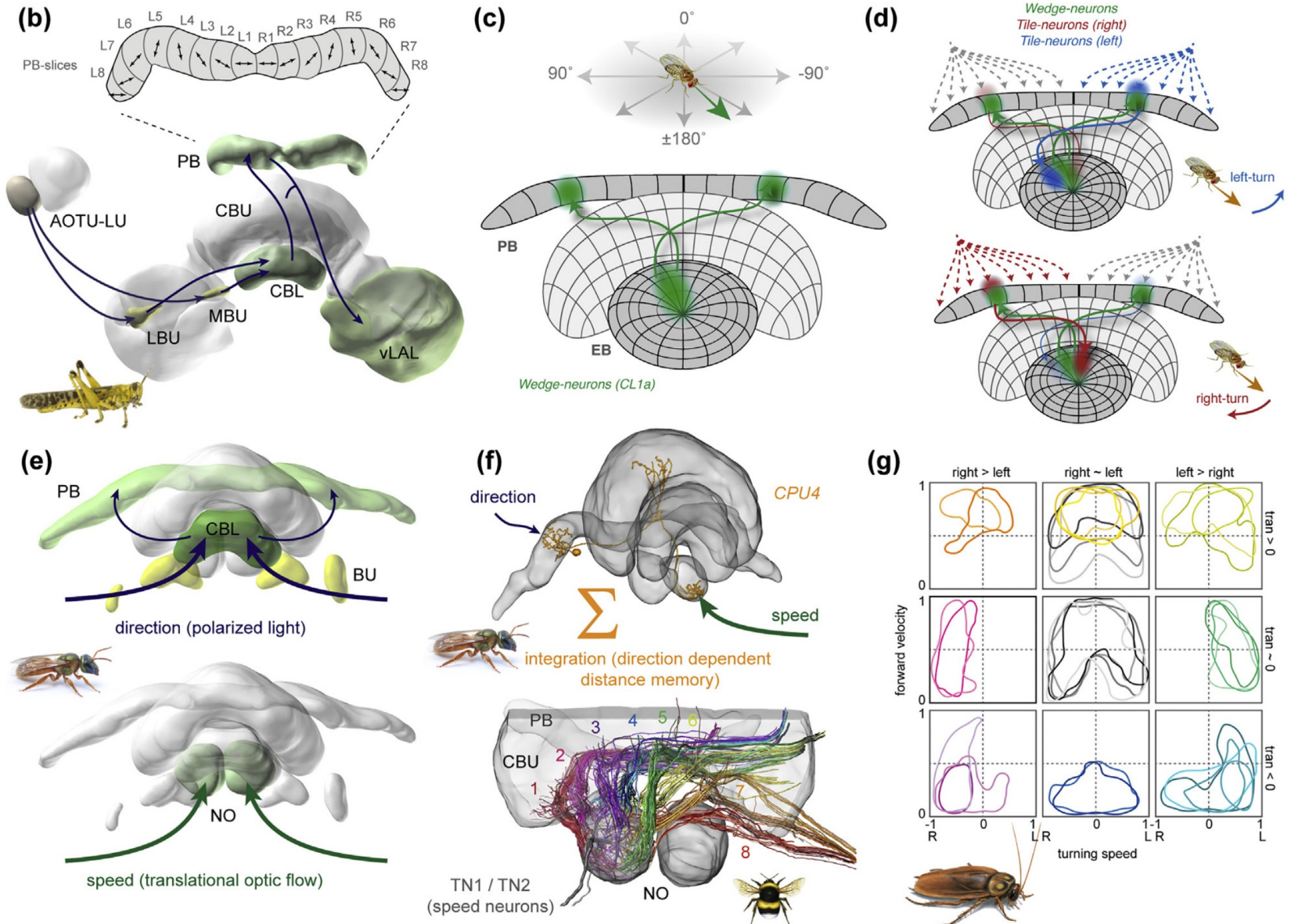
What about humans?

