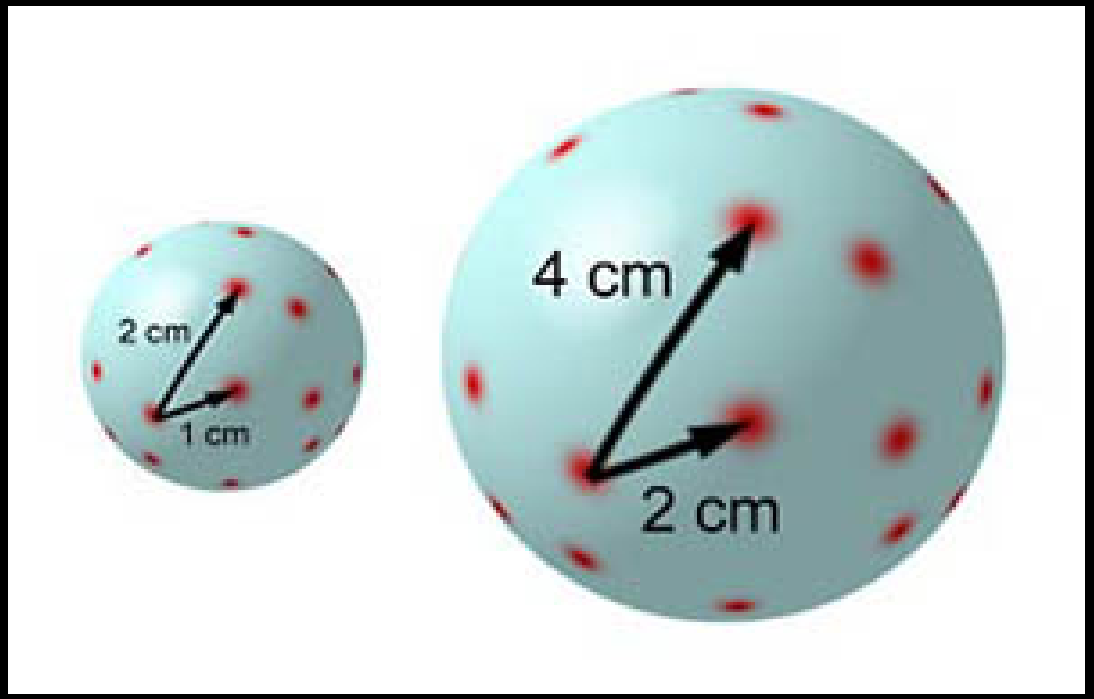
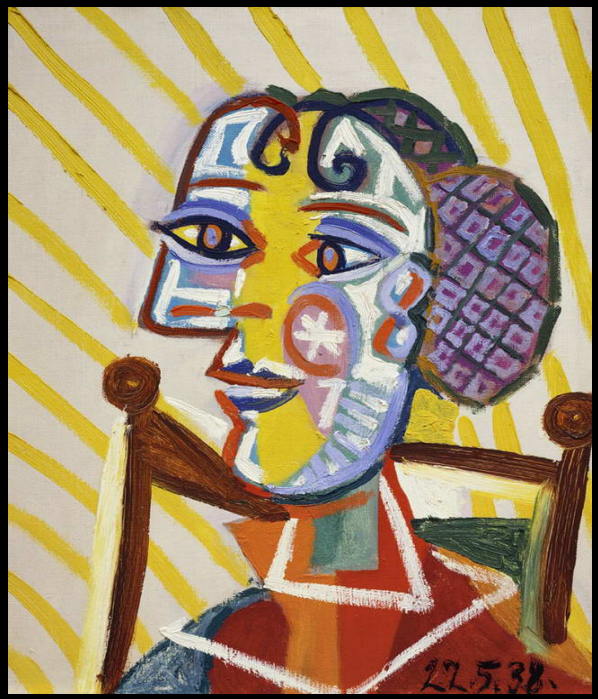
cogs1

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

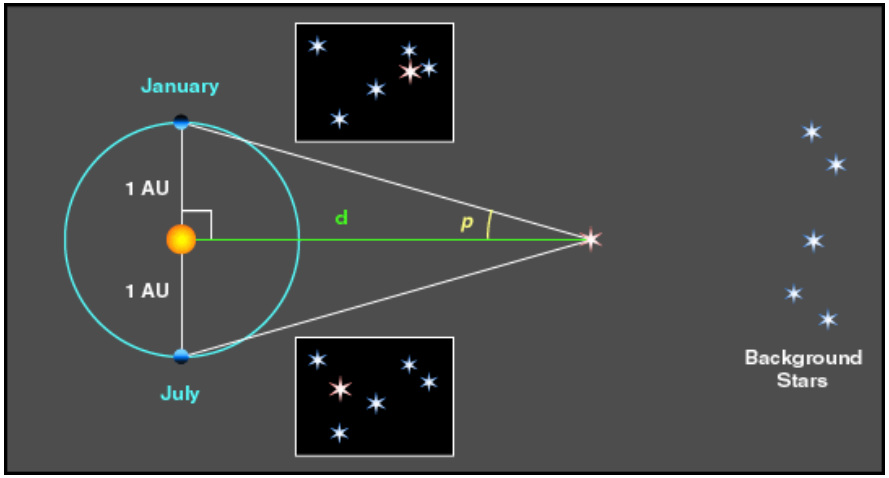
or

depth perception from retinal disparity (stereopsis)

:

:

but which?



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

senses

musculature

<u>egocentric frames</u>

retinal space

vestibular info.

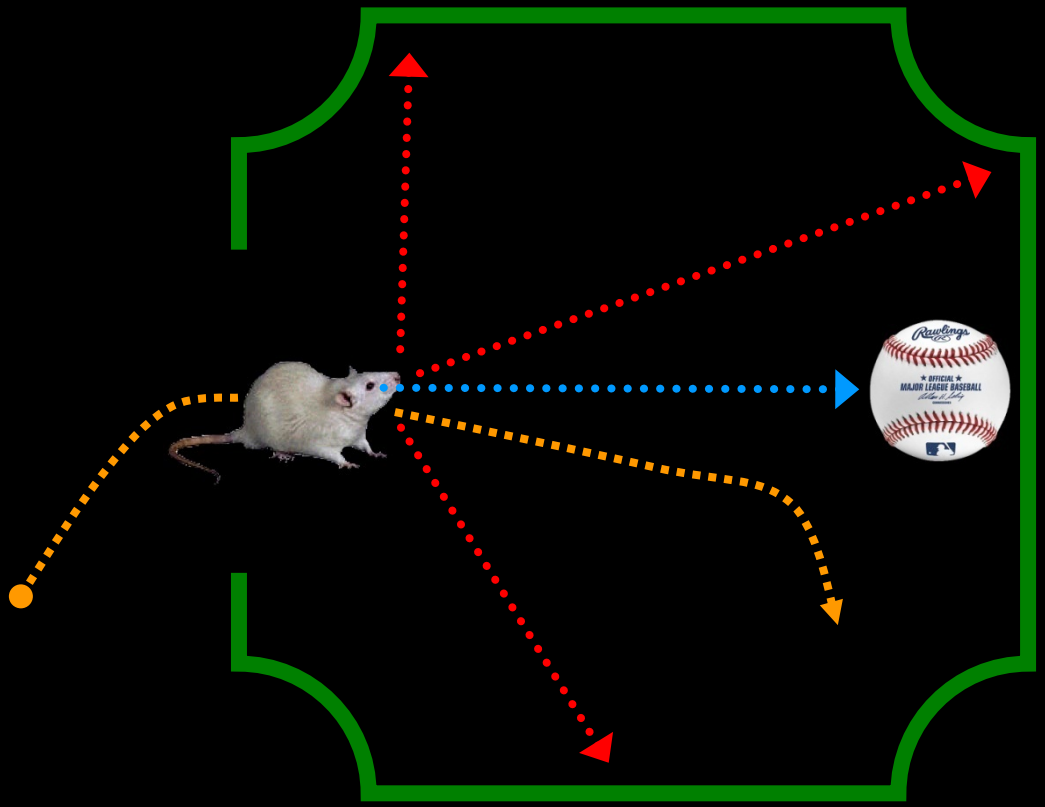
proprioception

<u>arbitrary frames</u>

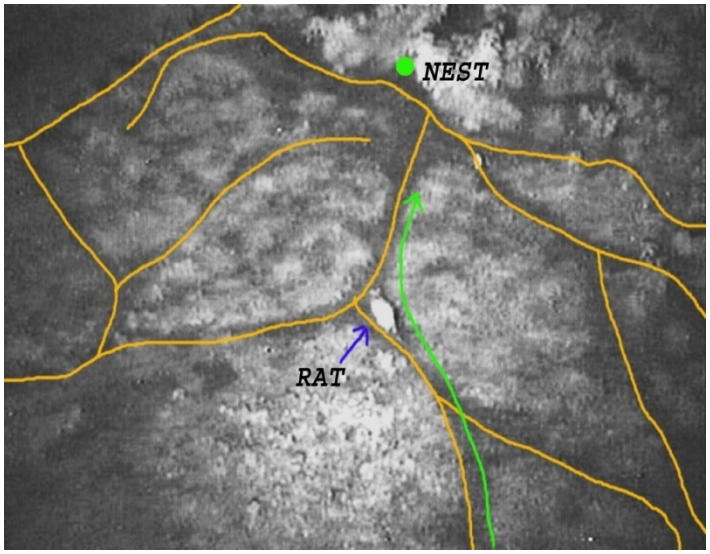
allocentric (world-centered)

