cogs1
mapping space in the brain
Douglas Nitz – April 23, 2019
MAPPING SPACE IN THE BRAIN – RULE 1: THERE MAY BE MANY POSSIBLE WAYS

depth perception from motion parallax
or
depth perception from texture gradient
or
depth perception from occlusion
or
depth perception from retinal disparity (stereopsis)

:  
:  
but which?
MAPPING SPACE IN THE BRAIN – RULE 2: DEFINE THE FRAME OF REFERENCE

egocentric frames
- retinal space
- vestibular info.
- proprioception

arbitrary frames
- allocentric (world-centered)
- route-centered
- object-centered

senses
musculature
similarity in features of navigational strategies across mammalian species

similarity in detailed structure of brain across mammalian species
Santiago Ramon y Cajal’s ‘neuron doctrine’: establishes the neuron as the basic structural and functional unit of the brain (translation: neurons are to brain function as atoms are to molecules)

Cajal’s ‘law of dynamic polarization’: neural/electrical transmission proceeds in one direction – from dendrite/soma → axon → axon terminal (translation: dendrites take in information from other neurons and decide what message to send to other neurons)
multiple single neuron recordings in behaving animals:

- hippocampal pyramidal neuron
- recording
- occupancy counts
- firing rate neuron 1
- firing rate neuron 2

- tetrode (braided set of 4 electrodes)
- relative-amplitude spike discrimination

- electrode interface board
- micro-drives
- plastic drive base
- collector cannula

'place' field
MAPPING SPACE IN THE BRAIN – RULE 2: DEFINE THE FRAME OF REFERENCE

egocentric frames
- retinal space
- body/touch space
- proprioception

arbitrary frames
- allocentric (world-centered)
- route-centered
- object-centered

senses
musculature
PENFIELD AND JASPER, 1951 – THE ‘HOMONCULUS’ – AN EGOCENTRIC MAP
area VIP of parietal cortex I: bringing together personal (egocentric) spaces of the somatosensory and visual systems
area VIP of parietal cortex II: bringing together personal (egocentric) spaces of the somatosensory and visual systems …and movement related to them
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- proprioception

senses

musculature

arbitrary frames
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- route-centered
- object-centered
tracking directional heading in the allocentric (world-centered) frame of reference I: ‘head direction’ cells

– firing is tuned to the orientation of the animal's head relative to the boundaries of the environment

– different neurons have different preferred directions (all directions are represented)
tracking position in the world-centered (allocentric) frame of reference: the ‘place cell’

– firing is tuned to the position of the animal in the environment (the place ‘field’)

– different neurons map different positions (all directions are represented)

– rotation of the environment boundaries = rotation of the place fields
mapping position in the environment by path integration: ‘grid cells’

– neurons of the medial entorhinal cortex exhibit multiple firing fields in any given environment

– such fields are arranged according to the nodes of a set of ‘tesselated’ triangles

– grids, like head-direction tuning and place cells firing fields rotate with the boundaries of the environment

Hafting et al., Nature, 2005
how do grid cells yield hippocampal allocentric position maps?

McNaughton et al., 2006, Nature Reviews Neuroscience
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together the triangles form an object the ‘top’ of which is perceived as indicated by the arrows – humans with damage to the right parietal cortex (and associated hemineglect) often fail to detect the gap in the triangle (red arrows) when it is on the perceived left side of the object (SE-NW) as opposed to the right (SW-NE)
parietal cortex neurons in behaving rats map path segments (e.g., start pt. to first R turn)
Parietal cortex: a rather abstract frame of reference – the space defined by the route (i.e., the space defined by sequence of behavior changes and the spaces separating them).

Nitz, Neuron, 2006
BOLD SIGNALS IMPLICATE HIPPOCAMPUS AND PARIETAL CORTEX IN NOVEL SCENE CONSTRUCTION

Hassabis et al., JNS, 2007