Hippocampus volume larger for London taxi drivers

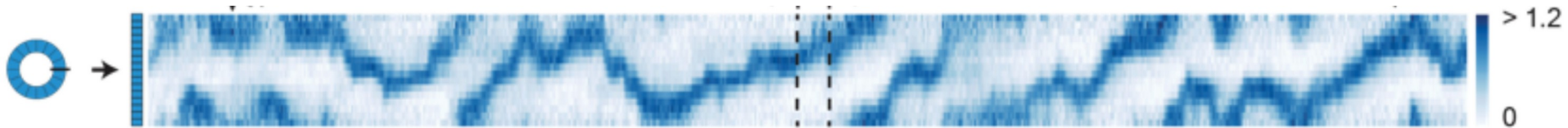
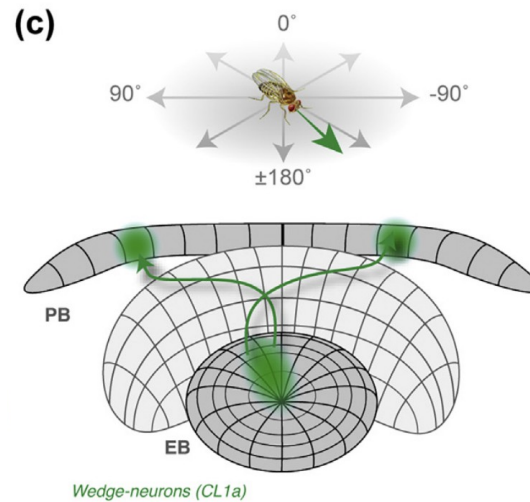


How could neural circuits track these variables needed for navigation?

