SAND2012-0064C

Pattern separation or pattern resolution?

A critical look at DG and neurogenesis function

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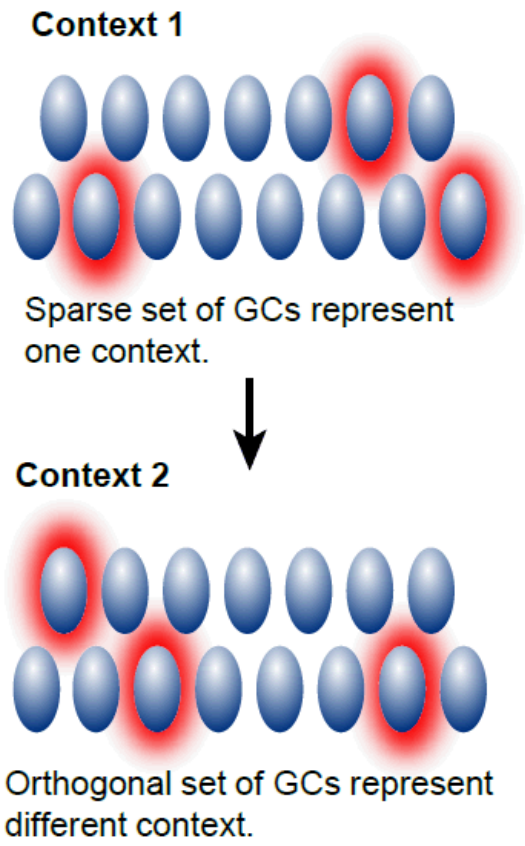
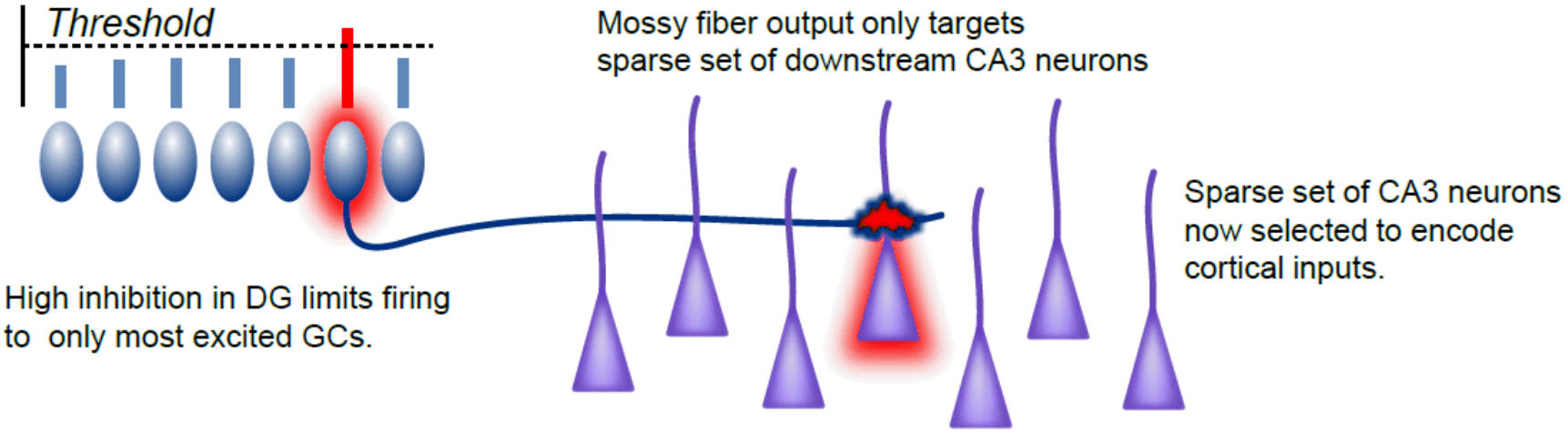
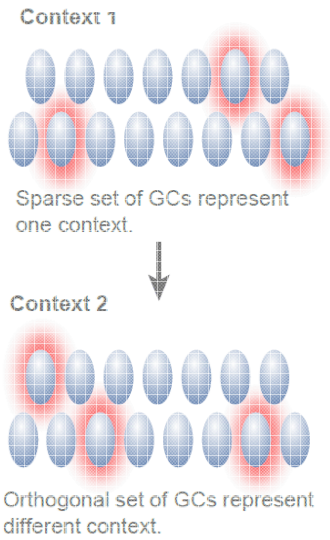
Salk Institute for Biological Studies
Sandia National Laboratories

What is pattern separation?
computational definition



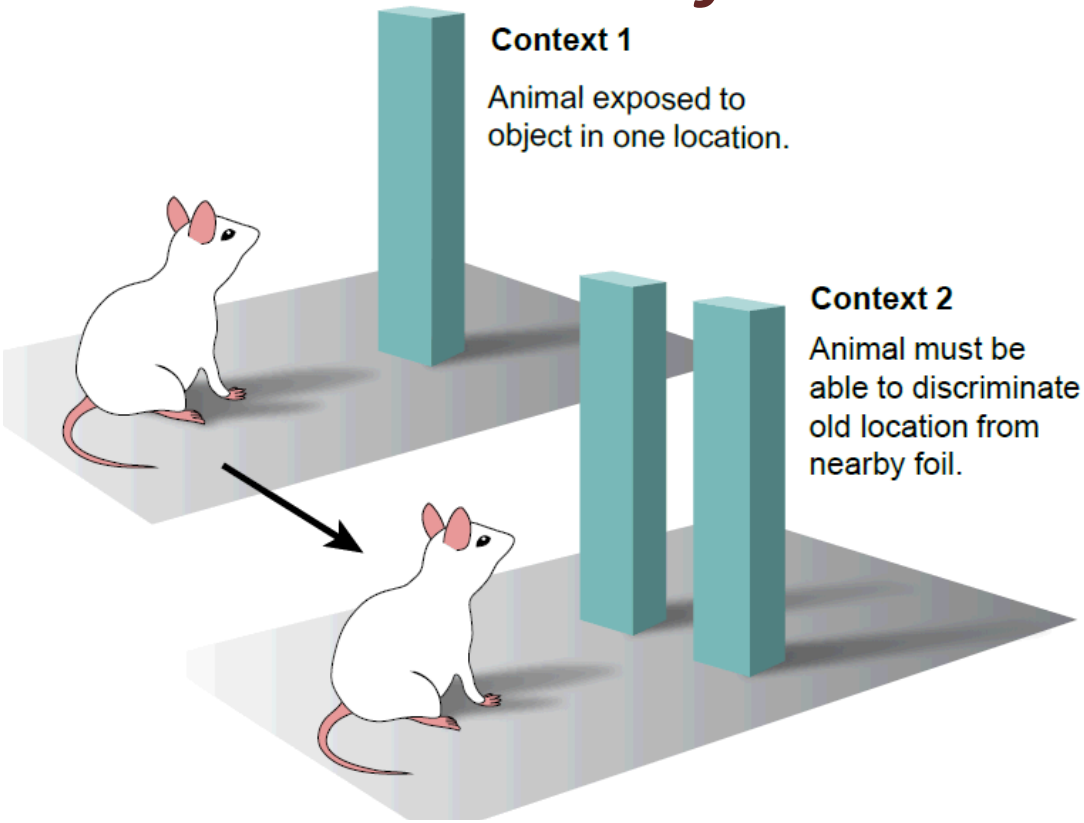
What is pattern separation?
anatomical definition

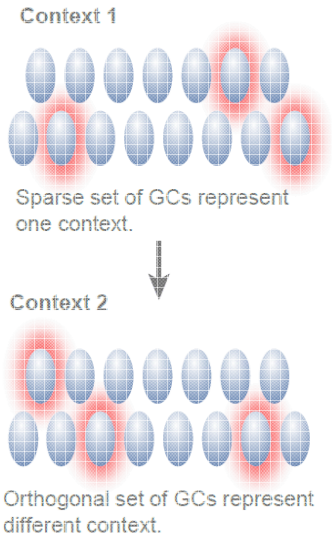


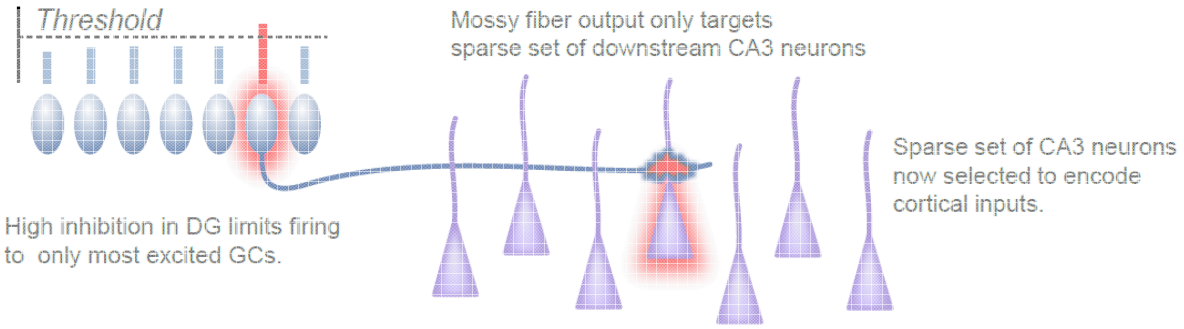


What is pattern separation?

