How the brain makes a map of space

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How does the brain make an internal model of complex space?

This is important for:
- Navigation
- Memory
- Language
Major cortical brain systems

The motor and sensory cortexes and the association areas for each

- **Motor Cortex**
  - Somatic motor association area

- **Gustatory Cortex**

- **Olfactory Cortex**
  - Primary auditory cortex
  - Auditory association area

- **Sensory Cortex**
  - Somatic sensory association area

- **Visual Cortex**
  - Primary visual cortex
  - Visual association area
Major subcortical brain systems
Different kinds of spatial behaviour
Local behaviour referenced to the body
Habit-based behaviour controlled by the structure of the environment
Long-range navigation based on an internal map

Hippocampus
How is all this done by neurons?
Studying knowledge formation at the single neuron level

Camera Recording system

Rat on arena

John O’Keefe
A compass in the brain: The head direction cells

Note that this “compass” is not tied to magnetic North
Does this mean the brain uses a hexagonal grid reference?
The Nobel Prize in Physiology or Medicine 2014

**John O’Keefe** discovered, in 1971, that certain nerve cells in the brain were activated when a rat assumed a particular place in the environment. Other nerve cells were activated at other places. He proposed that these “place cells” build up an inner map of the environment. Place cells are located in a part of the brain called the hippocampus.

![Fig. 1](image1)

**May-Britt Moser and Edvard I. Moser** discovered in 2005 that other nerve cells in a nearby part of the brain, the entorhinal cortex, were activated when the rat passed certain locations. Together, these locations formed a hexagonal grid, each “grid cell” reacting in a unique spatial pattern. Collectively, these grid cells form a coordinate system that allows for spatial navigation.

![Fig. 2](image2)
US-born neuroscientist John O'Keefe has jointly won the 2014 Nobel Prize for medicine for discovering the brain’s navigation system. Is it any surprise then that he loves Ordnance Survey maps, writes Luke Jones.

O'Keefe came to the UK from the US in the late 1960s. He was supposed to stay for only two years as part of post-doctoral study. He decided to relocate for good.

The 74-year-old told BBC Radio 4’s Today programme that he was "very attracted to many aspects of British culture".

Two aspects that he named were the NHS and the Ordnance Survey map. "I like the organisation of the British system, the fact that we get our street names in order, it’s very satisfying," he said.
Morris showed that rats need their hippocampus to navigate across featureless terrain.
Maguire showed that the hippocampus is needed for navigation in humans too.
Fried and colleagues have found place cells in humans.
What we know

How spatial neurons form a perceptual representation of immediate space

What we don’t know

How these local representations are, themselves, related

The foundation of complex cognition
We think the grid cell map may be ‘multi-planar’ in 3D
What happens in a volumetric space?
What is the future for the cognitive neuroscience of navigation?
Building spaces we can comprehend

DC Convention Center
Building navigable cities
Integrated technology
Multidimensional spaces
COGNAV (Cognitive navigation)

About COGNAV

Cognition = knowledge; the Cognition & Navigation (CogNav) group is for those interested in the navigator as a thinking, behaving agent, be it human, animal or machine.

The aim of the group is to bring together academics and those working in industry in order to provide a two-way conduit for scientific knowledge to impact on technology design, and for real-world problems with the potential to offer an interesting setting to inform academic enquiries.