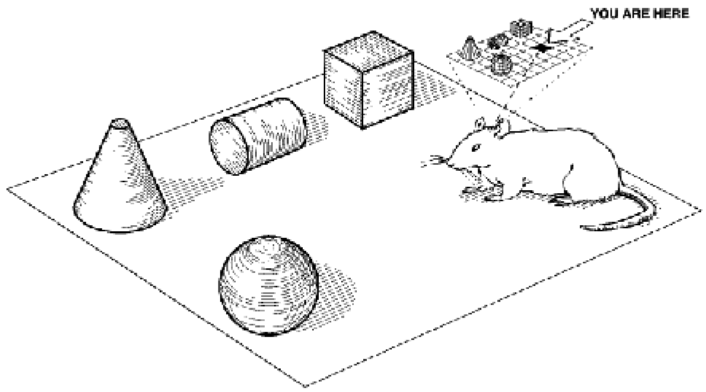
1 of 10

Associative Memory-I: Storing Patterns

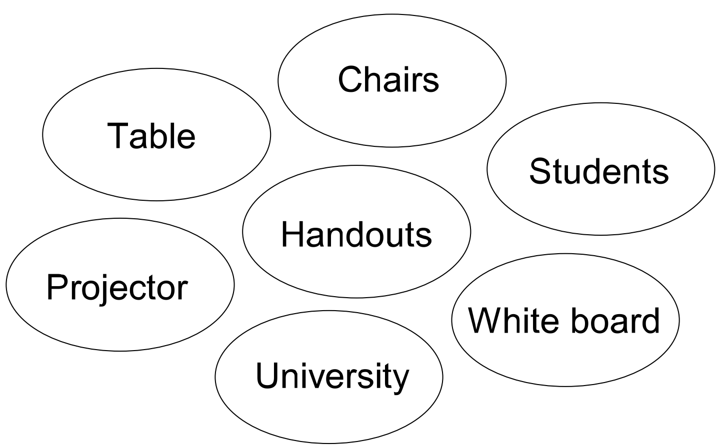


Finding its way around is important to an animal's survival.

Navigational memory is important for locating food.
Odor memory is important for determining if food is safe to eat.

2 of 10

Components of an object



Classroom

 ©1988–2008 Wolfram Research, Inc. All rights reserved.

Some objects can be broken up into their constituent components.

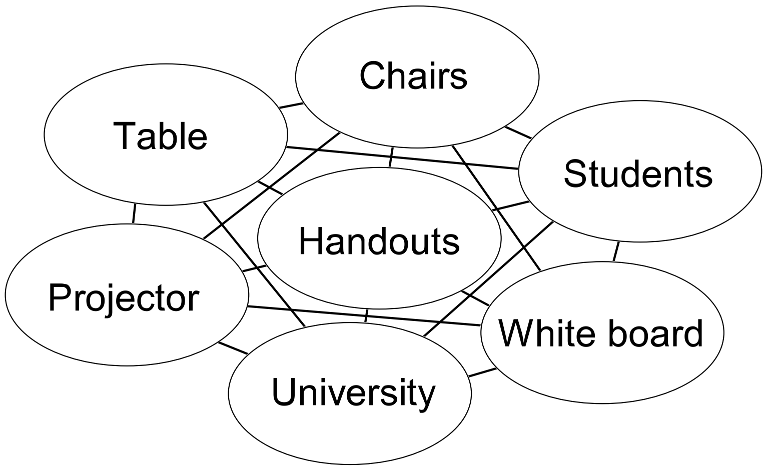
Objects may be defined by their components (or features).

We associate these components with the object.

We recognize that we are in a classroom because the things we expect to find are present.

3 of 10

Associative memory



Classroom

Objects can be stored and recalled associatively by linking their components.

Components are linked together, such that when a few a present, they activate the others.

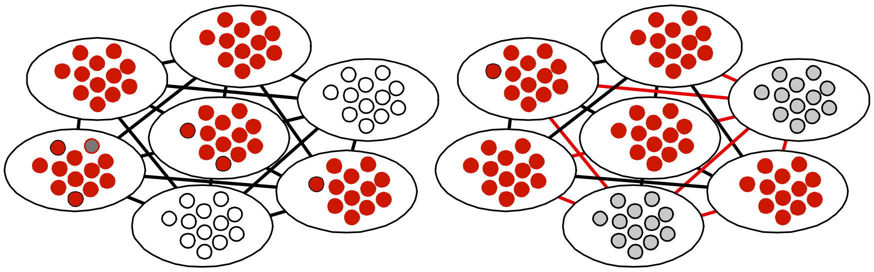
This way, the representation is identical to that produced if all the components were present.

