Content Addressable Memory Without Catastrophic Forgetting by Heteroassociation with a Fixed Scaffold

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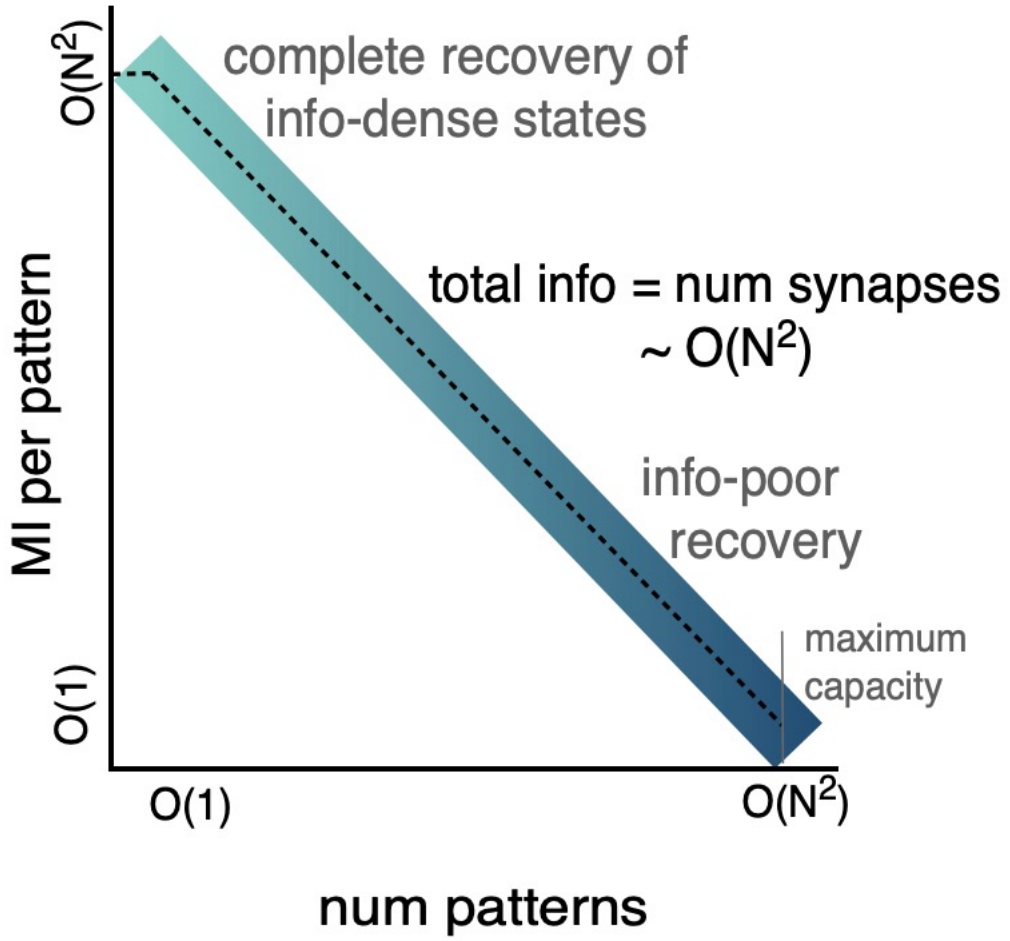
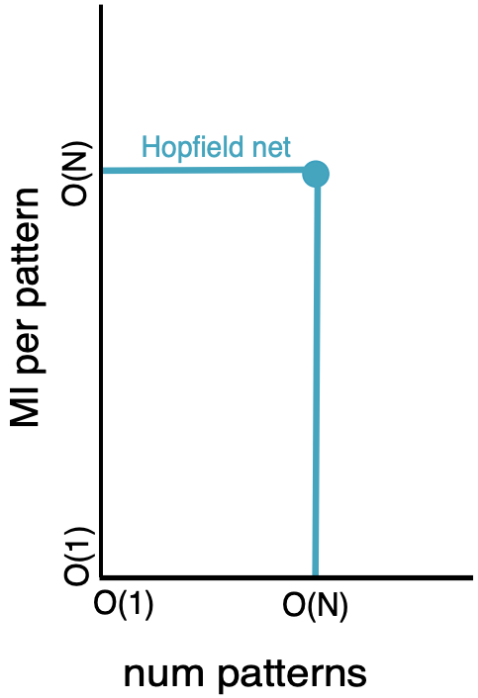
Sugandha Sharma
July 19, 2022

