principles of the week: ‘frame of reference’ and ‘reentry’
the hippocampus proper = dentate gyrus (DG) + CA3 + CA1
intrahippocampal and extrahippocampal connections (with cortex) exhibit patterns of convergence, divergence, and reentry at multiple scales.
MAPPING SPACE IN THE BRAIN – RULE 1: THERE ARE 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
- eye position
- hand space

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

senses
musculature
tracking directional heading in the allocentric (world-centered) frame of reference: ‘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 directional heading: the ‘head direction’ cell

– firing is tuned to the orientation of the animals head relative to the boundaries of the environment (i.e., not to magnetic north)

– directional tuning may differ completely across two different environments provided that they are perceived as different
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
medial entorhinal cortex contains grid cells, grid X head-direction cells, and head-direction cells – each cell type is also velocity sensitive, thus allowing for determination of position according to path integration (i.e., tracking of direction and speed over time) all within one structure

Sargolini et al., Science, 2006
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
given that different hippocampal neurons bear different place fields, the firing rates of those neurons at any given time can be used to predict the animal’s position in the environment

for a set of neurons, the firing rates across the full set describe the ‘pattern’ of activity across the full population – this is called a ‘population firing rate vector’

all brain regions appear to register information according to such ‘population’ patterns
‘what’ (temporal) and ‘where’ (parietal) pathways in monkey and human

- Damage to IT (TE + TEO) impairs object identification (but only via visual information)

- Damage to parietal cortex (MT, MST, 7a, VIP, LIP) impairs visuospatial abilities (e.g., reaching to an object)

MT / MST = detection of movement direction

V4 = first site for figure/ground separation
along the ‘where’ pathway: area MST integrates optic and vestibular ‘flow’
area VIP of parietal cortex: bringing together personal spaces of the somatosensory and visual systems
mapping position in the egocentric frame of reference: area LIP maps position, relative to the space of the retina, for visual stimuli, the memory of them, and saccade direction

Barash et al., JNP, 1991
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
more parietal abstraction – ‘object space’ as a frame of reference for monkey parietal area 7a neurons

Crowe et al., JNS, 2008
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)
BOLD SIGNALS IMPLICATE HIPPOCAMPUS AND PARIETAL CORTEX IN NOVEL SCENE CONSTRUCTION

Hassabis et al., JNS, 2007