# Evaluation of O'Keefe's System

- Changing the size of cues should not elicit exploration (because distance is not estimated by cue size.) This agree's with Muller's experiment changing the size of a cue card.
- The system could conceivably navigate in the absence of visual cues, using the translation terms L and K to update the position matrix.
- No biological evidence for the specific matrix calculations proposed in this model.
- Matrix inversion in CA1? Requires an iterative algorithm.
- Many unanswered questions about the neural representations of these matrix quantities.

# Computations in O'Keefe's System

- Egocentric polar representation of landmarks
  - Q = stimulus quality
  - $\alpha$ = egocentric landmark angle
  - R = estimated landmark distance

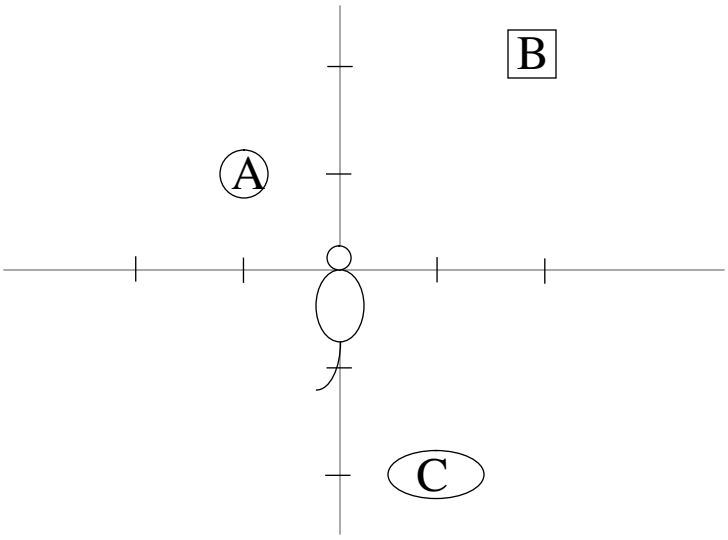
- Egoventric Cartesian representation of landmarks:
  - $X = R \cos (90 - \alpha)$
  - $Y = R \cos \alpha$

- Allocentric cartesian representation of landmarks:
  - C = current location
  - T = transformation matrix
  - $N = C \bullet T$ = new location

- Other terms in the model:
  - L,K = forward, lateral increments (from body motion)
  - I = incentive matrix (amygdala)
  - $TI = C^{-1} \bullet I$ = incentive transform
  - A = auto-association terms for environment recognition

# O'Keefe's Cognitive Map Model

- Egocentric perceptual representation:




- Homogeneous coordinate representation:

$$\begin{bmatrix} A \\ B \\ C \end{bmatrix} = \begin{bmatrix} -1 & 1 & 1 \\ 2 & 2 & 1 \\ 1 & -2 & 1 \end{bmatrix}$$

- Transform matrix (rotate, translate, and scale):

$$\begin{bmatrix} \cos\alpha & -\sin\alpha & 0 \\ \sin\alpha & \cos\alpha & 0 \\ -X & -Y & s \end{bmatrix}$$

# Does the Assoc.Memory Theory Work?

- How many memories must be stored?
  - ♠ For every distinguishable location A, there must be a set of memories. Each memory includes an AL compound.
- How many AL compounds must be learned?
  - ♠ For every distinguishable direction of movement, there must be a separate AL compound.
- For a 10 x 10 environment with 16 distinguishable directions:
  - ♠ 100 distinct locations; 1600 memories
- How long does training take?
  - ♠ Must experience every AL combination. No provision for generalization.
- What is the computational status of the model?
  - ♠ Never implemented.

# McNaughton's "Local View" Idea

- The local view is a set of landmark distances and bearings as viewed from a specific location.
- In a reasonably rich environment, local views will be unique to specific locations.
- By recognizing the local view, an animal can determine its location in a familiar environment.
- Associative memory function makes allowances for missing cues.
- But how do place fields persist in the dark?

# Three Types of Cells

1. **Place cells.**

   Pyramidal cells in hippocampus.

   Firing is robust against landmark deletion (cf. associative memory, partial cues.)

   Firing fields are maintained in the dark.

   Immobilizing the animal eliminates place cell responses.

2. **Head direction cells.**

   Found in postsubiculum, thalamus (LDN, ATN), striatum, and parietal cortex.

   Controlled by visual cues in a familiar environment, but can persist in the dark.