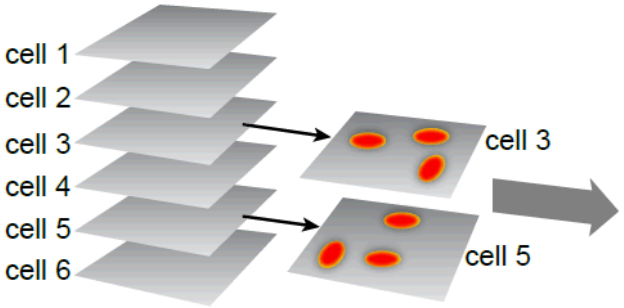
behavioral definition



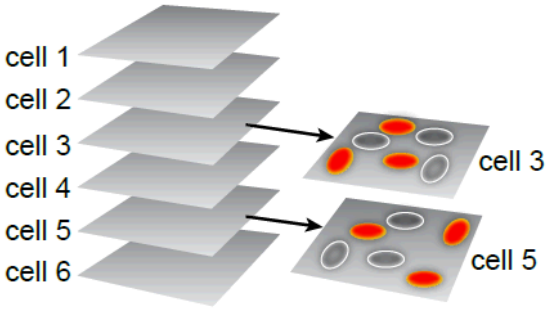




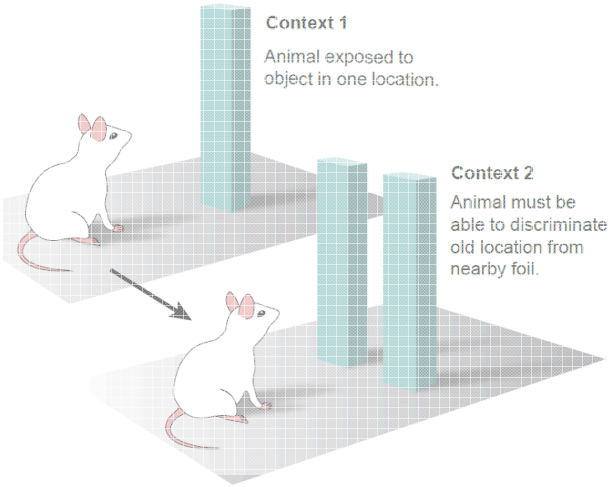
What is pattern separation?
in vivo physiology definition

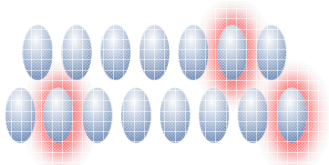


Subset of GCs show multiple place fields in one context.



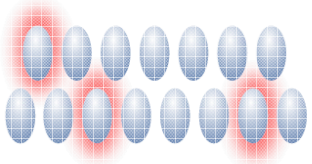
Same subset of GCs show different place fields in new context.



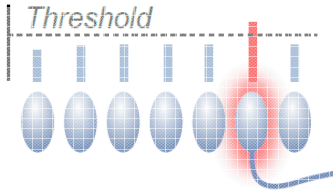


Sparse set of GCs represent one context.

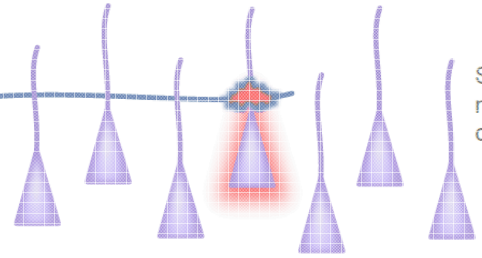
Context 2



Orthogonal set of GCs represent different context.



High inhibition in DG limits firing to only most excited GCs.

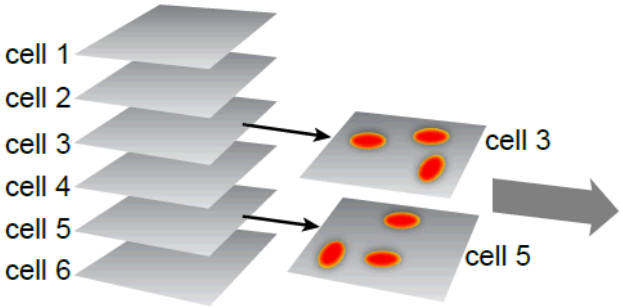


Mossy fiber output only targets sparse set of downstream CA3 neurons

Sparse set of CA3 neurons now selected to encode cortical inputs.

What is pattern separation?

messy definition → messy description



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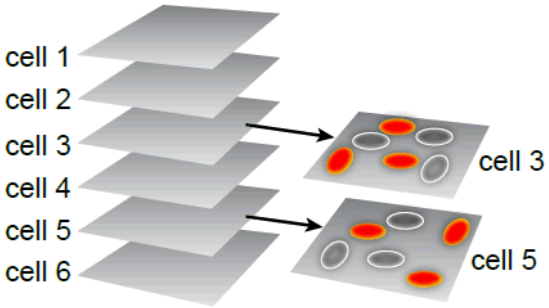

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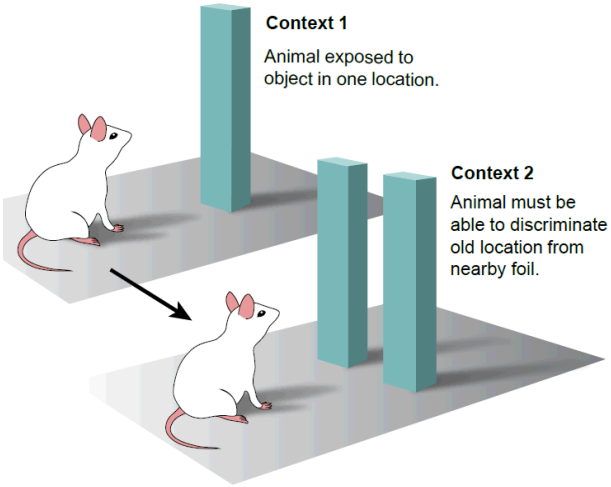

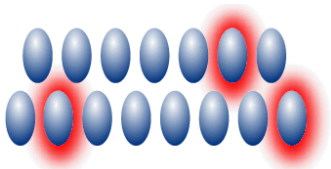

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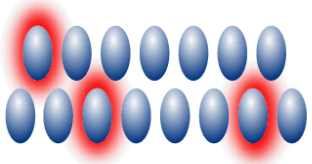
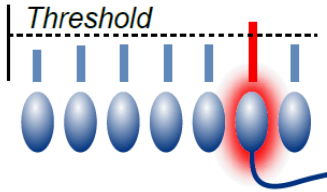


Orthogonal set of GCs represent different context.