Any memory model should exhibit a Continuum



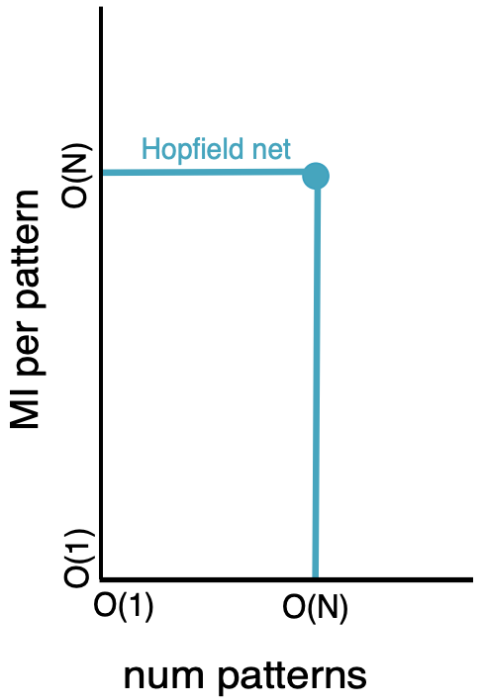
- Memories should only be gradually forgotten
- Key is to recover all stored memory states but with a lower information (accuracy) per memory

Existing CAM models lack a memory continuum



Hopfield network

Existing CAM models lack a memory continuum



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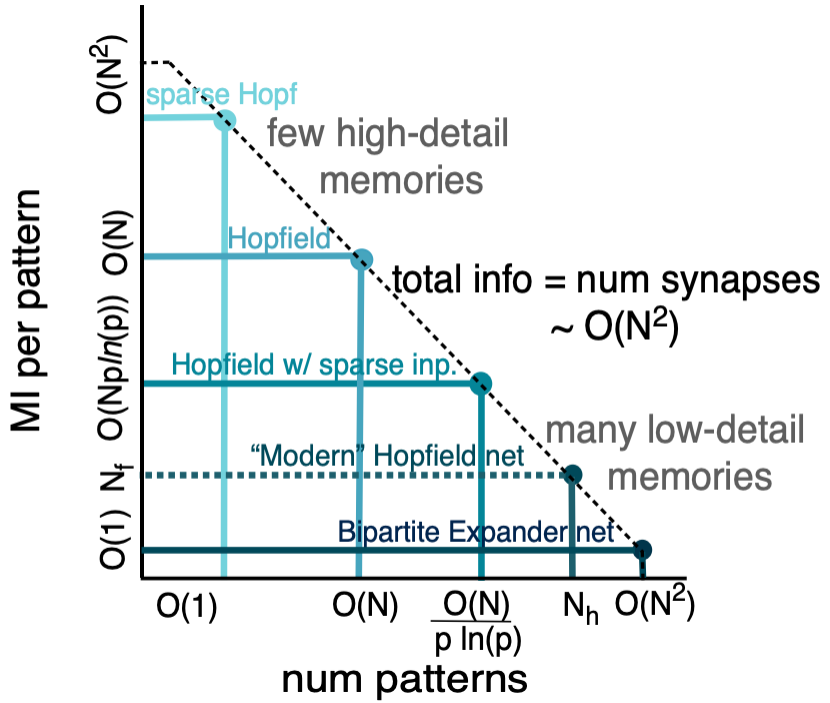

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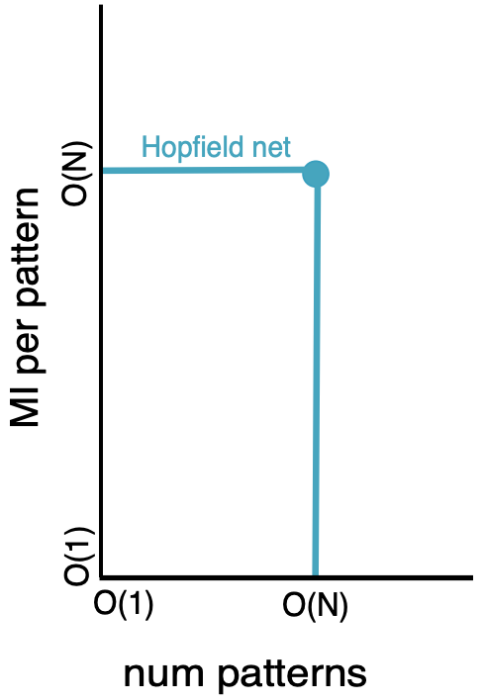