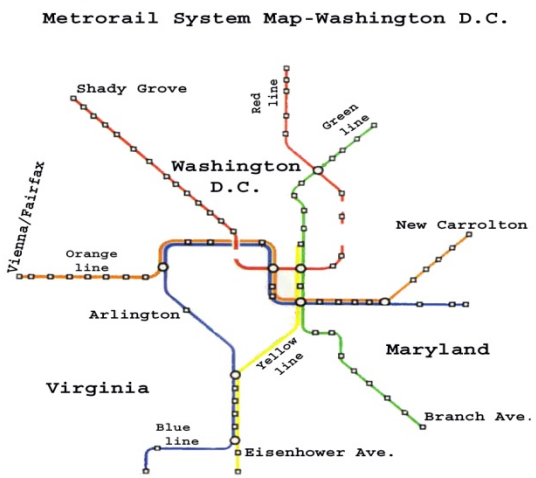
route-centered

object-centered



similarity in features of navigational strategies across mammalian species





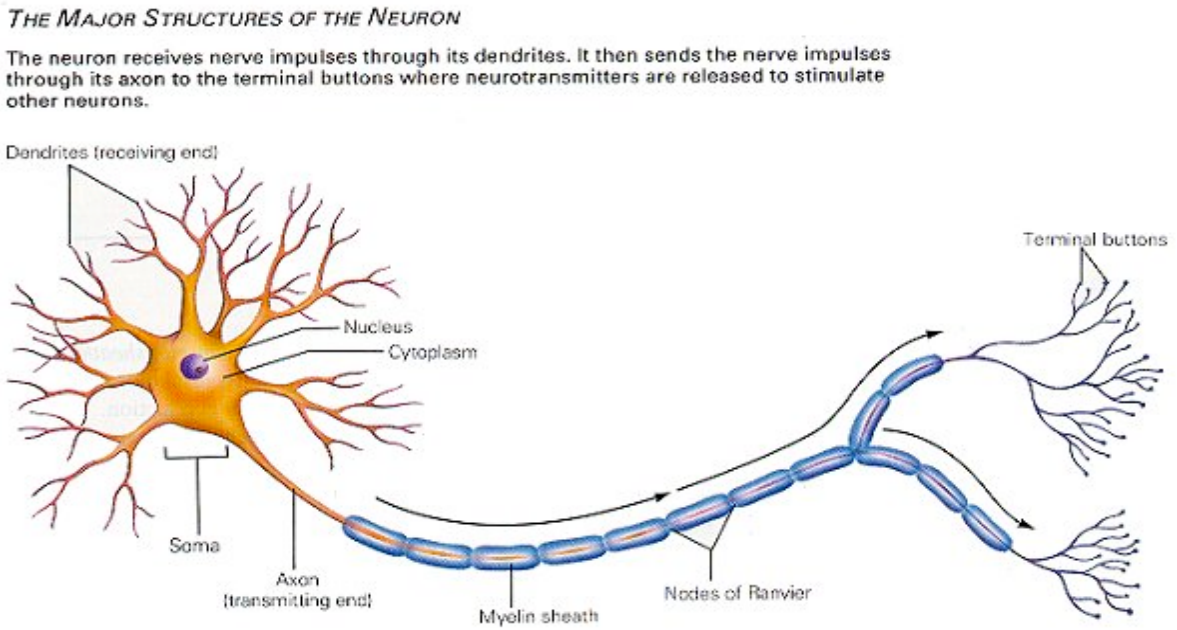
similarity in detailed structure of brain across mammalian species

rat brain – dorsal view

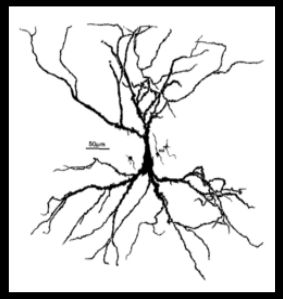
human brain – sagittal view

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)

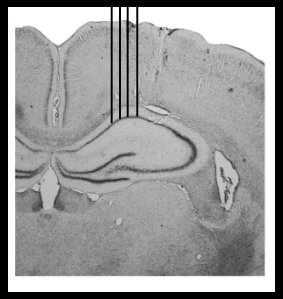
Cajal's 'law of dynamic polarization': neural/electrical transmission proceeds in one direction – from dendrite/soma → axon → axon terminal (translation: dendrites take in information from other neurons and decide what message to send to other neurons)



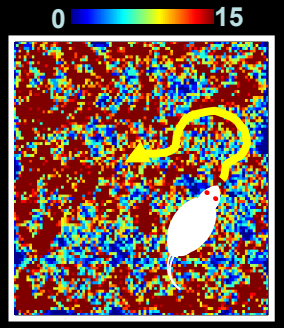
multiple single neuron recordings in behaving animals:



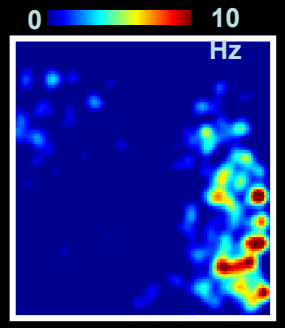
hippocampal pyramidal neuron



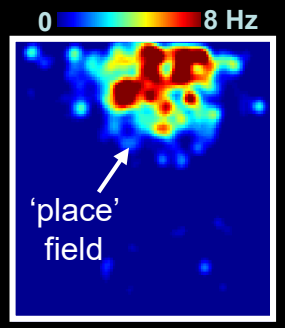
recording



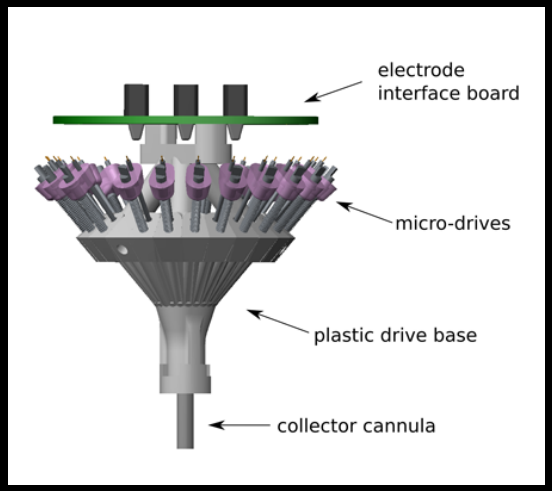
occupancy counts



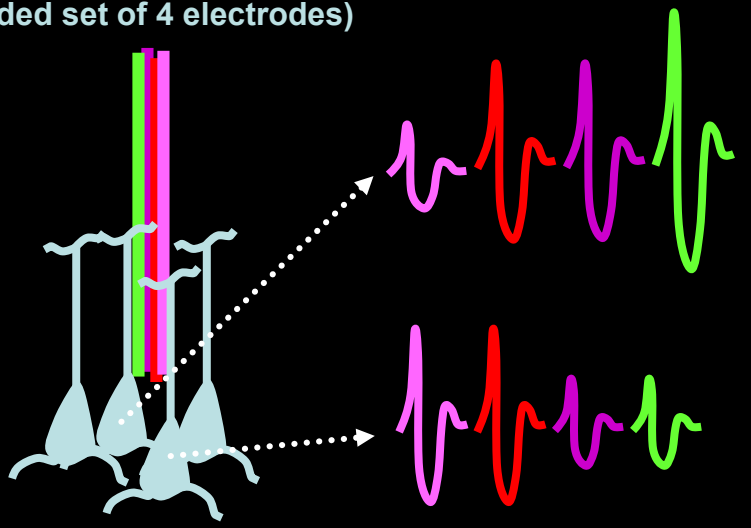
firing rate neuron 1



firing rate neuron 2



tetrode
(braided set of 4 electrodes)