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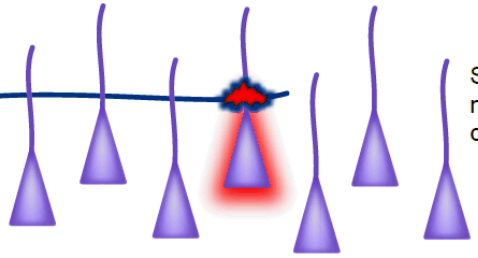
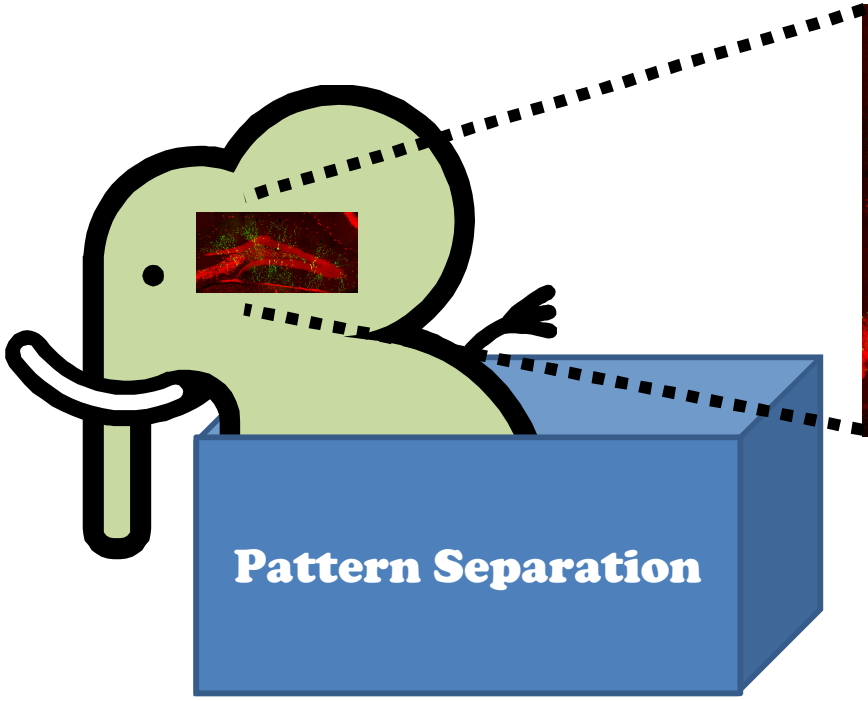
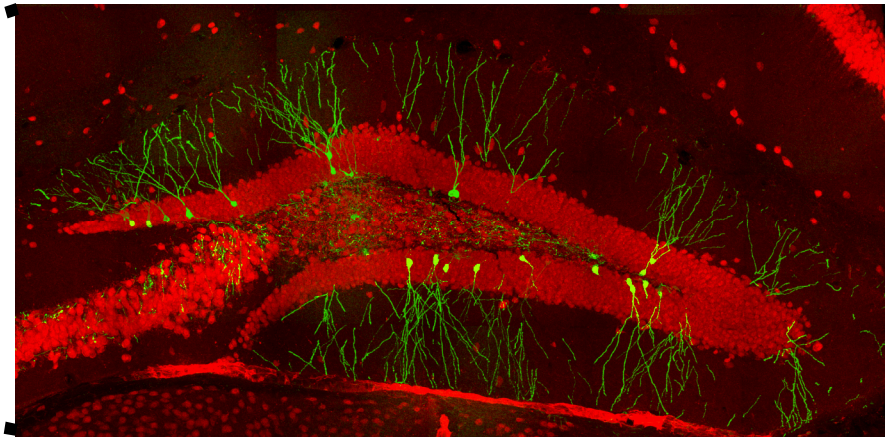


Sparse set of CA3 neurons now selected to encode cortical inputs.

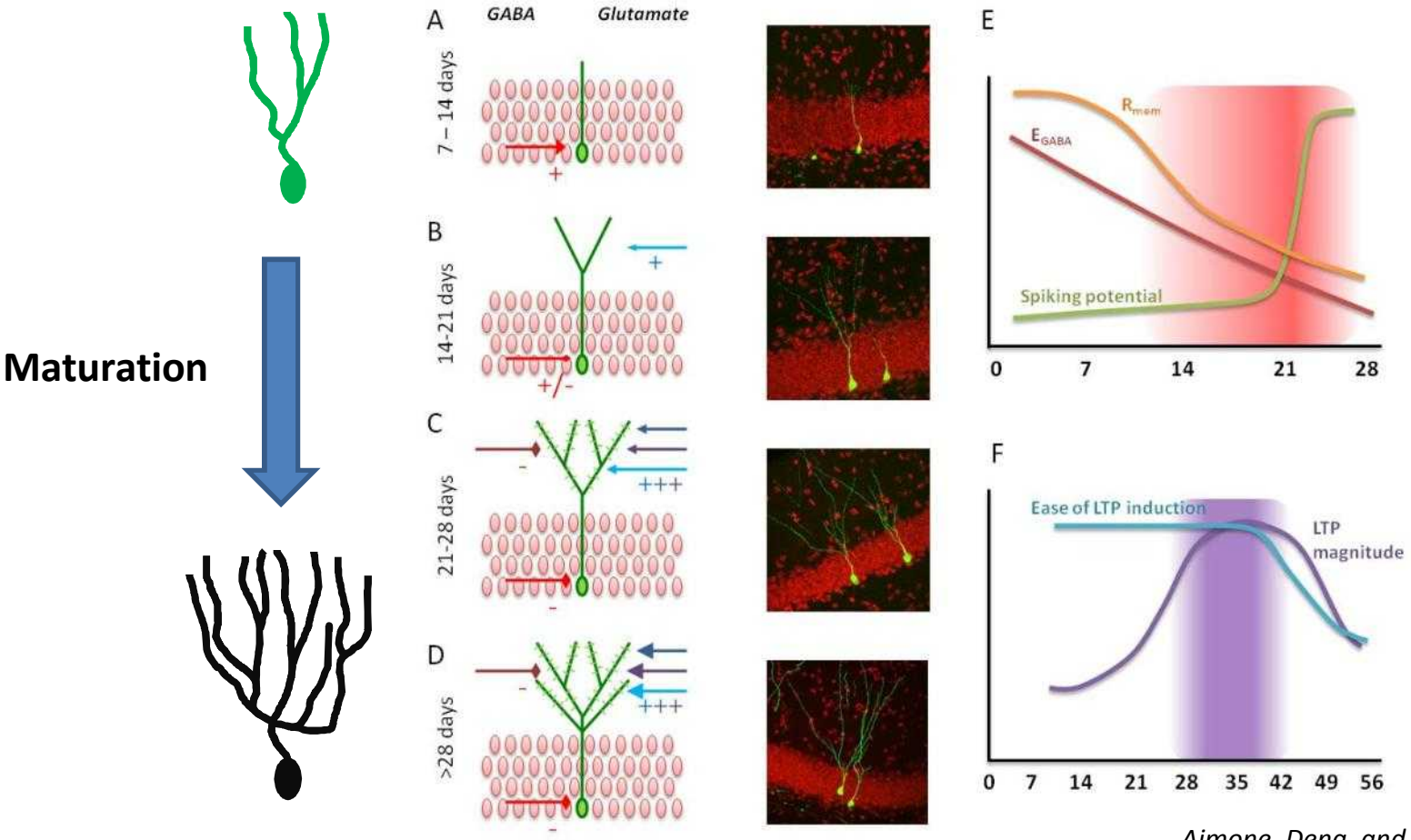
The real elephant in the room…





What are all those new neurons doing?

Adult neurogenesis results in a mixed population of GCs



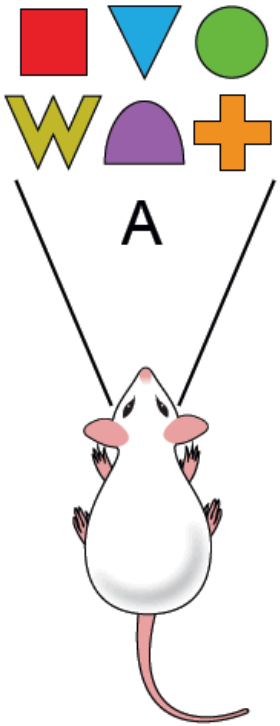
Aimone, Deng, and Gage
Trends in Cog. Sci. 2010

What about *memory resolution?*

Why “memory resolution” and what do I mean?

- DG provides training signal for EC-CA3 and CA3-CA3 learning (*i.e., Treves & Rolls, 1992*)
- The selection of CA3 neurons, by DG, determines how much information stored in each memory
  - More DG neurons active → more CA3 neurons involved → more “memory pixels”