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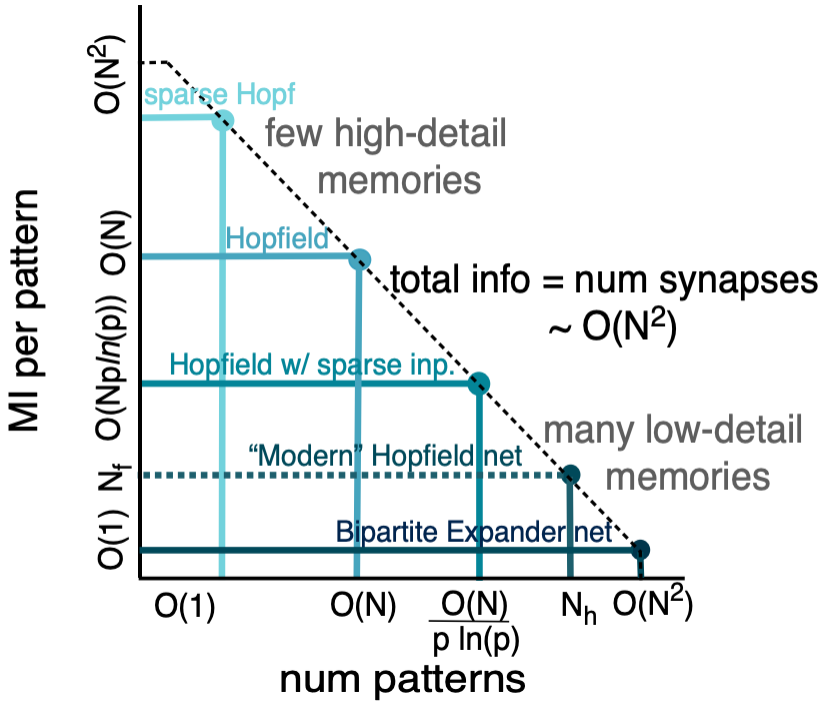

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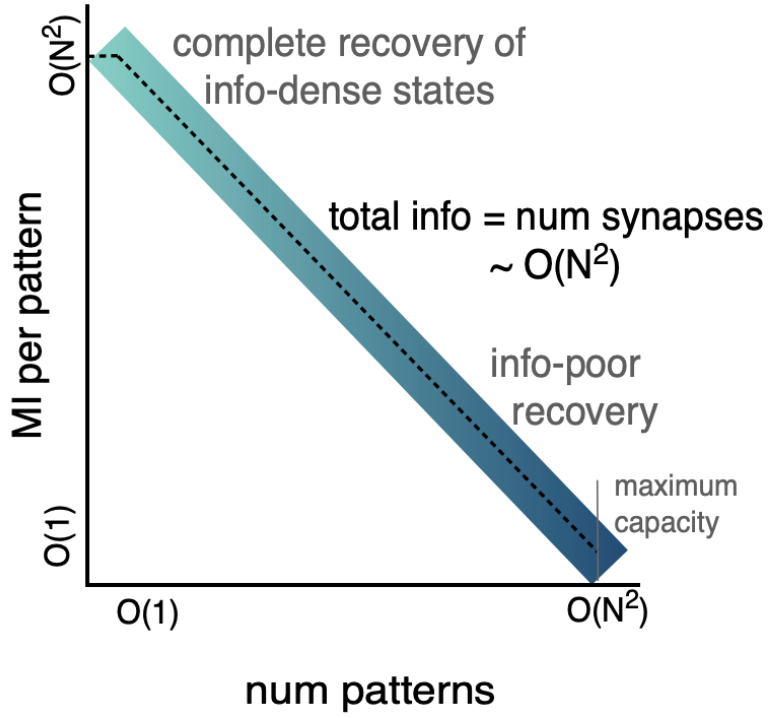
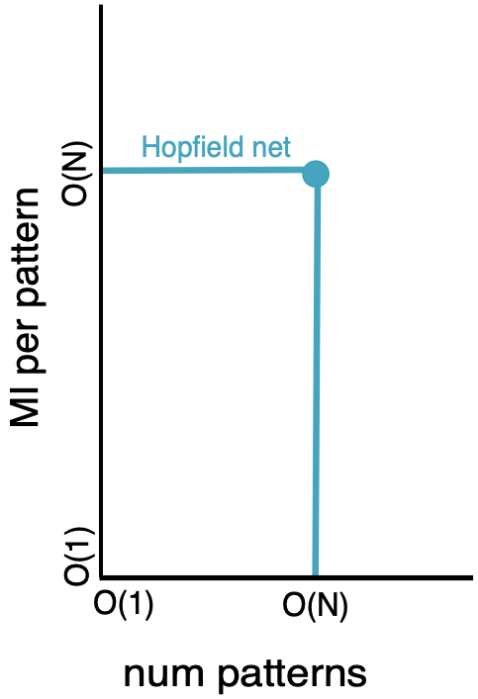


