

Positional information is acquired from two sources

- Extrinsic cues: (Landmark cues), from visual, auditory, olfactory input
- Intrinsic cues: (Internal cues), proprioception, efferent copy, vestibular system, ability to navigate when external cue is absent

Place cells: Found in the hippocampus proper: CA1 to CA3.

- Encodes positional information, place cell firing correspond to relative position of animals in the box.
- Place cells respond to external cues: **Moving the position of the visual cue card result in changes in firing pattern, but remains same relative position to the cue card.**
- Place cells respond to intrinsic cues: **Place cell maintains firing in darkness, due to intrinsic cues.**

Head direction cells (HD cells): found in the subiculum and entorhinal cortex (parahippocampal), project to CA1~3

- Firing relative to head direction, neurons active when head points at specific directions.
- HD cells - external cues: Visual cues into the thalamus influences firing pattern.
- HD cells - internal cues: linked to vestibular nuclei, head turning changes firing pattern.
 - **Moving rat from one box to another with different cue card position — shift in HD firing pattern**
 - **Rat walk from one box to another (presence of intrinsic cue — no shift in HD firing pattern)**

Grid cells: found in the parahippocampal cortex, project to the hippocampus.

- Regularly spaced cells, firing follows regular repeating pattern, used to estimate distance and navigation.
- **Stronger firing at faster running speed in rats, intrinsic + extrinsic cues.**
- **Most prominent in right entorhinal cortex in humans when exposed to VR simulation.**

Development of the hippocampus:

- In the hippocampus, GABAergic cells form (E13-18) before glutamatergic cells (E16-21), tangentially migrate into the hippocampal network (first wave arrive at E17)
- Glutamatergic cells follows radial migration, formed in late embryogenesis (in rat).
- GABAergic synapse form (E18) before glutamatergic synapse (P2), myelination occur from P15
- GABAergic synapses are first stimulatory, become inhibitory at around P12 following chloride flow direction switch (NKCC1 → KCC2)
 - In the mean time (P0~P10), glutamatergic synapses emerge, large depolarising waves form, contribute to neuron refinement, after GABA switch become desynchronised.

Development of spatial navigation abilities

- HD cells develop earliest at P12
 - HD cells appear around 3 days before eye opening, **refined with eye opening**
 - Other sensory input contribute to HD maturation: **Rat in smaller box with boundaries stabilise HD cells**
 - Angular head velocity contribute to HD cell maturation
- Place cells develop early (P16), refined gradually.
 - **In early development of place cells, higher stability is observed in boundary place cells compared to central place cells. No such correlation in later place cells**
 - Transition from high boundary place cell stability to uniform stability occur at around **P21**
- Grid cells develop from around P21: may contribute to stabilisation of central place cells.