relative-amplitude spike discrimination

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

senses

musculature

<u>egocentric frames</u>

retinal space

body/touch space

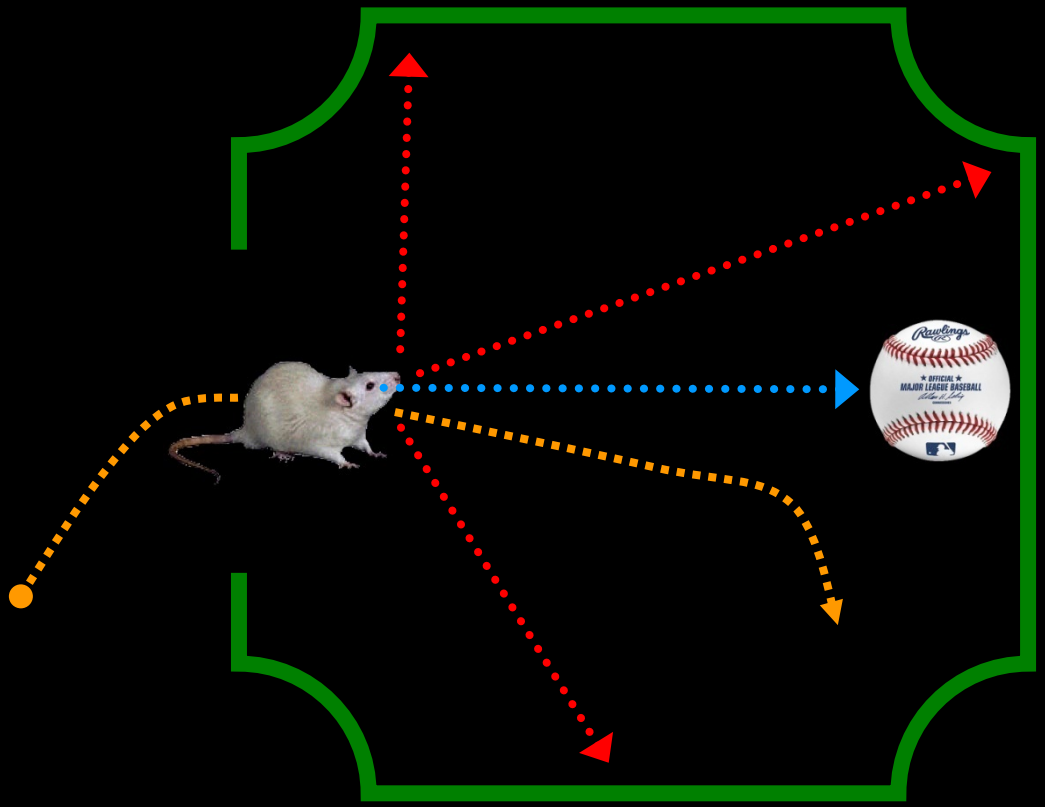
proprioception

<u>arbitrary frames</u>

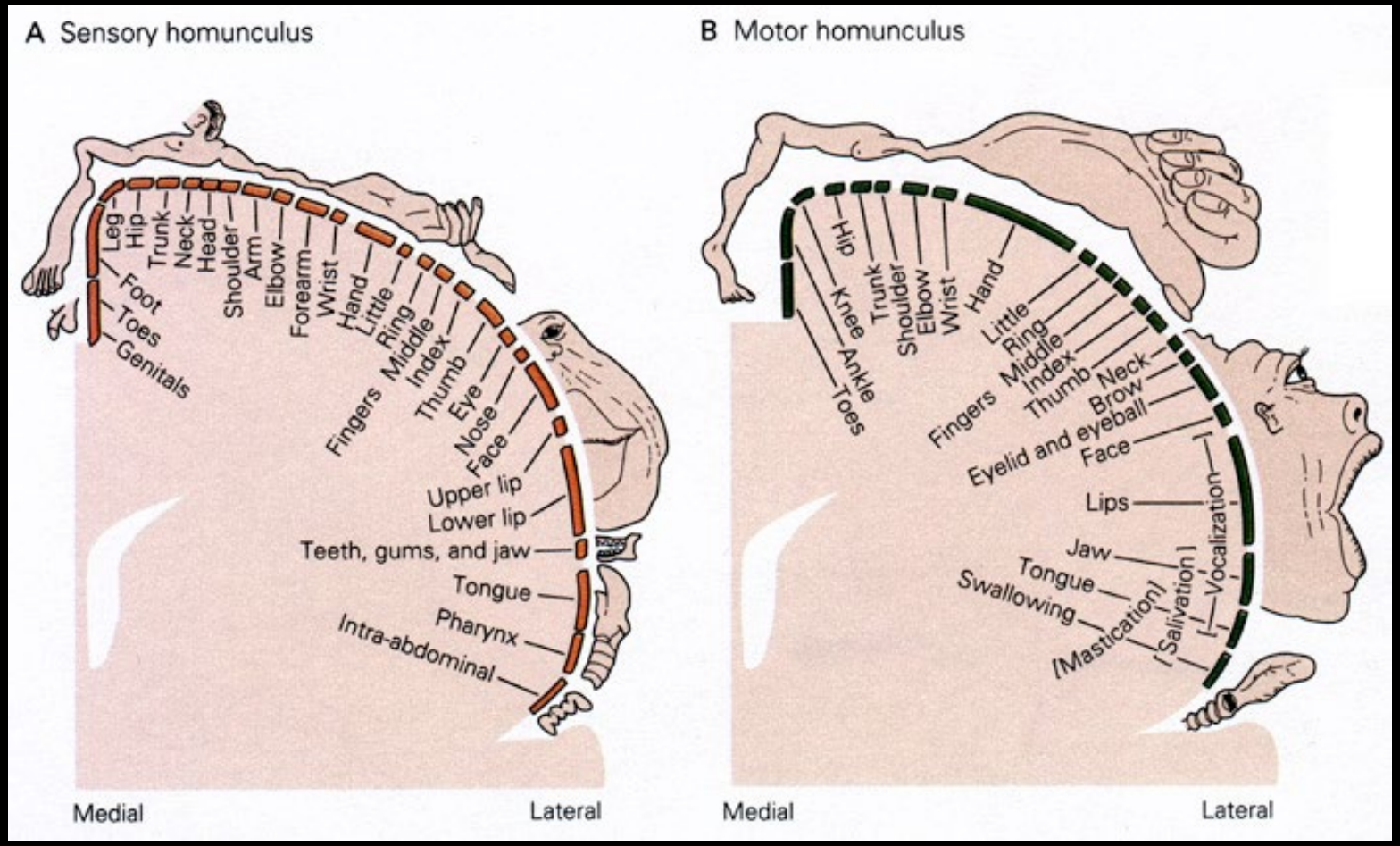
allocentric (world-centered)