Desired CAM continuum

Existing CAM models lack a memory continuum



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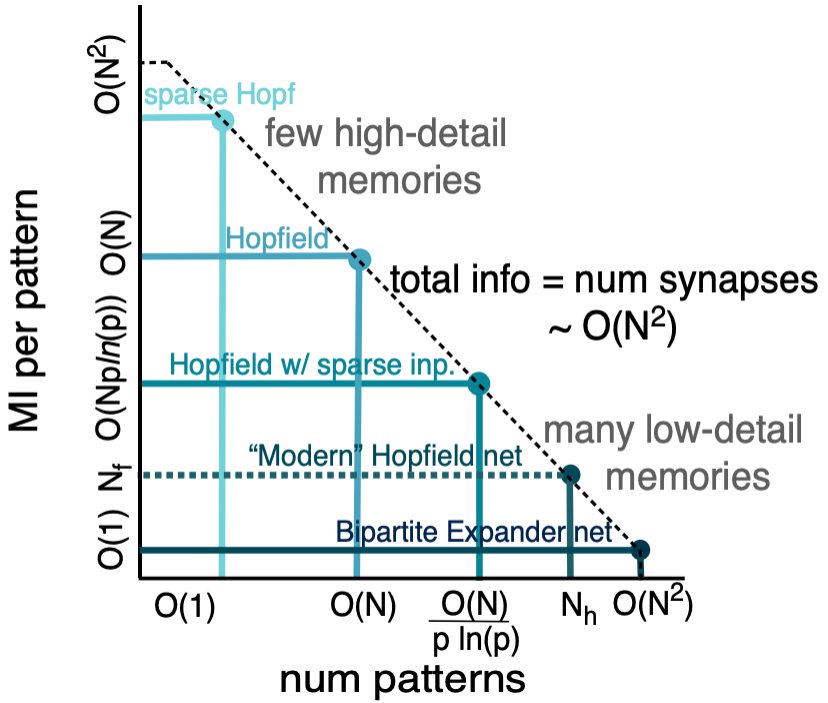

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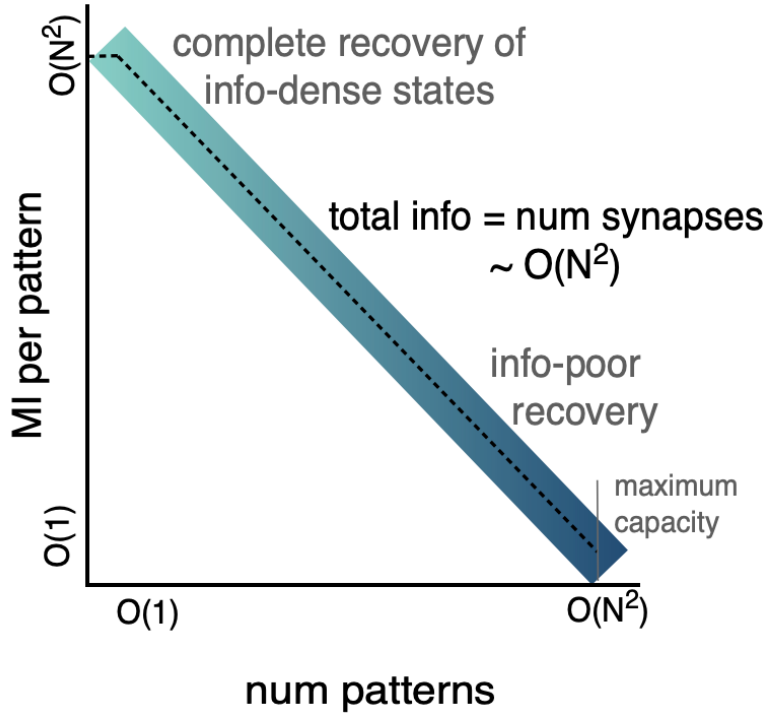
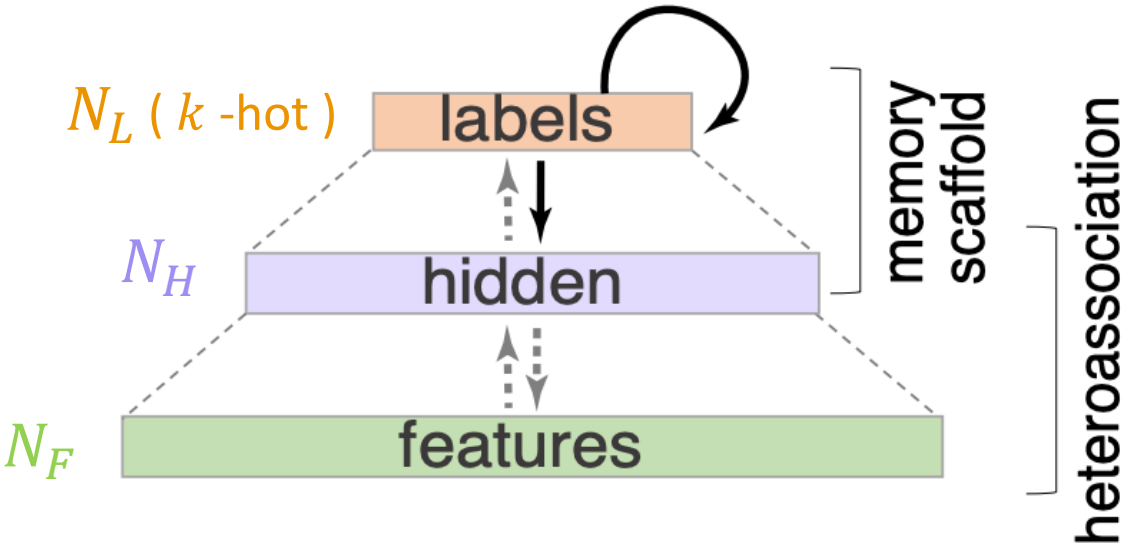
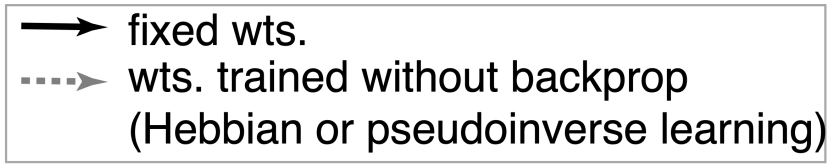


Desired CAM continuum achieved through our model!