Insect Head direction cells

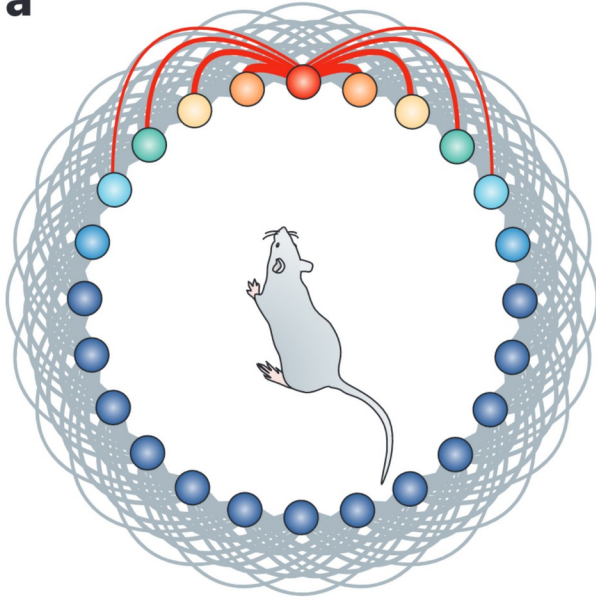


Insect Head direction cells

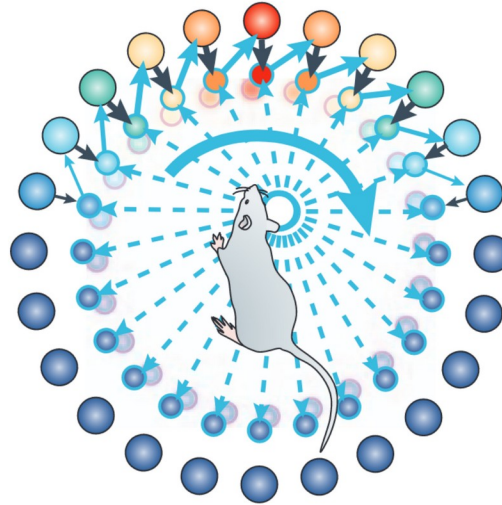


Ring attractors

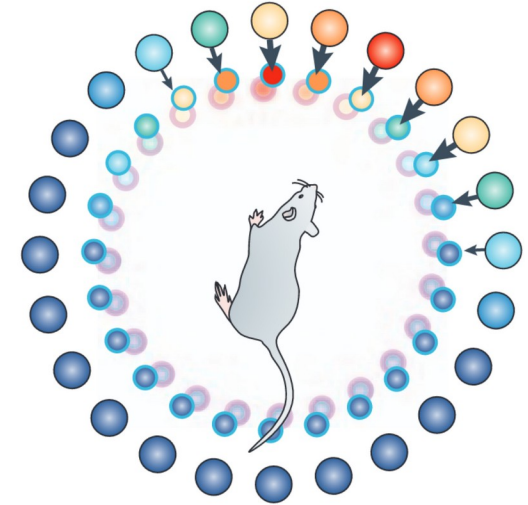
a



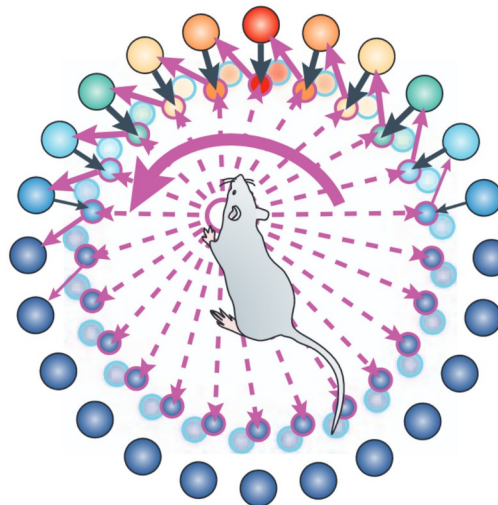
b Clockwise motion



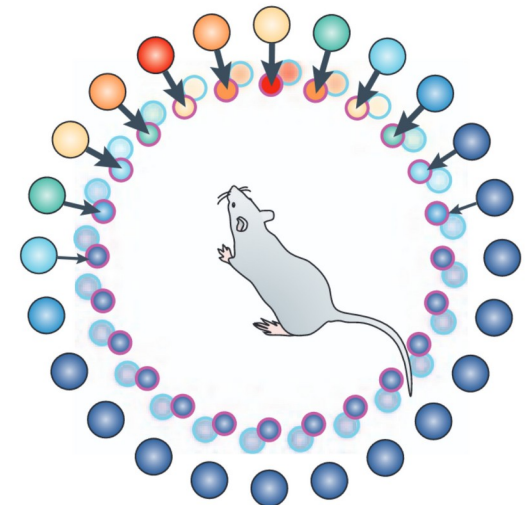
No motion



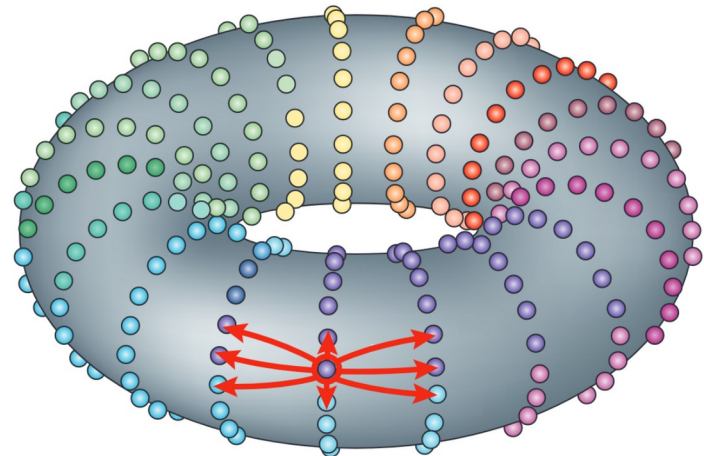