route-centered

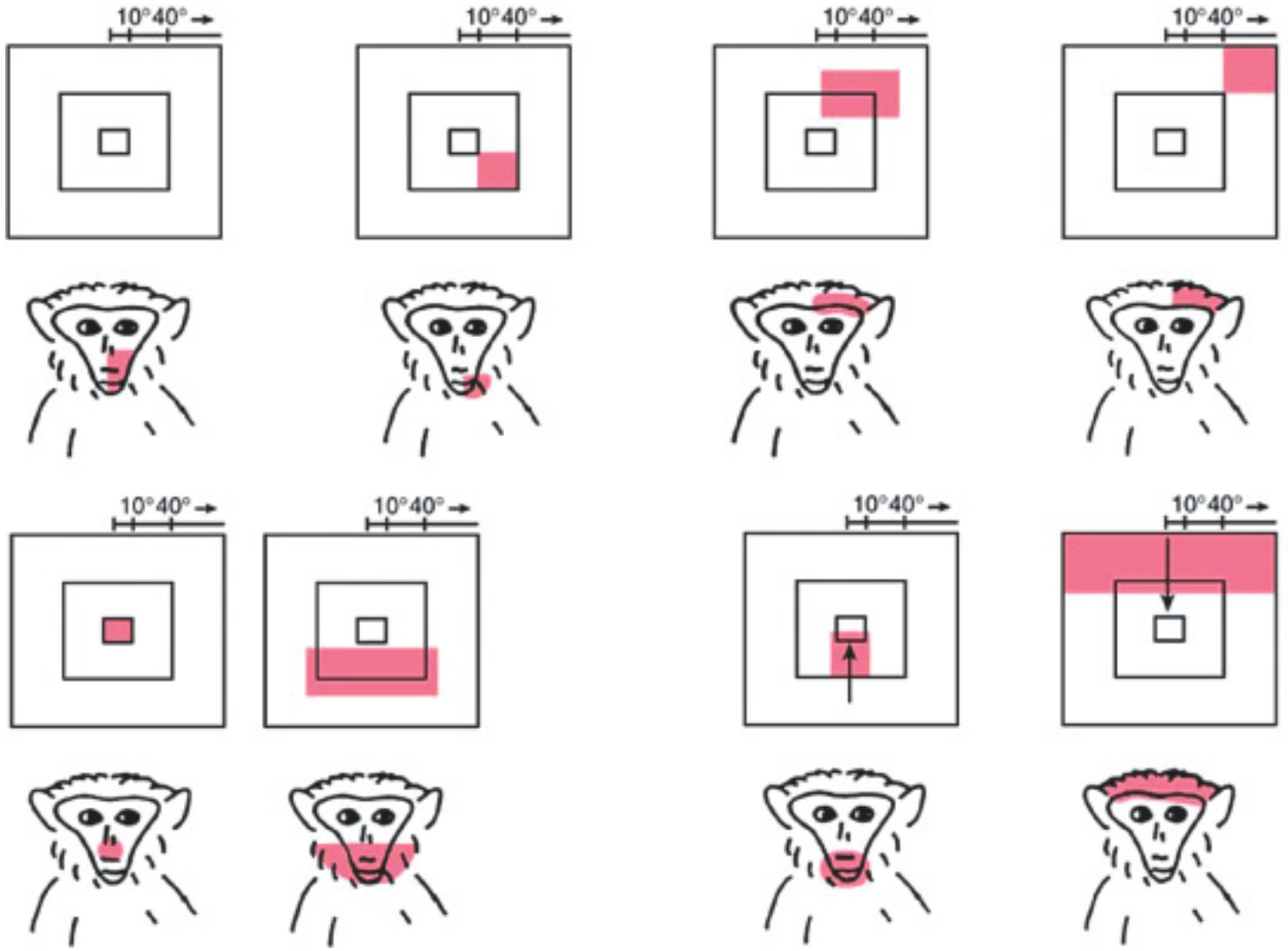
object-centered



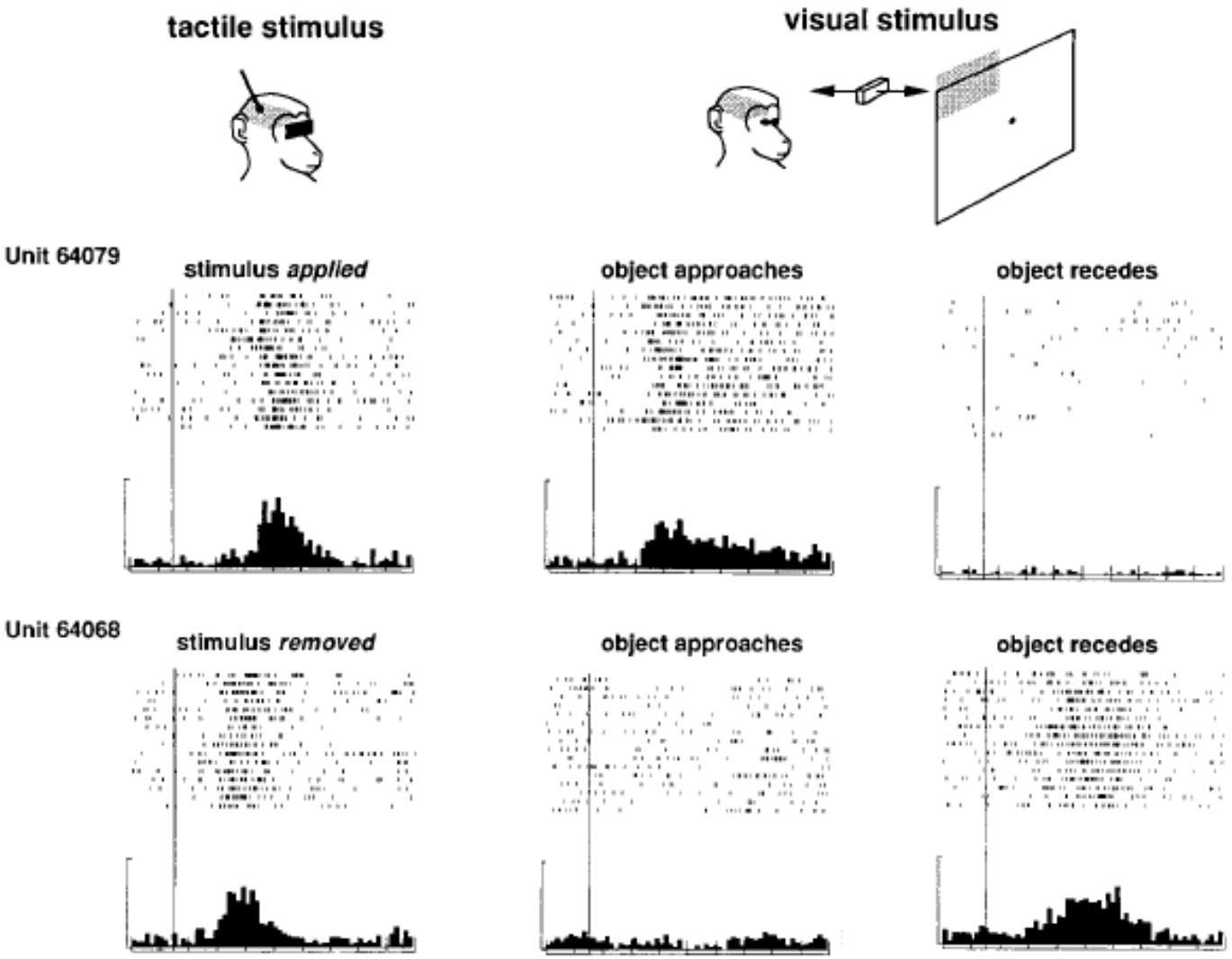
PENFIELD AND JASPER, 1951 – THE 'HOMONCULUS' – AN EGOCENTRIC MAP



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



Duhamel et al., JNP, 1998

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

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retinal space

vestibular info.

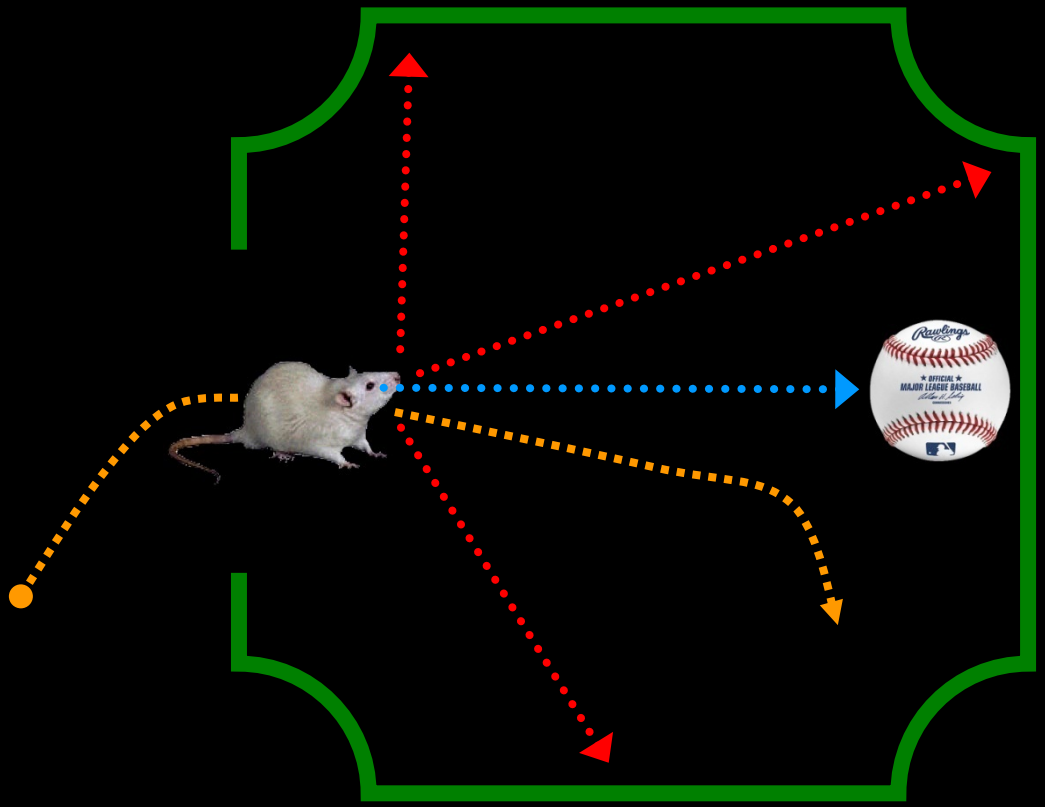
proprioception

<u>arbitrary frames</u>

allocentric (world-centered)