Memory **S**caffold with **H**eteroassociation (MESH)

Separation of input features and persistence of memory





$N_H \sim O(1)$ $N_F \sim O(N_L^k)$

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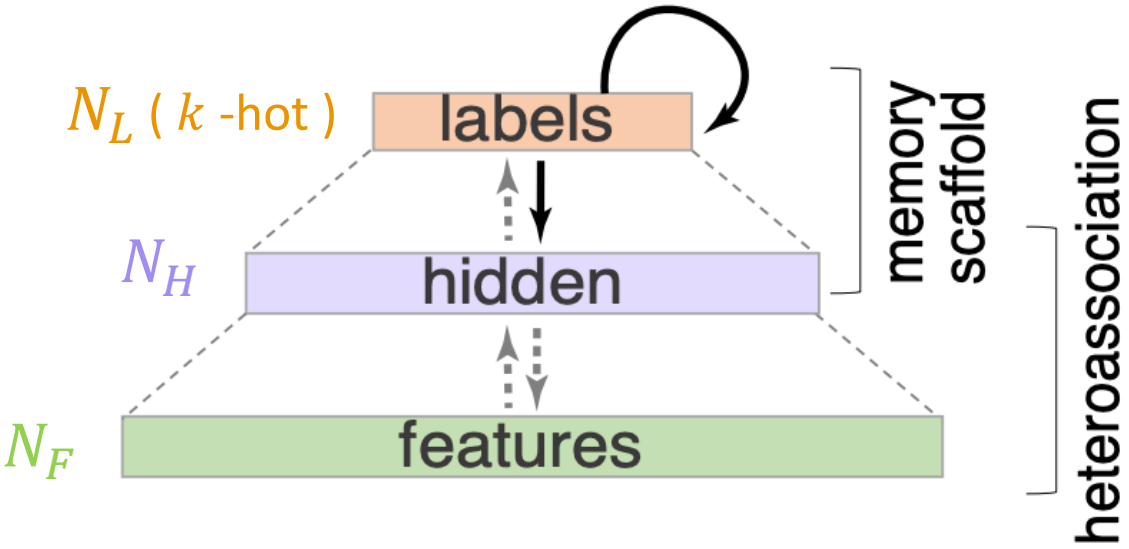

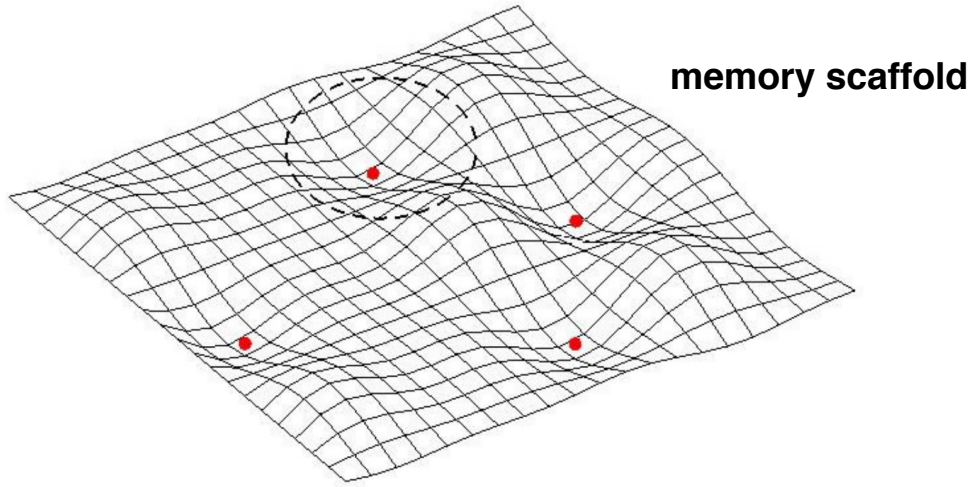

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Total number of states: $\binom{N_L}{k} \sim \exp(dN_L)$