How memory resolution equates to discrimination behaviors



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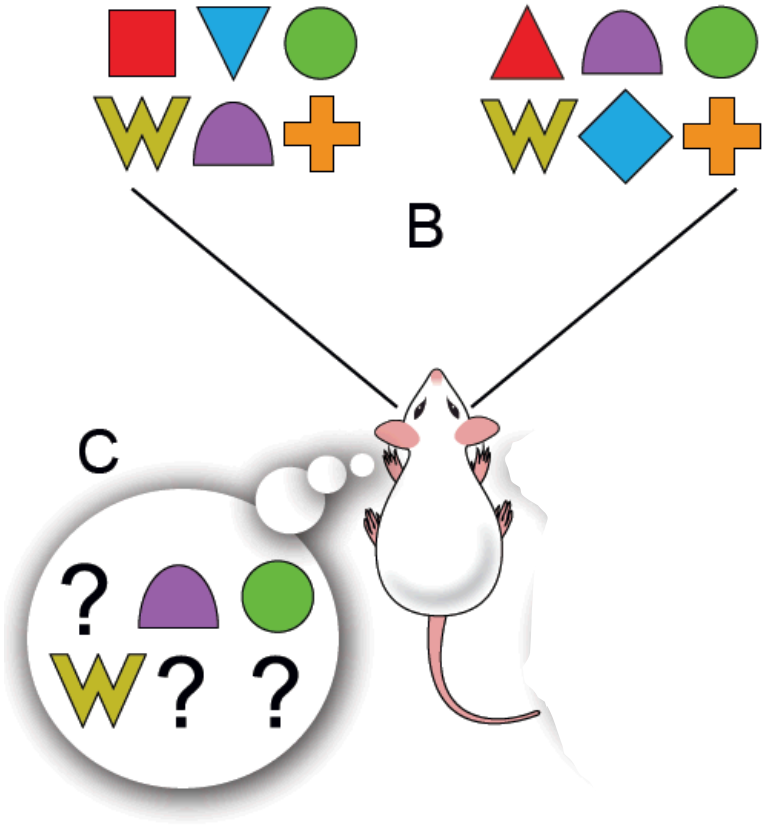
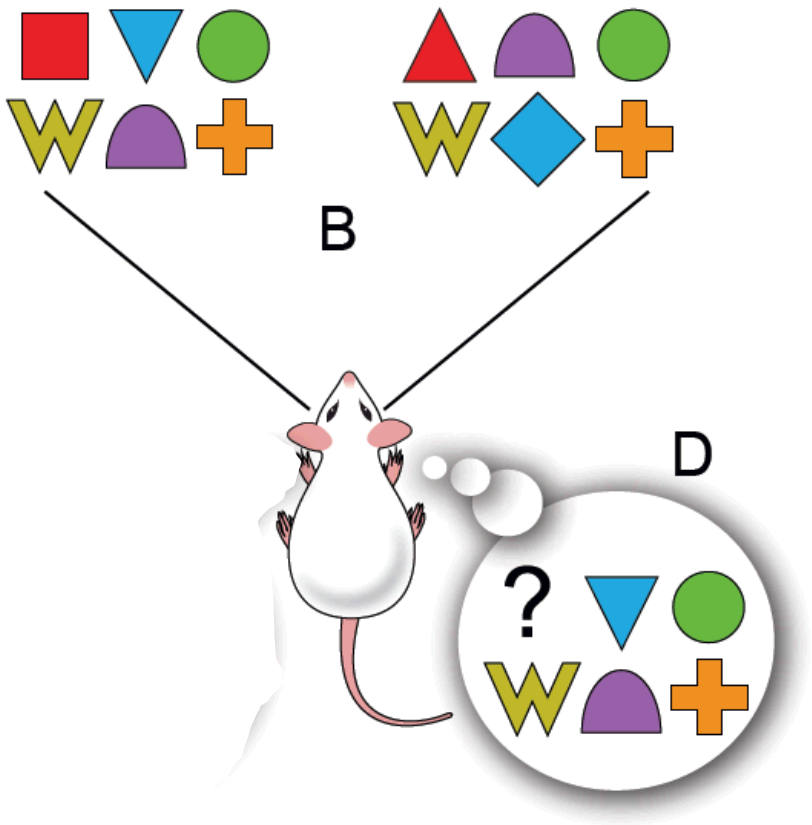
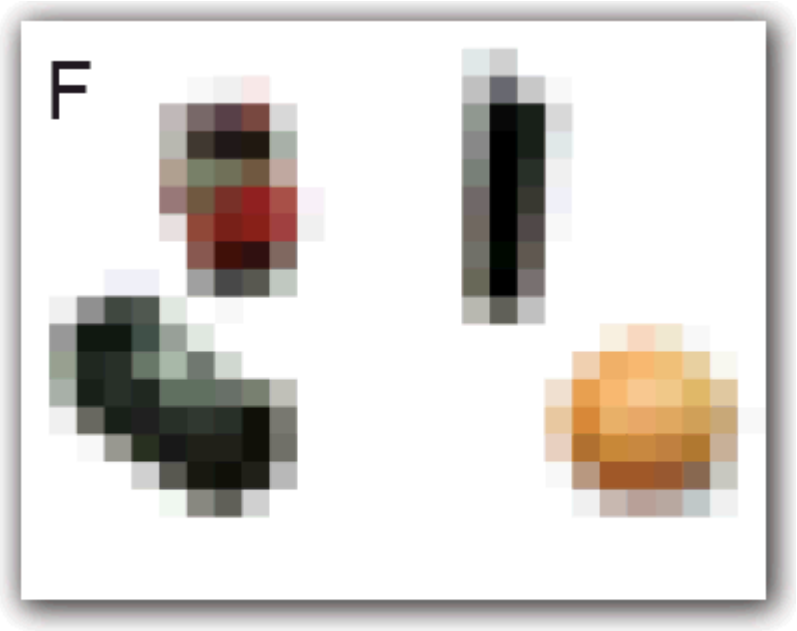


How memory resolution equates to discrimination behaviors

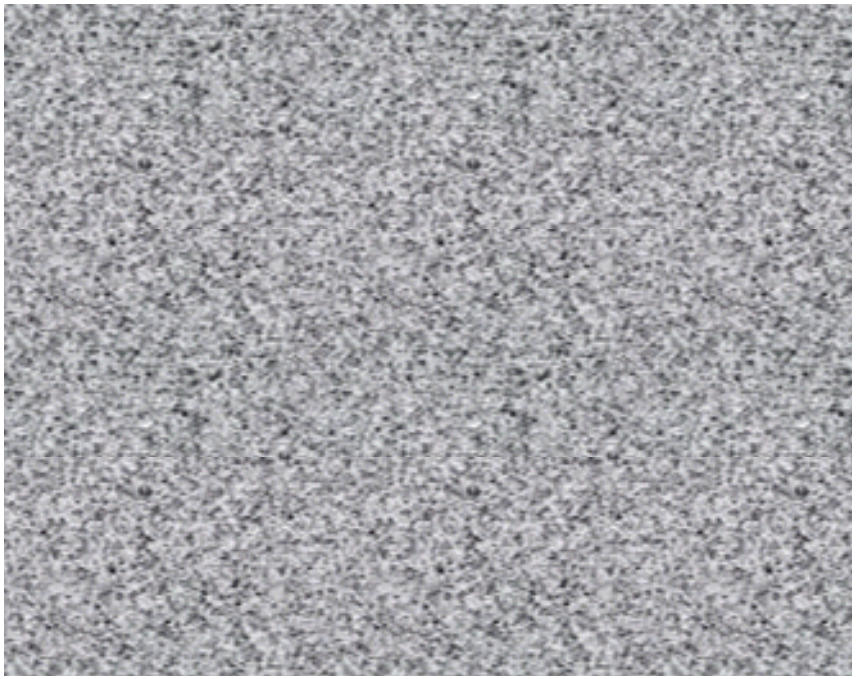


Another demonstration

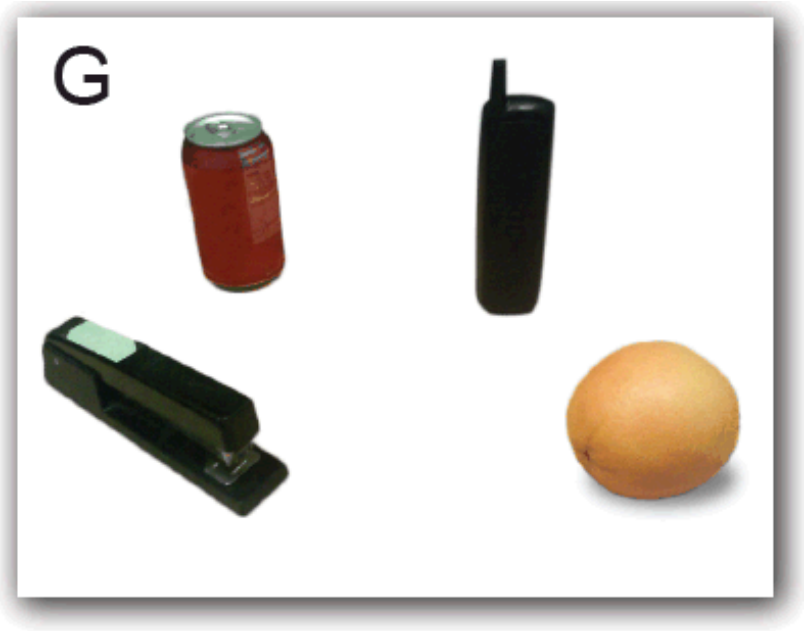


Low resolution memory of test objects

Can you remember the original objects?