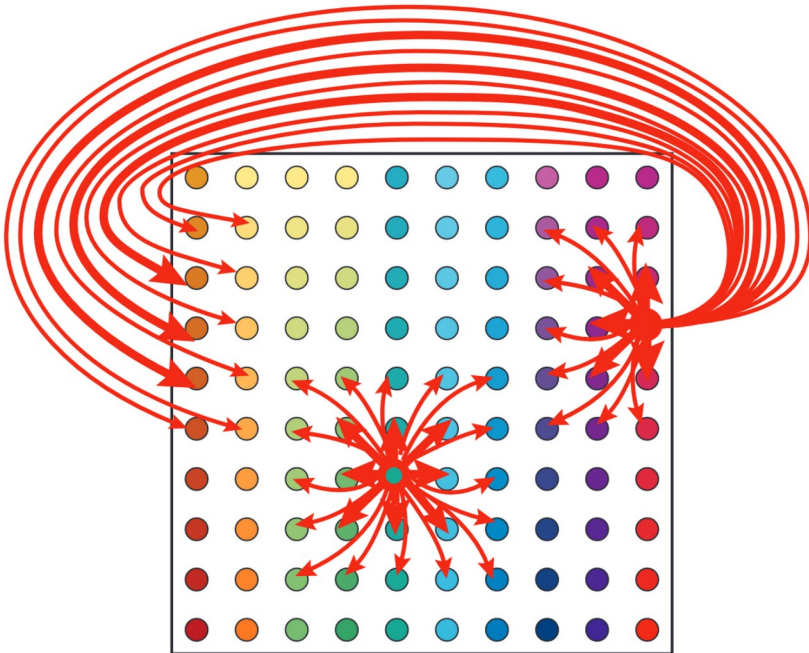
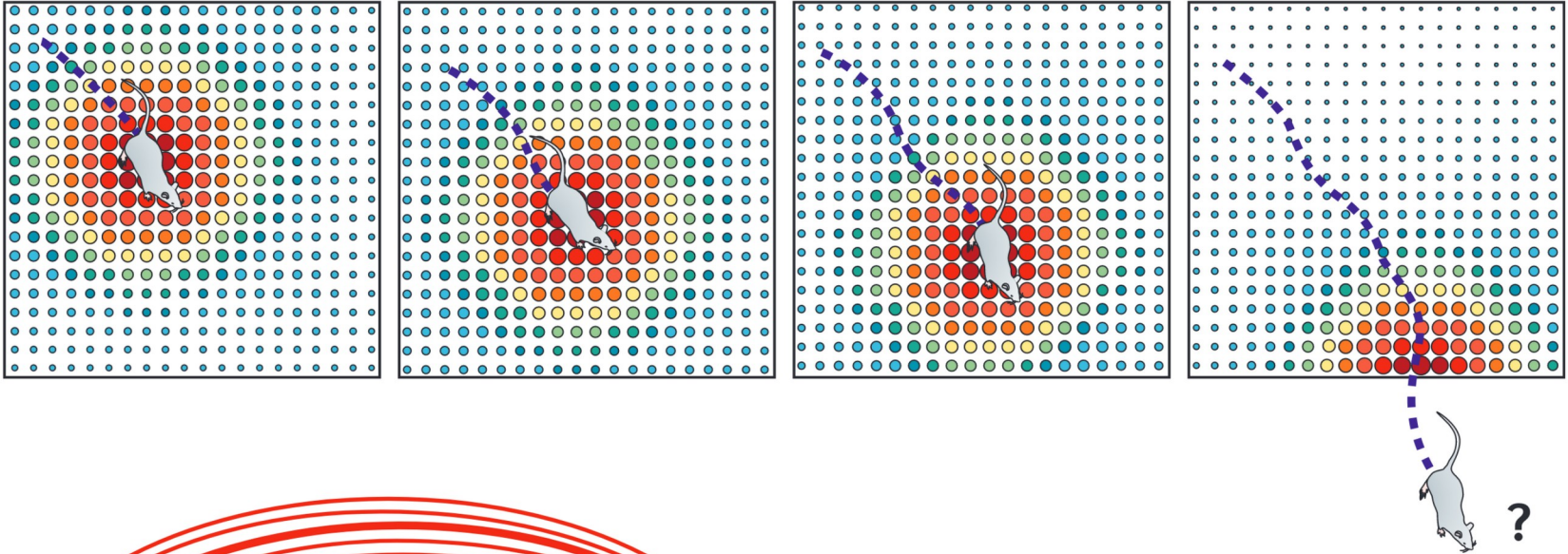
Anticlockwise motion



No motion



Toroidal attractors



Open Questions

- Hippocampus: Space vs memory
- 3D
- Grid / place cell formation
- Large scale grids

Any questions?

Today's papers:

Which are the neural substrates for path integration in the fly?