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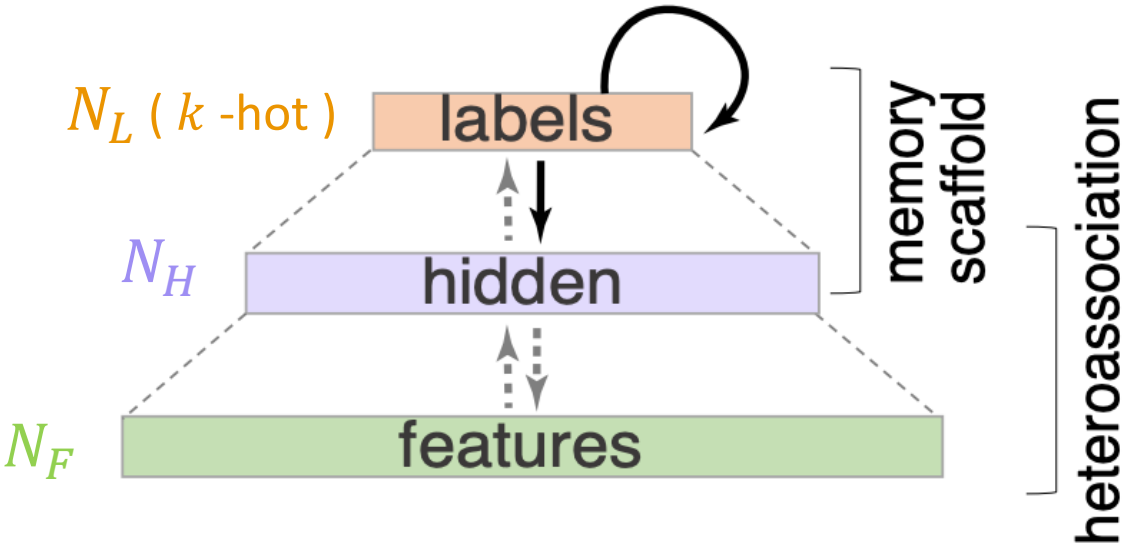