Thus, we recognize that we are in a classroom even if some of the things we expect to find are absent.

4 of 10

©1988–2008 Wolfram Research, Inc. All rights reserved.

Associating with neurons



Pools of neurons represent components; synapses represent links.

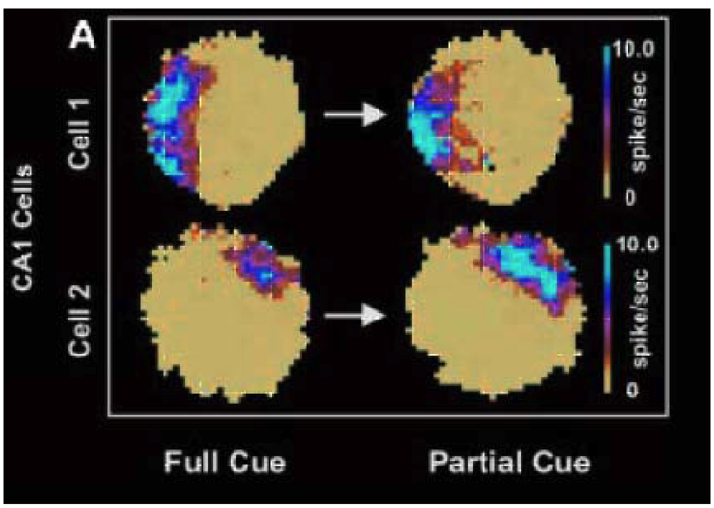
Distinct pools of neurons represent an object's components.

Synapses between these pools link the components together.

The same pool participates in representing other objects with the same feature.

5 of 10

Hippocampal recall with partial cues



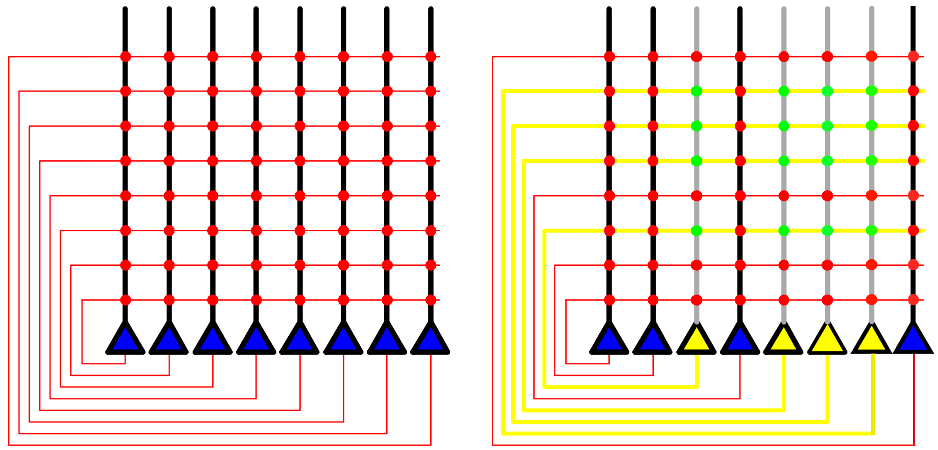
Place fields with full (four pictures) and partial cues (one picture) [Nakazawa 2002].

After learning to navigate a maze with four wall pictures, mice perform as well when three pictures are removed. This is consistent with the associative memory model.

6 of 10

©1988–2008 Wolfram Research, Inc. All rights reserved.

The Hopfield Network



Synapses (green) between active neurons (yellow) are strengthened.

During recall, neuron j's input (y_j) is the weighted sum of neurons $i = 1, \ldots, N$'s outputs (x_i). This input is thresholded (f) to obtain its output (x_j), which is binary (0 or 1).