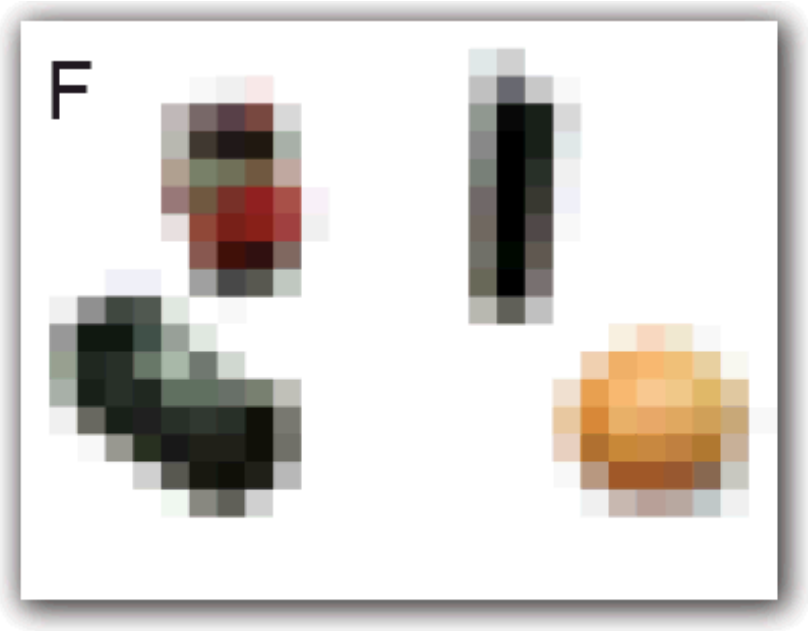


Low resolution memory of test objects

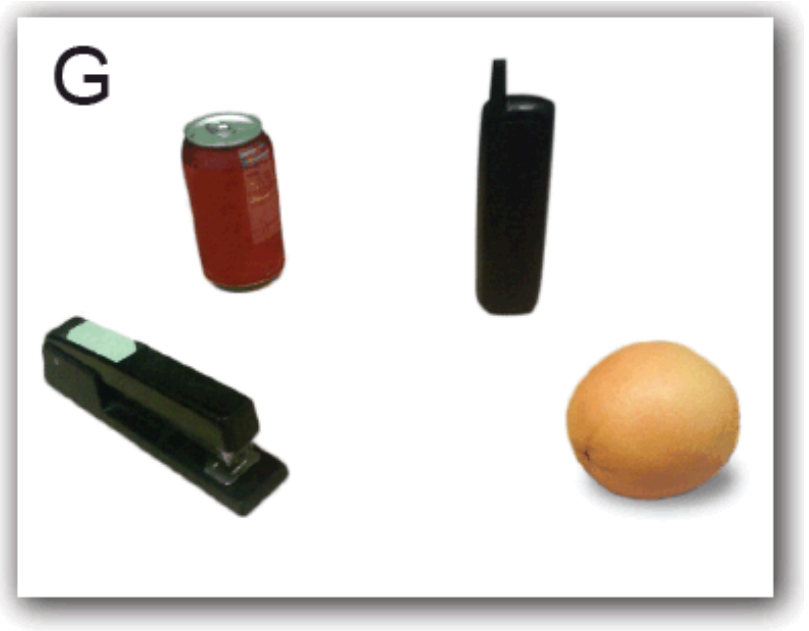


Which test objects are novel?

Low resolution memories make discrimination hard



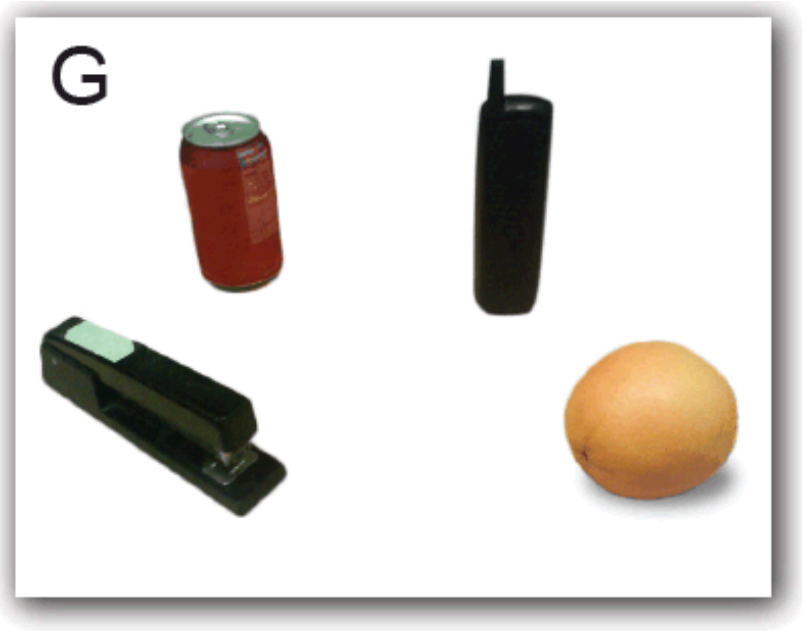
Low resolution memory of test objects



Which test objects are novel?

High resolution memories enable behavioral discrimination

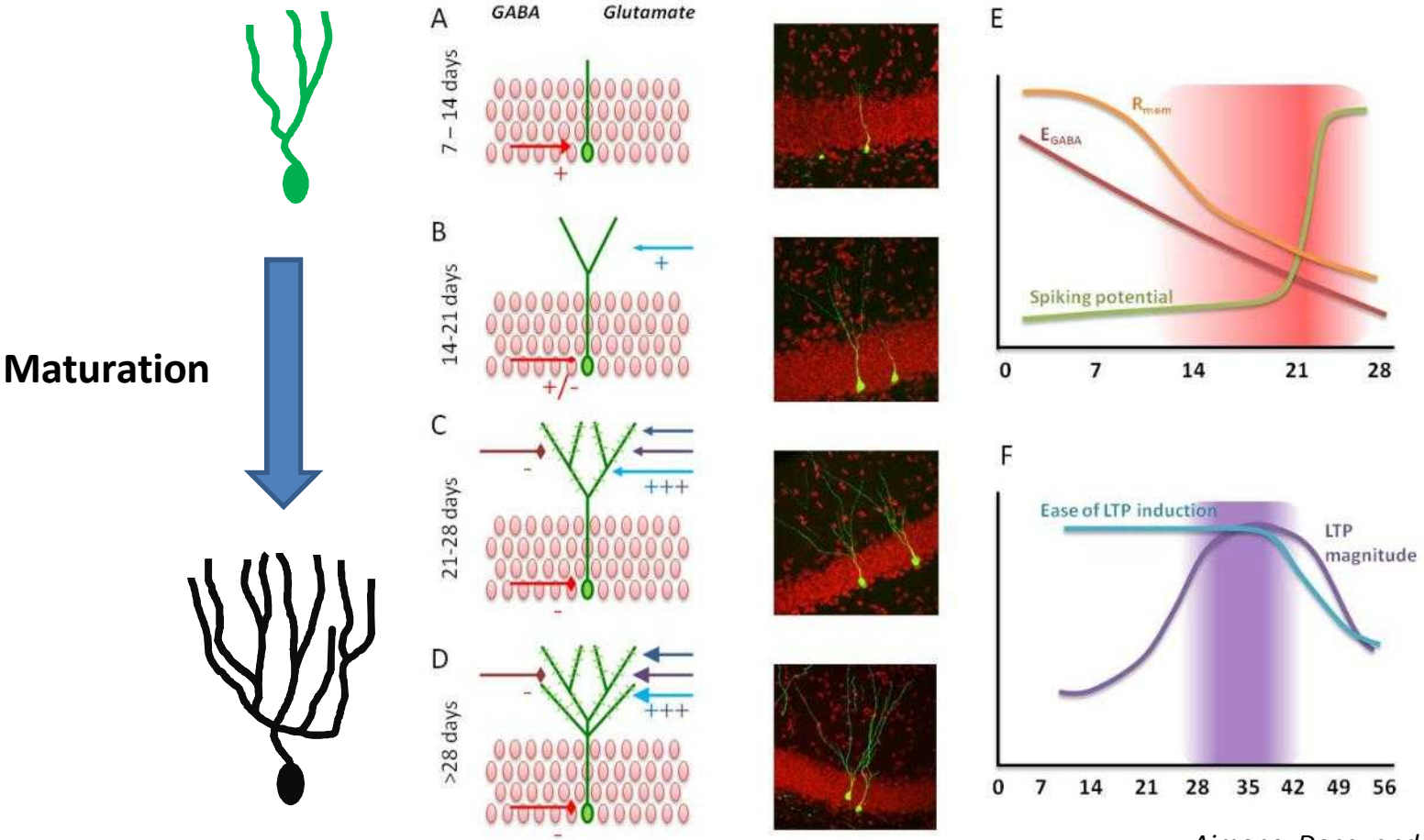
High resolution memory of test objects



Which test objects are novel?