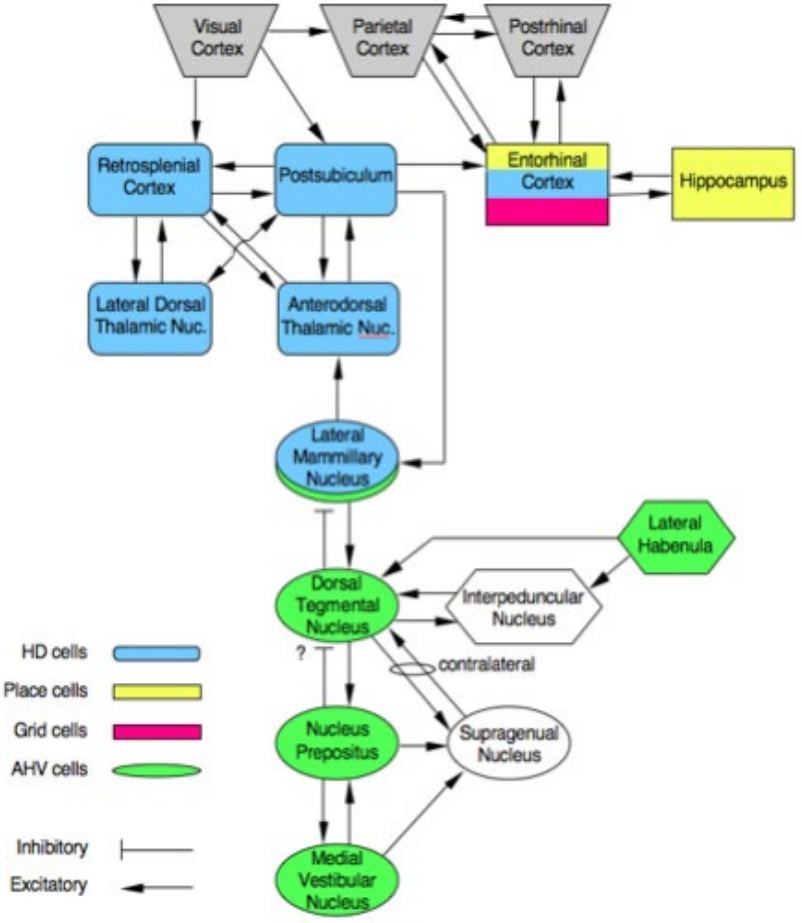
route-centered

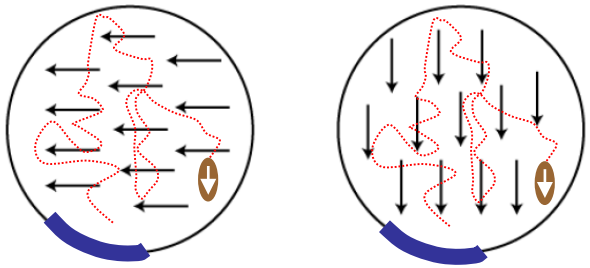
object-centered

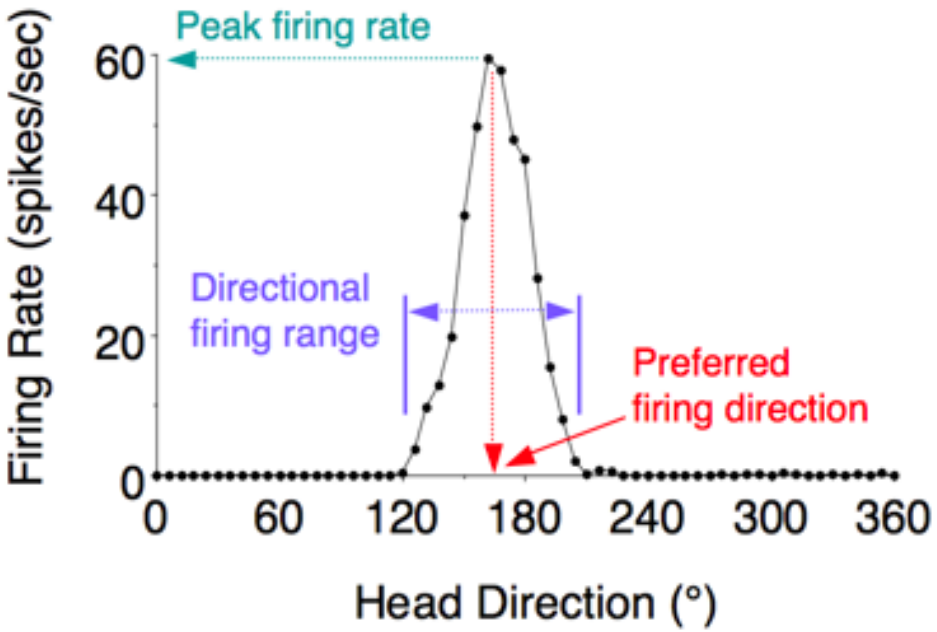


tracking directional heading in the allocentric (world-centered) frame of reference I: 'head direction' cells

- **firing is tuned to the orientation of the animals head relative to the boundaries of the environment**
- **different neurons have different preferred directions (all directions are represented)**