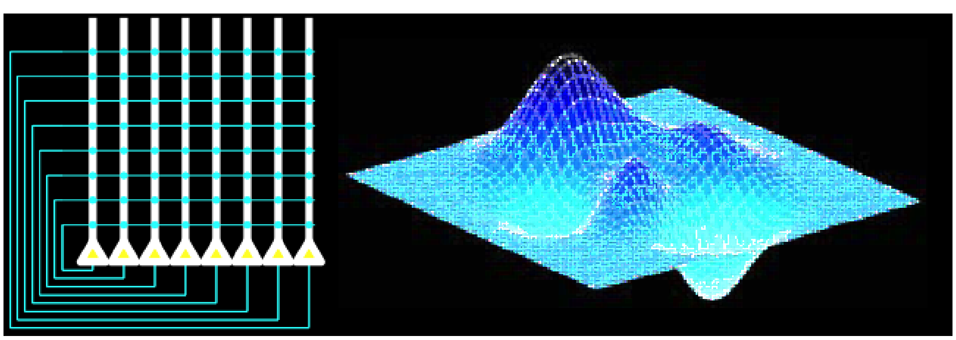
$$y_j = \sum_{i=1}^{N} w_{ij}\, x_i \quad \text{and} \quad x_j = f\,(y_j)$$

During learning, weight w_{ij} is incremented if neuron i and neuron j are both active in pattern $m = 1, \ldots, M$

$$w_{ij} = \sum_{m=1}^{M} x_i^m\, x_j^m$$

7 of 10

How memories are recalled



©1988–2008 Wolfram Research, Inc. All rights reserved.

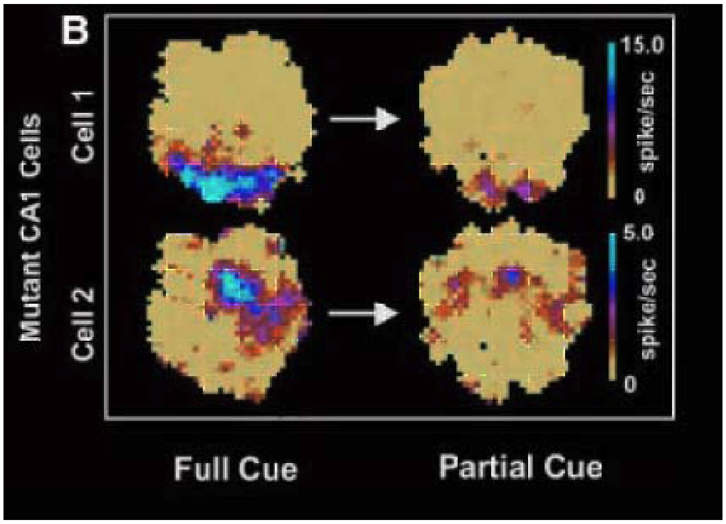
Stored patterns become stable fixed points (attractors).

Hopfield analyzed the network's dynamics using an energy landscape (Lyapunov function). A more intuitive understanding comes from reversing the order of summation

$$y_j = \sum_{i=1}^{N} \sum_{m=1}^{M} x_i^m x_j^m x_i = \sum_{m=1}^{M} x_j^m \sum_{i=1}^{N} x_i^m x_i$$

A pattern's similarity to the input determines its contribution to the output. Thus, the network will tend to recall the closest-matching pattern.

Hippocampal associative memory requires NMDA



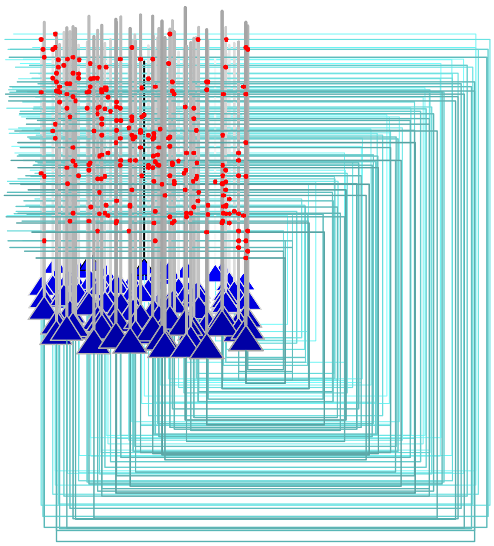
Place fields collapse with a partial cue in NMDA knockouts [Nakazawa2002].

Eliminating learning at recurrent CA3 synapses (by knocking out NMDARs) damages associative recall.

After learning to navigate a maze with four picturess, NMDA knockouts perform poorly when three pictures are removed.

 ©1988–2008 Wolfram Research, Inc. All rights reserved.

Spiking network model



Spiking neurons make (random) local recurrent connections with STDP synapses.

Like the Hopfield network, this network stores patterns by strengthening recurrent synapses among coactive neurons.

10 of 10

Spiking network's performance

The whole pattern (square) is recalled when half of the neurons in the it are activated.

©1988–2008 Wolfram Research, Inc. All rights reserved.