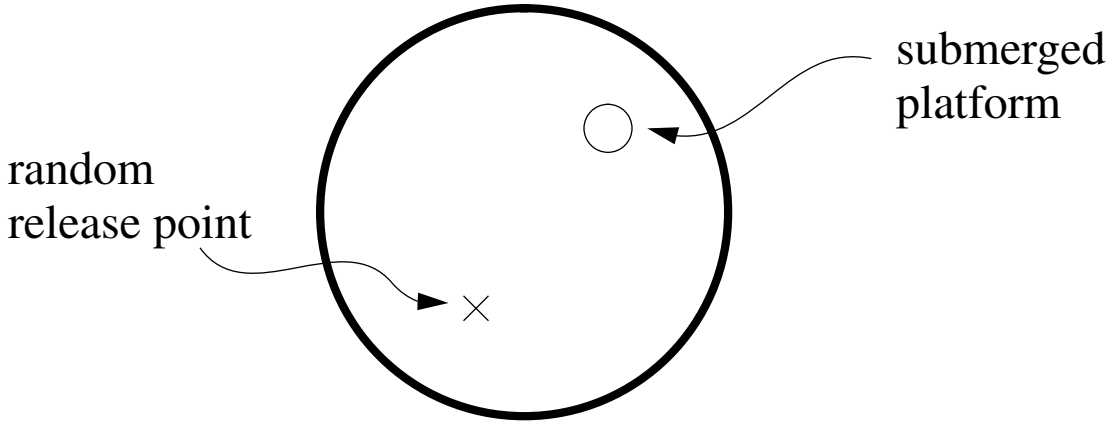
3. **Turn/motion cells.**

   Found in parietal cortex.

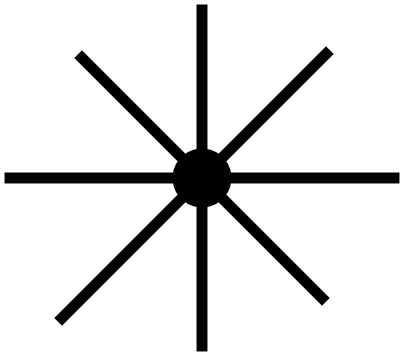
   Three classes: left turns, right turns, and forward motion.

# Other Spatial Tasks

- Morris Water Maze

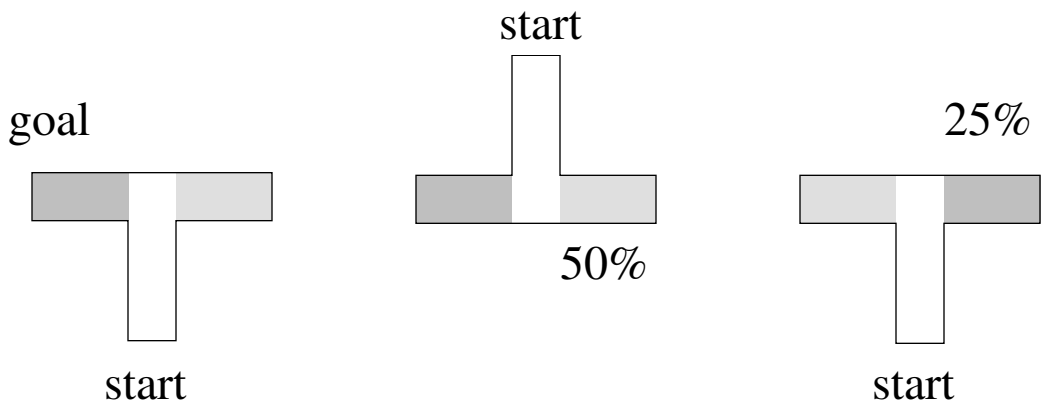



- Eight-arm radial maze: used to test working memory.



# Competing Cues

- With practice, the performance on a spatial task can change.
- Learned motor programs are one example.
- Experiment: train rat to choose particular arm of T-maze.




- 50% of the response is governed by the "left turn" motor program.
- 25% is governed by spatial location.
- 25% is governed by sensory features of the reward arm.

# Rats and Spatial Learning

- Space is extremely important to the rat.
- Rats brought into a familiar place can tell if certain features have been rearranged or altered. (Enhanced exploratory behavior is seen.)
- Spontaneous alternation: rats will choose alternate arms of a T-maze on successive trials.
- Flip the T-maze 180 degrees before a trial: rat chooses the alternate *spatial location* (meaning the same arm.)
- *"Before one can teach a rat a visual discrimination problem... many trials may be required to dissuade the rate from its conviction, gained on the first trial, that reinforcement is associated with a particular place."* (McNaughton & Nadel)

# The Hippocampus As A Cognitive Map: Part 1

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COMPUTATIONAL MODELS OF NEURAL SYSTEMS

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