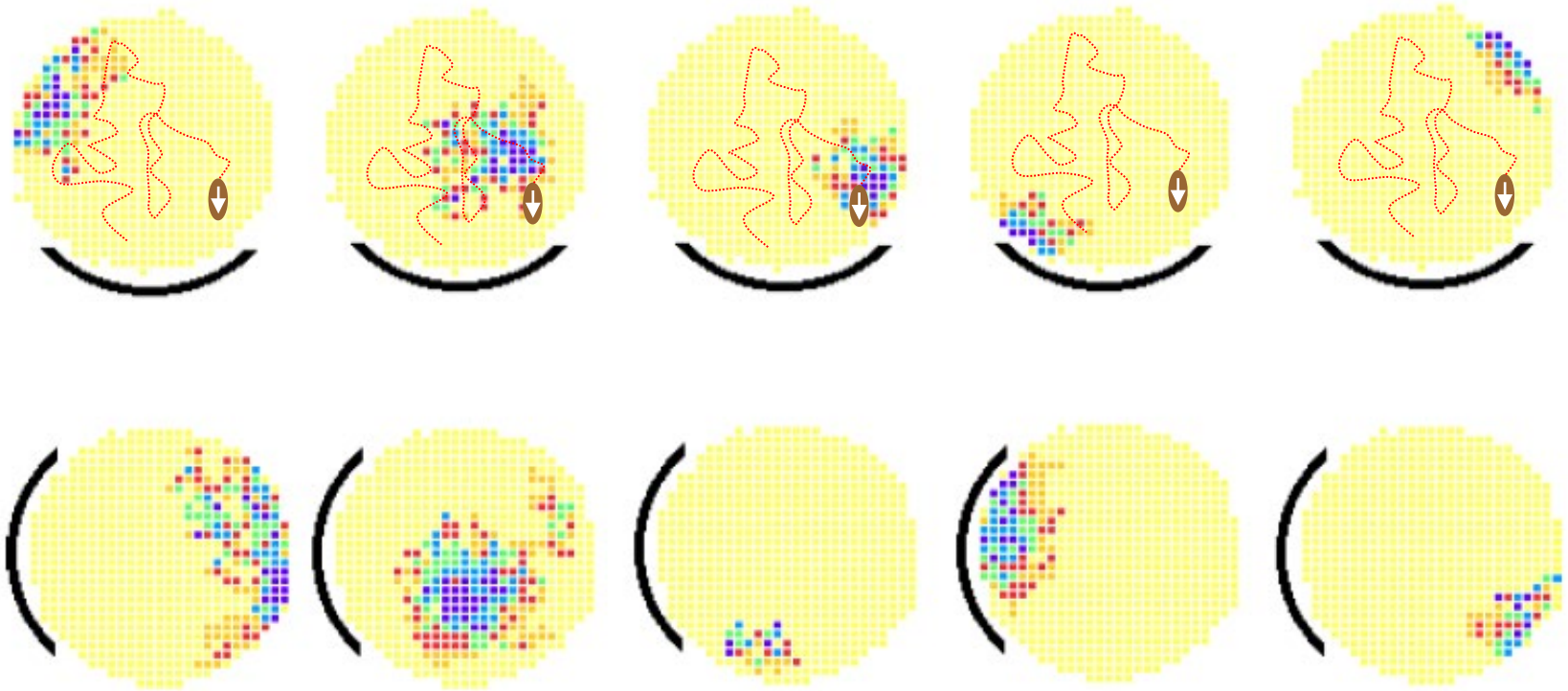






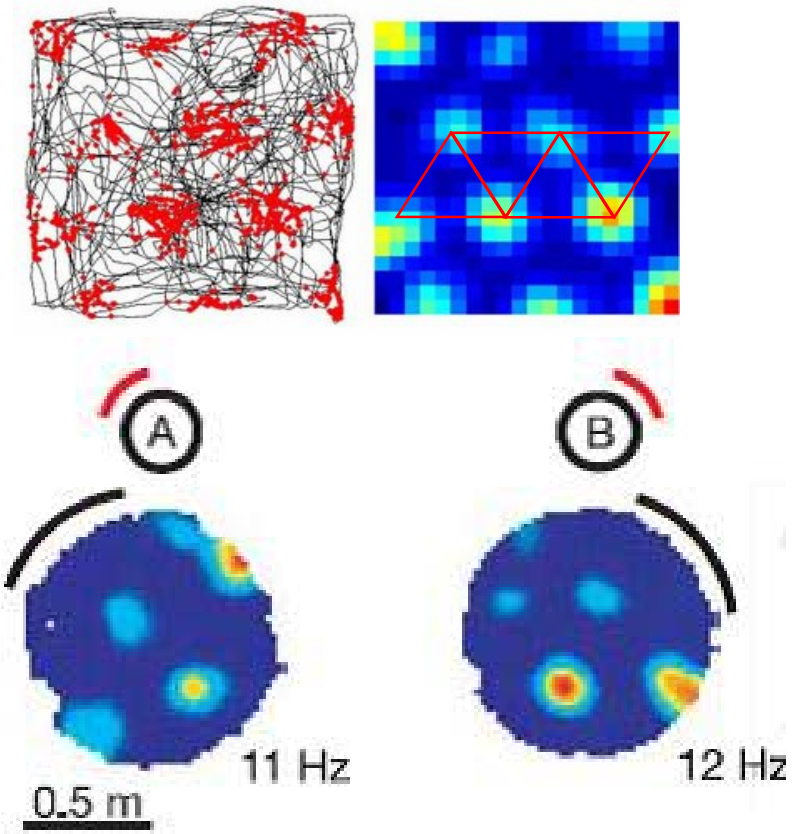
tracking position in the world-centered (allocentric) frame of reference: the 'place cell'

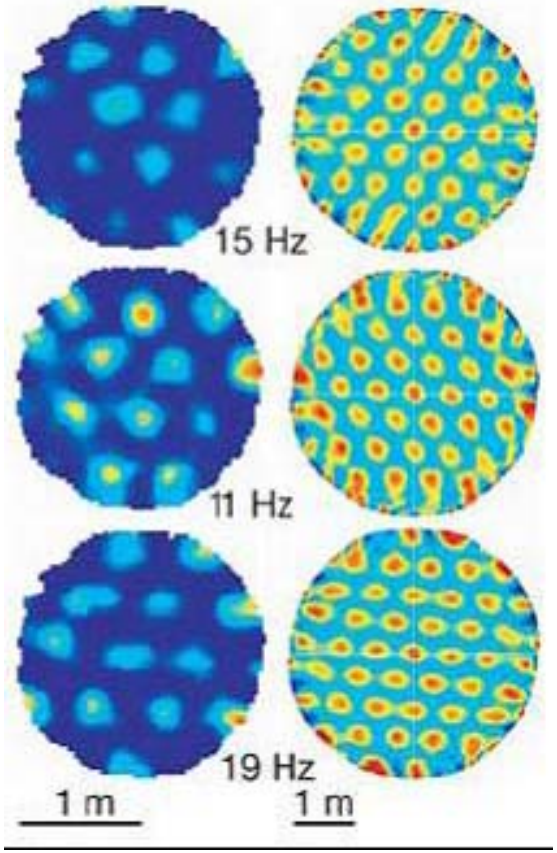
- **– firing is tuned to the position of the animal in the environment (the place 'field')**
- **– different neurons map different positions (all directions are represented)**
- **– rotation of the environment boundaries = rotation of the place fields**



mapping position in the environment by path integration: 'grid cells'

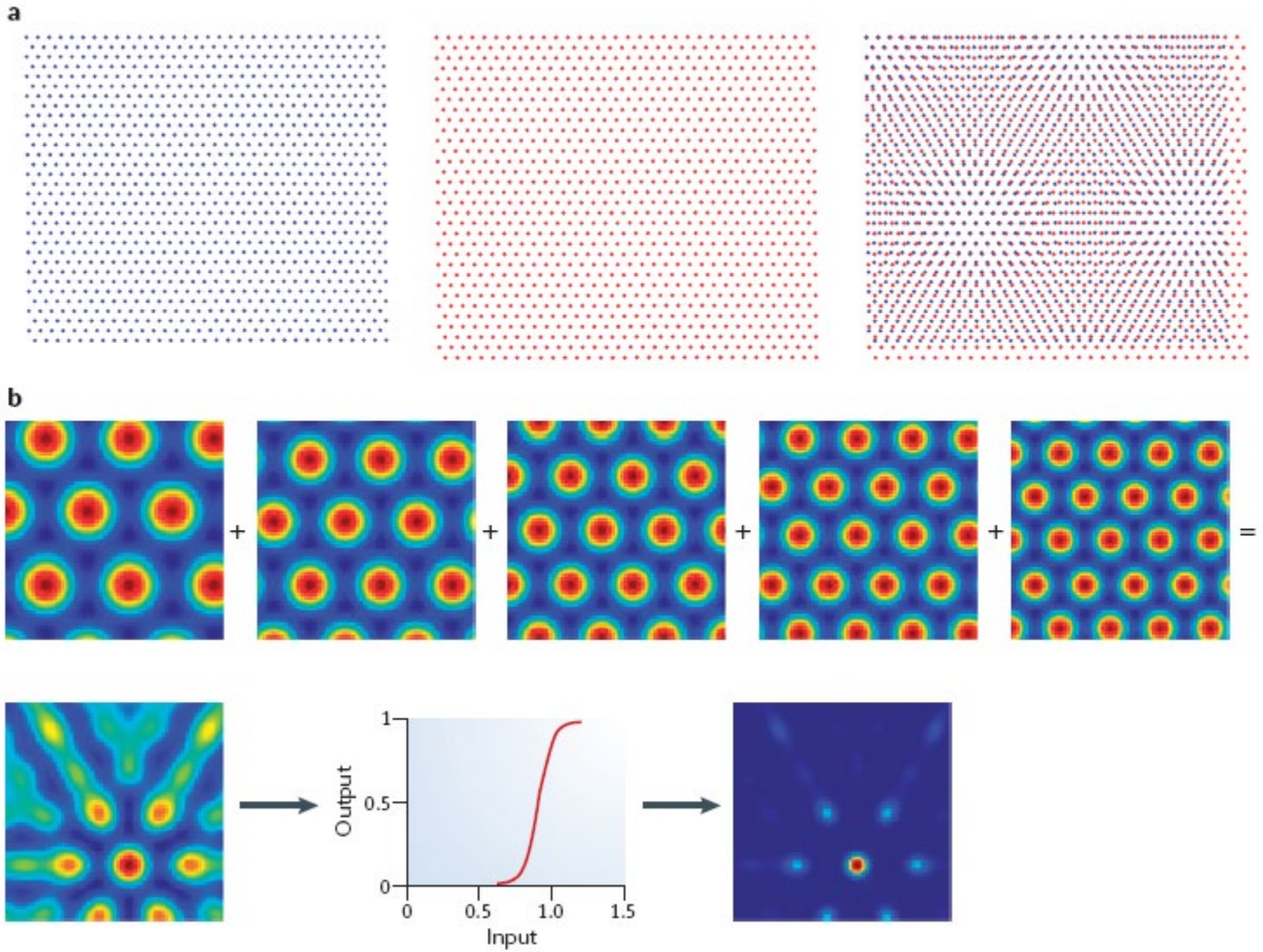
- **neurons of the medial entorhinal cortex exhibit multiple firing fields in any given environment**
- **such fields are arranged according to the nodes of a set of 'tesselated' triangles**
- **grids, like head-direction tuning and place cells firing fields rotate with the boundaries of the environment**





Hafting et al., Nature, 2005

how do grid cells yield hippocampal allocentric position maps?