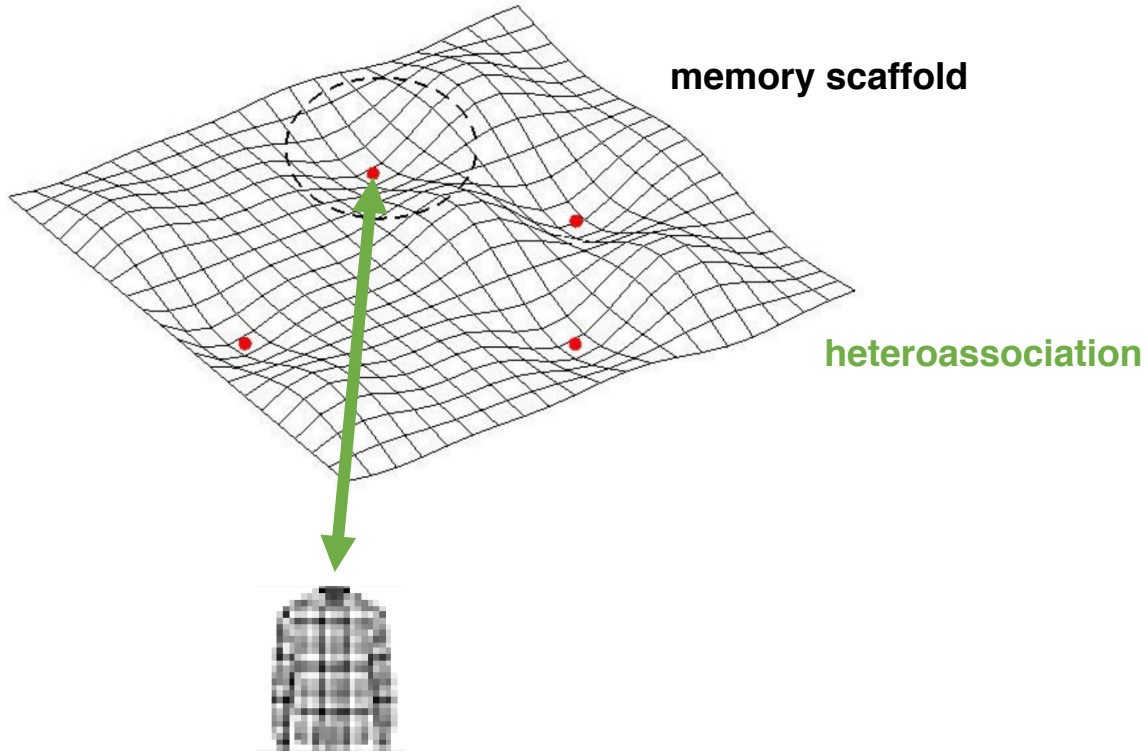

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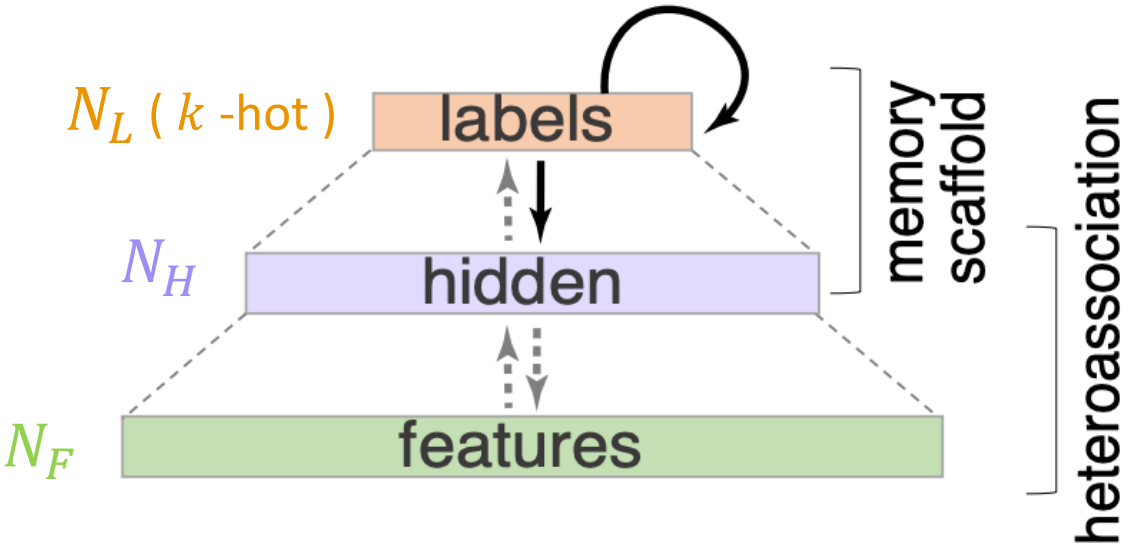

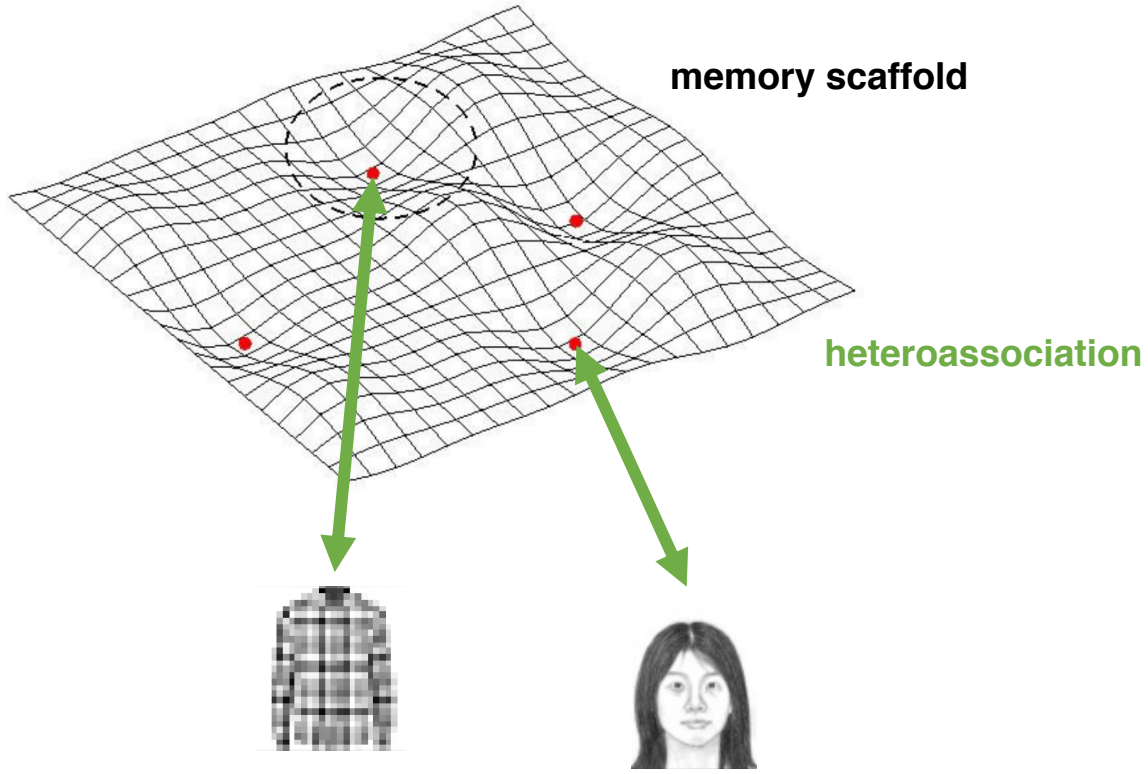

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Memory Scaffold with Heteroassociation (MESH)