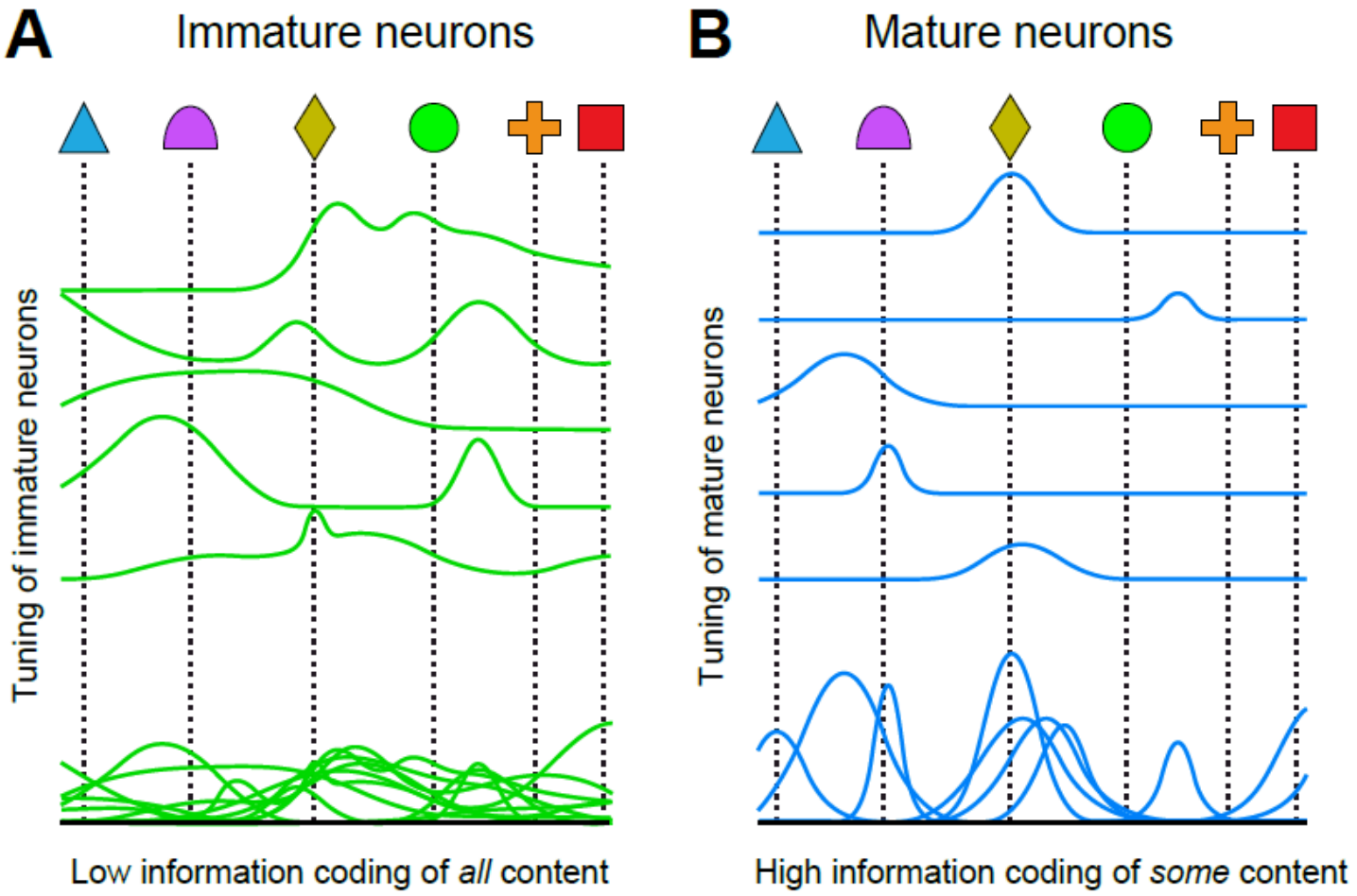
What does this have to do with neurogenesis?

Neurogenesis results in a mixed population of GCs



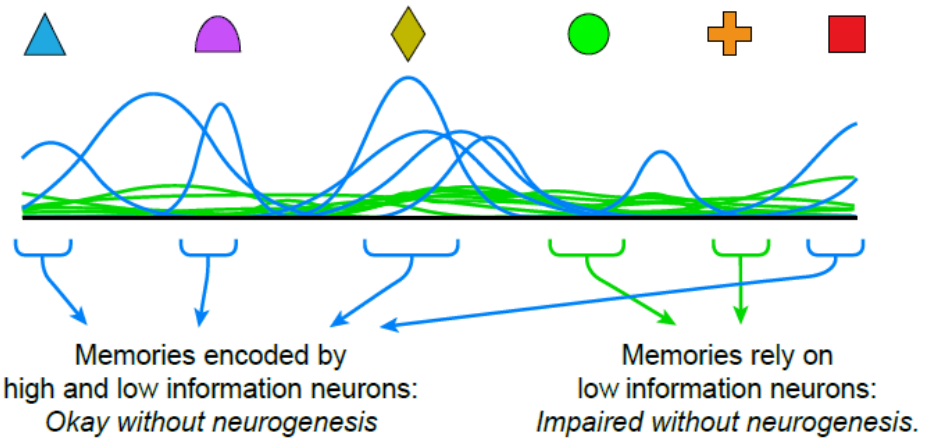
Aimone, Deng, and Gage
Trends in Cog. Sci. 2010

Immature and mature neurons encode information differently

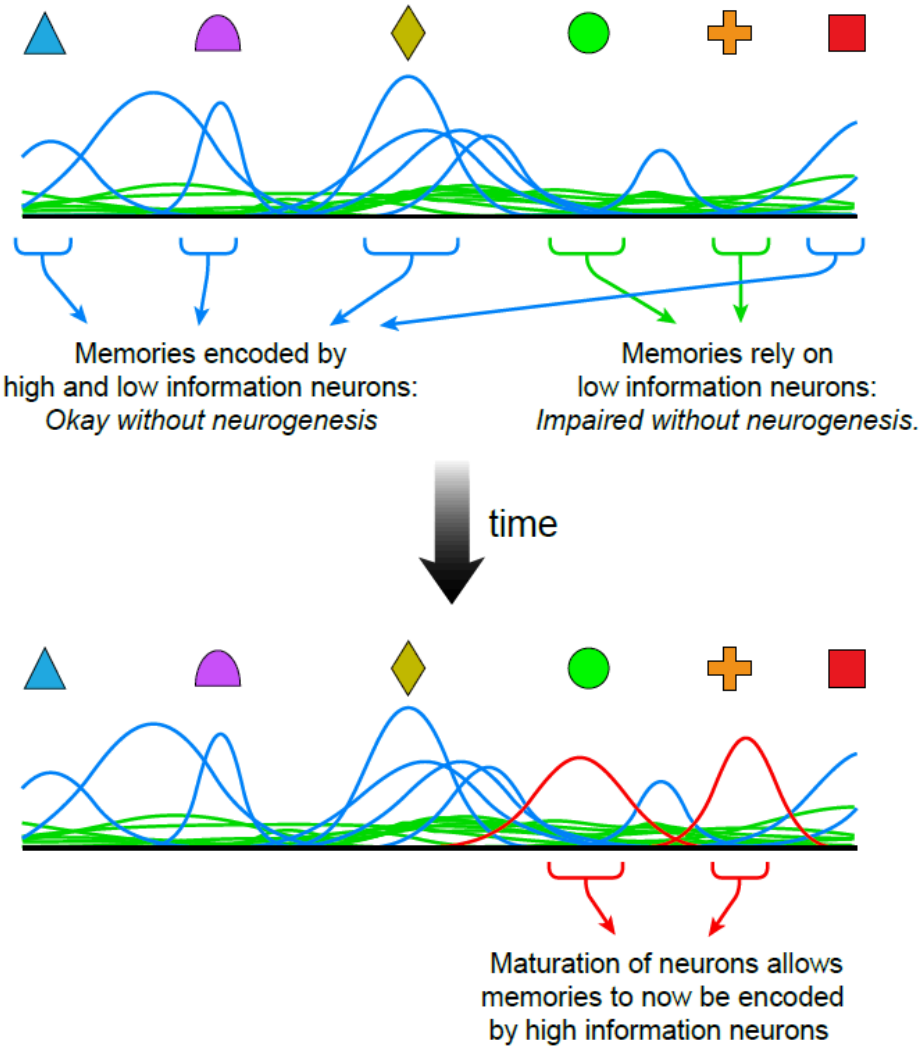


Combination of immature and mature neurons yields

- Young neurons ensure all information is encoded at a baseline level
- Old neurons provide high information signal about familiar features