McNaughton et al., 2006, Nature Reviews Neuroscience

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

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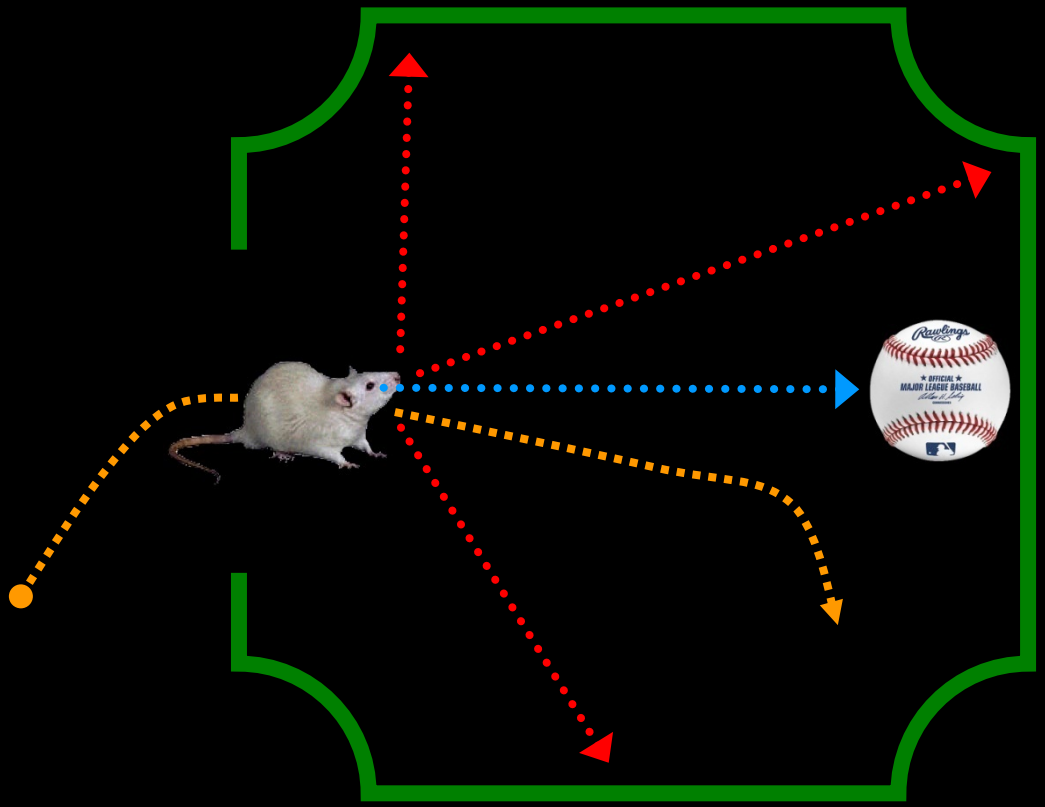
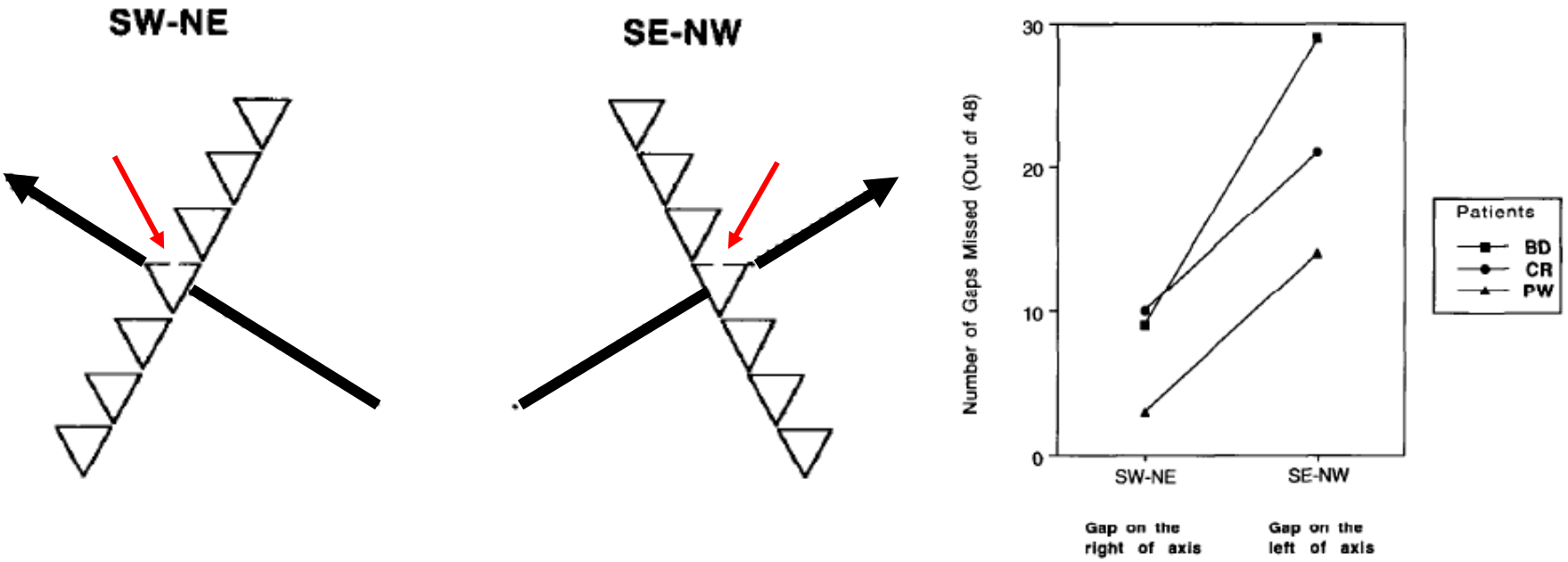


LOCALIZATION OF OBJECT-CENTERED MAPPING TO THE PARIETAL CORTEX



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 hemi-neglect) 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)

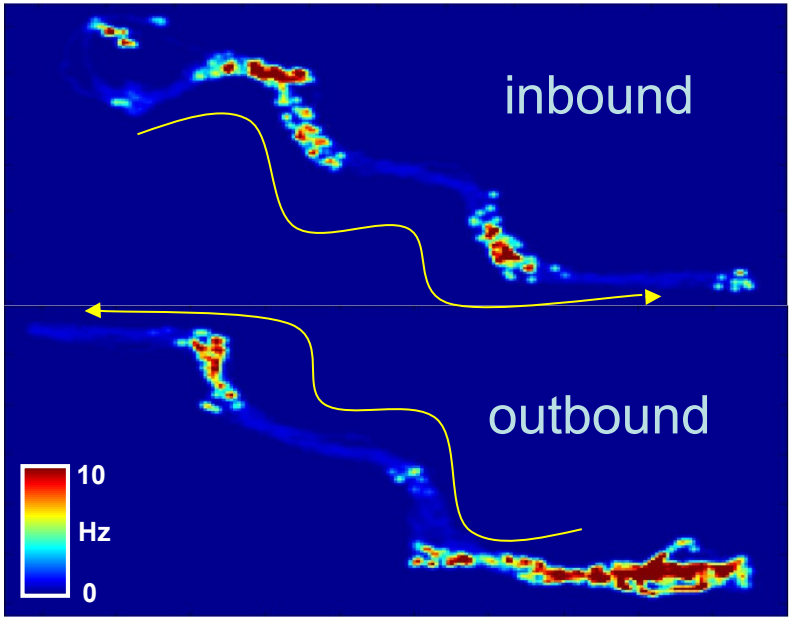
Driver et al., Neuropsychologia, 1994

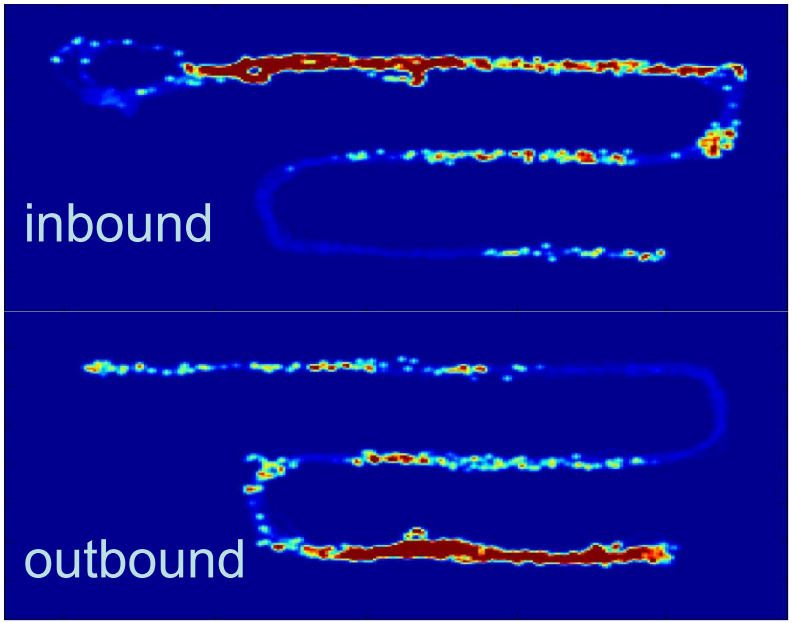
Nitz, Neuron, 2006

parietal cortex neurons in behaving rats map path segments (e.g., start pt. to first R turn)

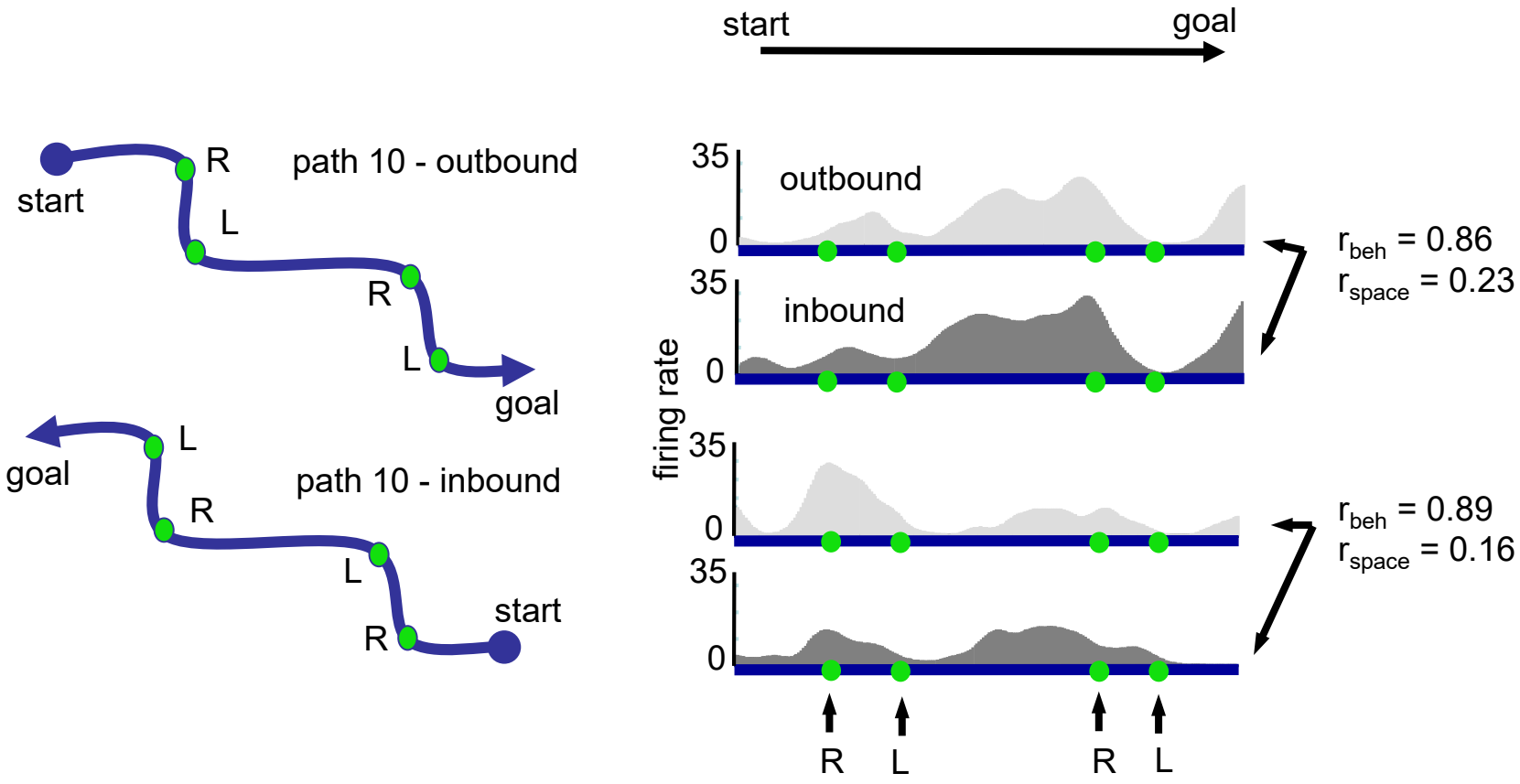
familiar path

newly-learned path



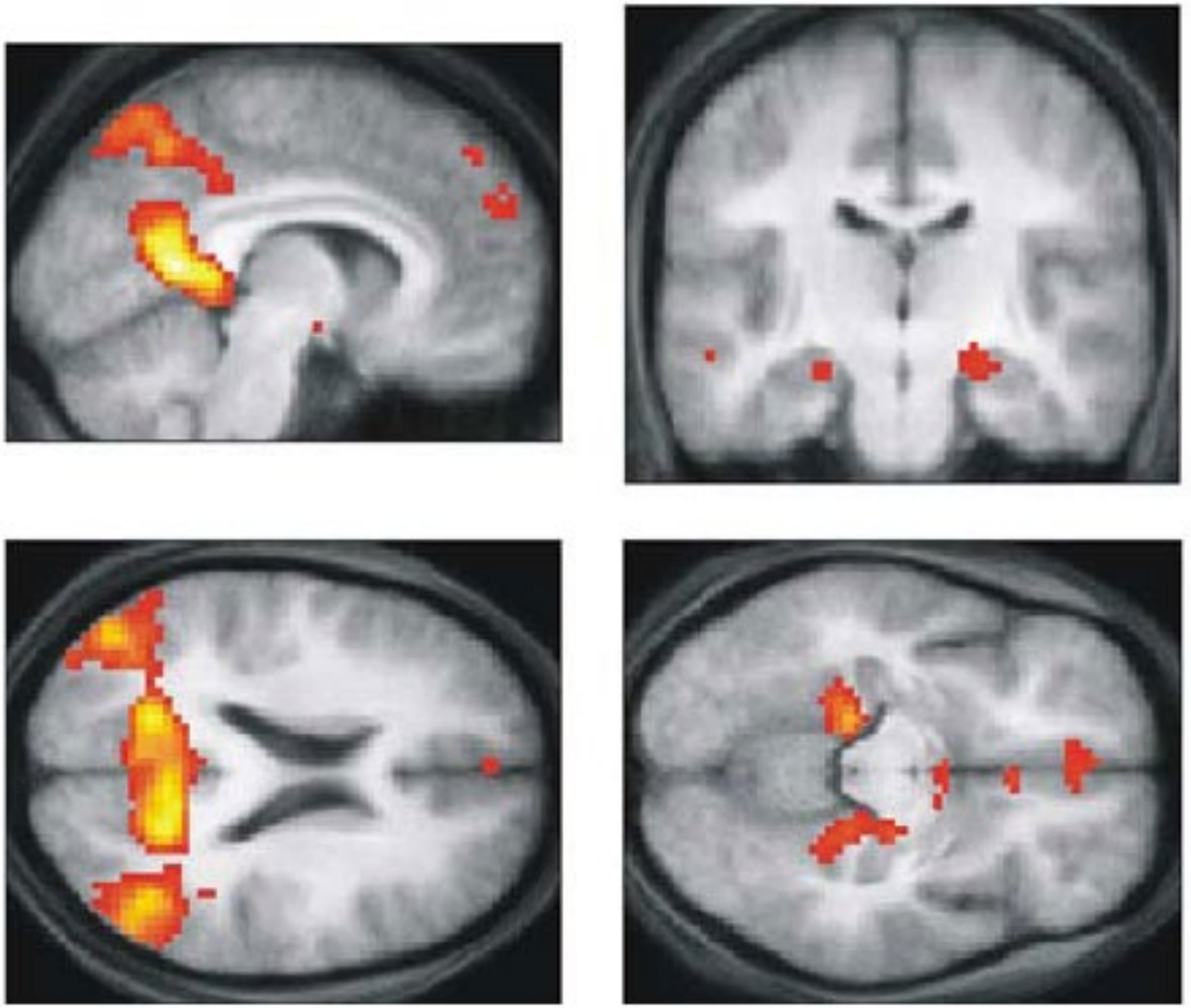


parietal cortex: a rather abstract frame of reference – the space defined by the route (i.e., the space defined by sequence of behavior changes and the spaces separating them)



Nitz, Neuron, 2006

BOLD SIGNALS IMPLICATE HIPPOCAMPUS AND PARIETAL CORTEX IN NOVEL SCENE CONSTRUCTION



Hassabis et al., JNS, 2007