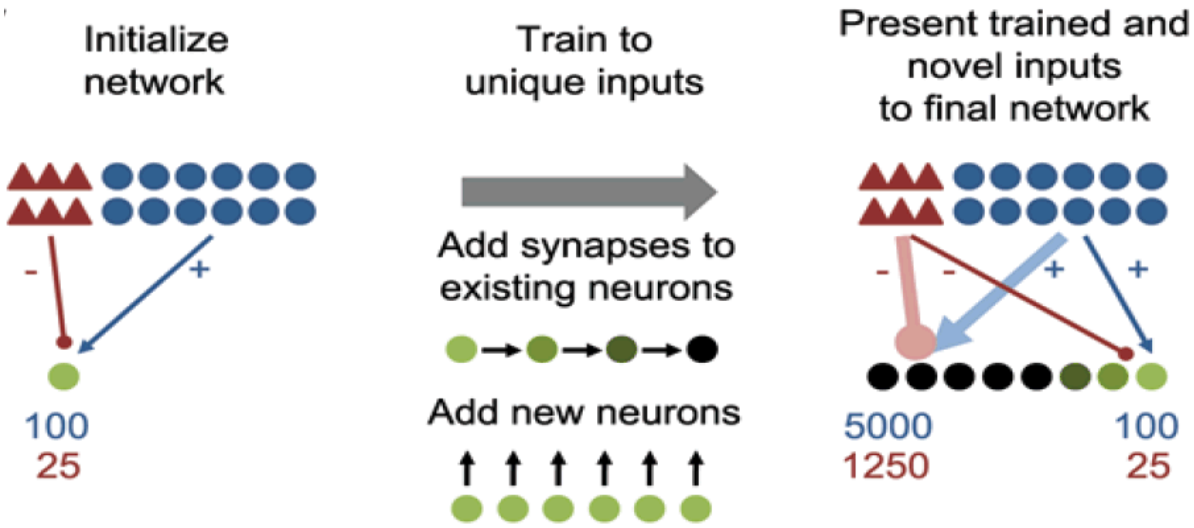


As neurons mature, they become high information encoders themselves

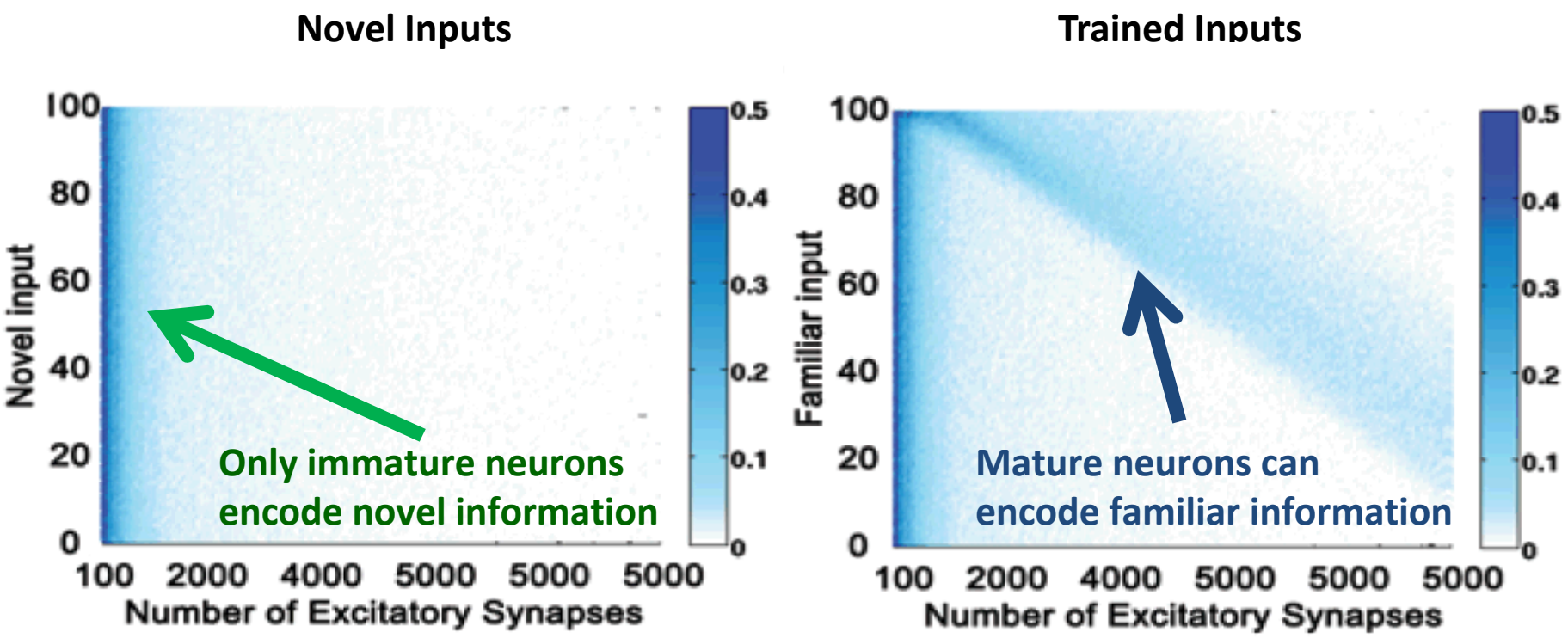


Model evidence relevant to neurogenesis and memory resolution

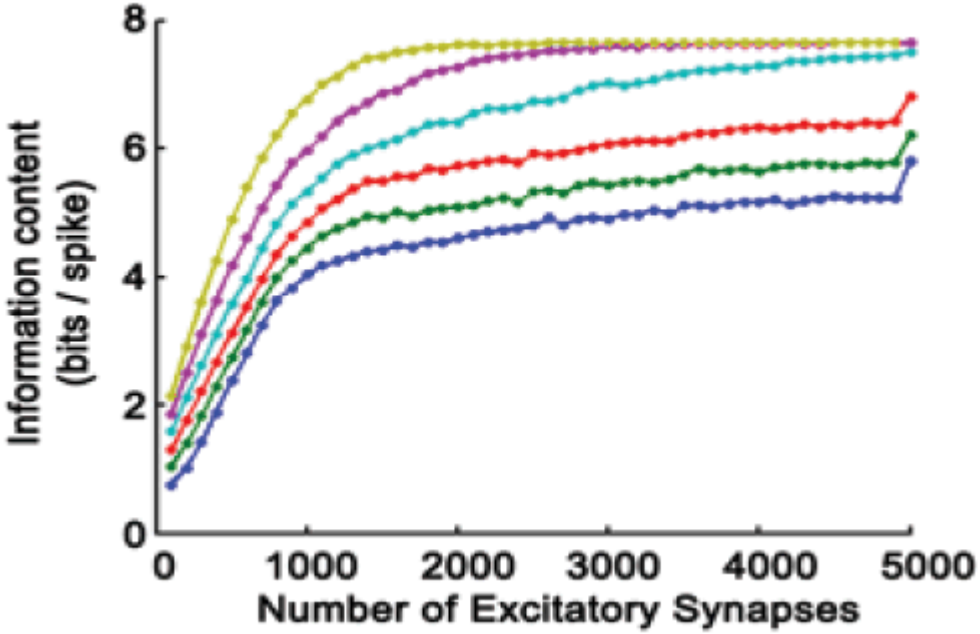
Abstract model: simple neurogenic network stores and recalls memories



Neurons maturing to large number of synapses contain high information about maturation cues



High synapse neurons have higher information content

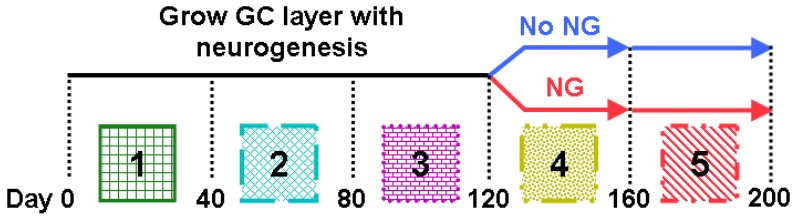


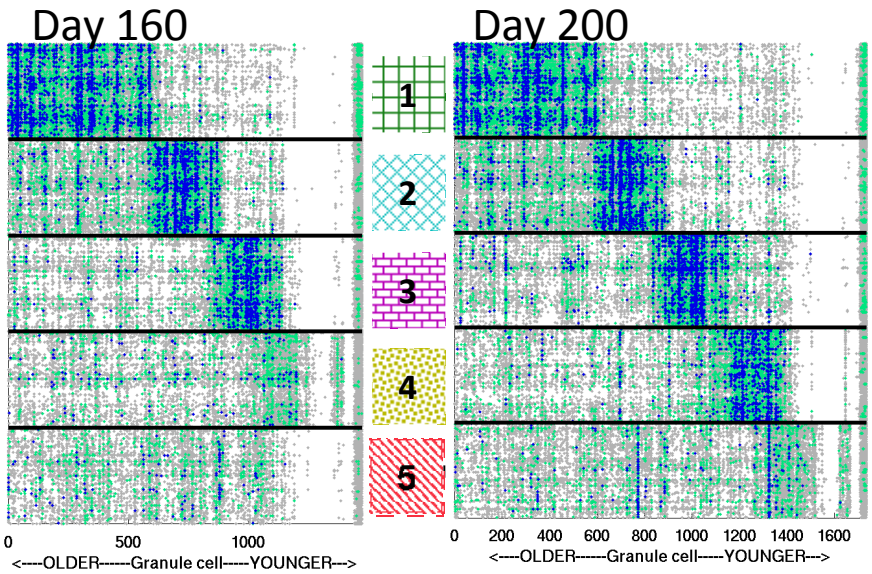
More complex model: Environmental commitment of adult-born neurons

- Neurons learn to represent environment present during maturation

- Prolonged exposure to environment will result in a population of DG granule cells that are “specialized” to that environment

- Networks without neurogenesis stop developing specialized groups of neurons





Aimone, Wiles, and Gage Neuron 2009

Conclusions

- “Memory resolution” lens is useful for describing DG function
- Consistent with neurogenesis behaviors
- Neurogenesis models indicate that information is encoded differently by young and old neurons

Thanks!

Salk Institute

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University of California San Diego

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Lara Rangel

University of Queensland

Janet Wiles

James S McDonnell Foundation

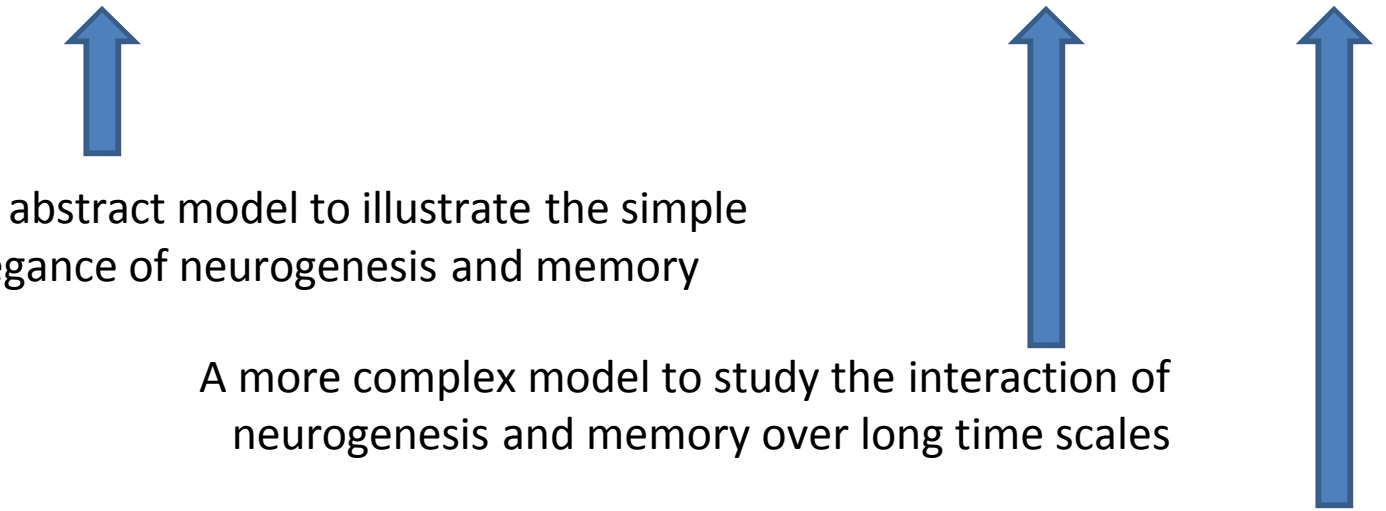
Kavli Institute for Brain and Mind

NSF Temporal Dynamics of Learning Center

Approaches to modeling neurogenesis

Abstract
Low biological detail
Small network sizes
Computationally and analytically tractable

Complex
High biological detail
Realistic network sizes
Computationally and analytically challenging

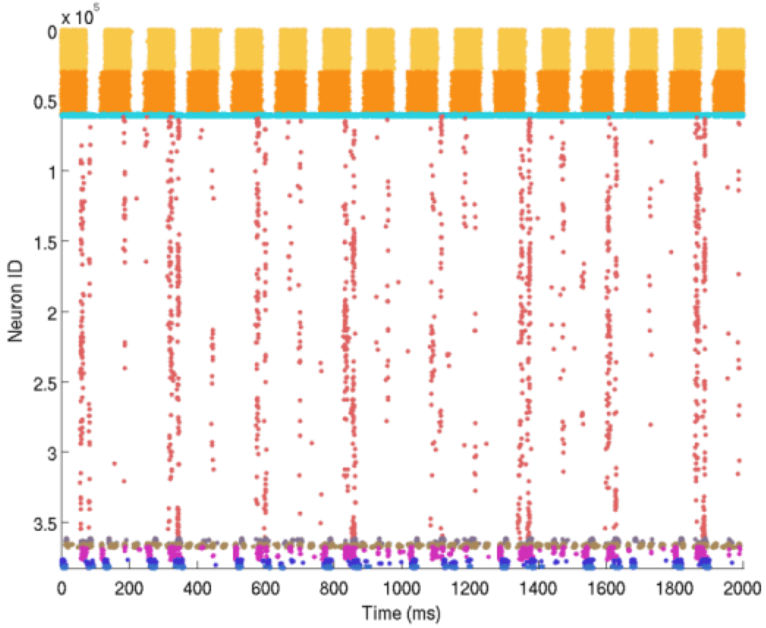


An abstract model to illustrate the simple elegance of neurogenesis and memory

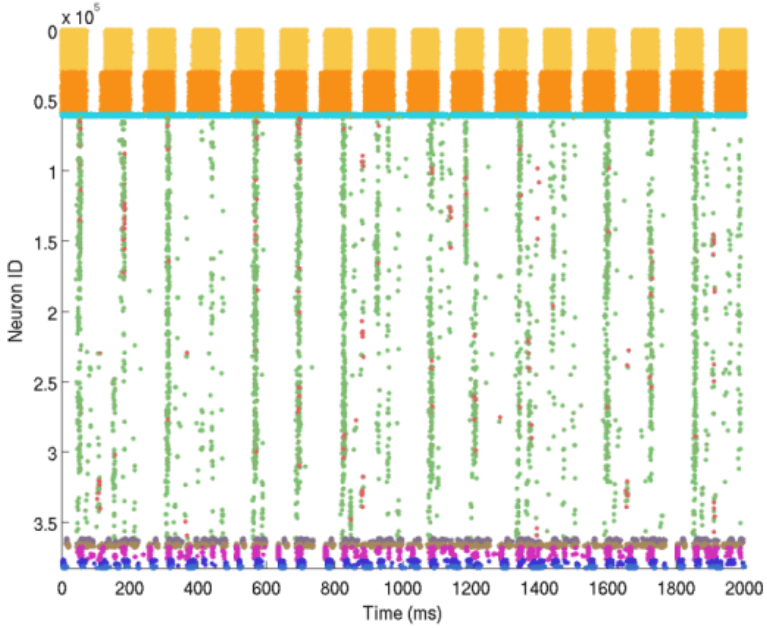
A more complex model to study the interaction of neurogenesis and memory over long time scales

A highly complex model to study the effects of network size and biological realistic dynamics on neurogenesis function

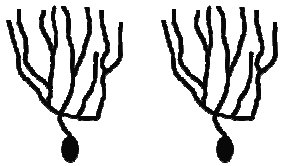
Realistic sized model: Young neurons perform most novel encoding



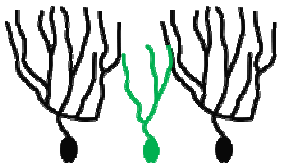
No Neurogenesis



Neurogenesis



300000 GCs



Realistic sized model: Young neurons perform most novel encoding