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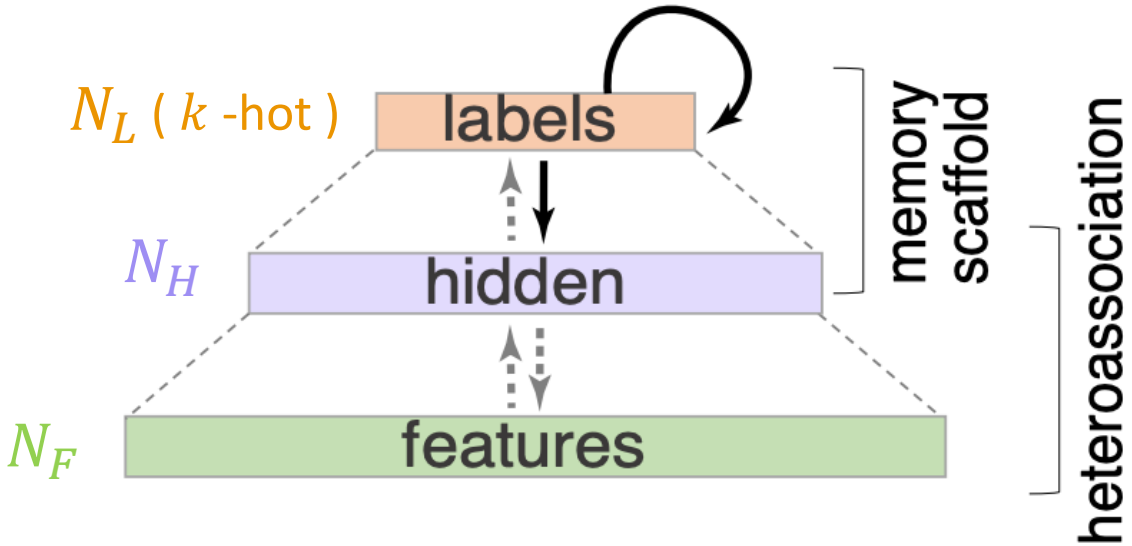

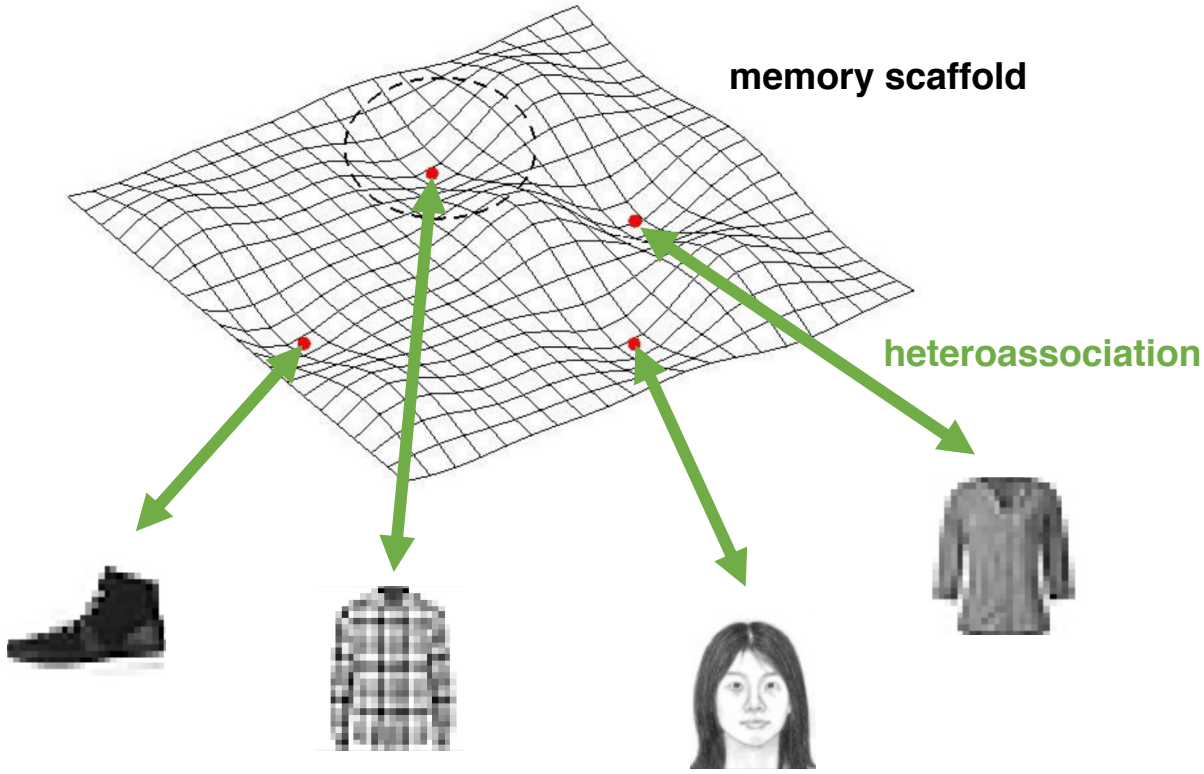

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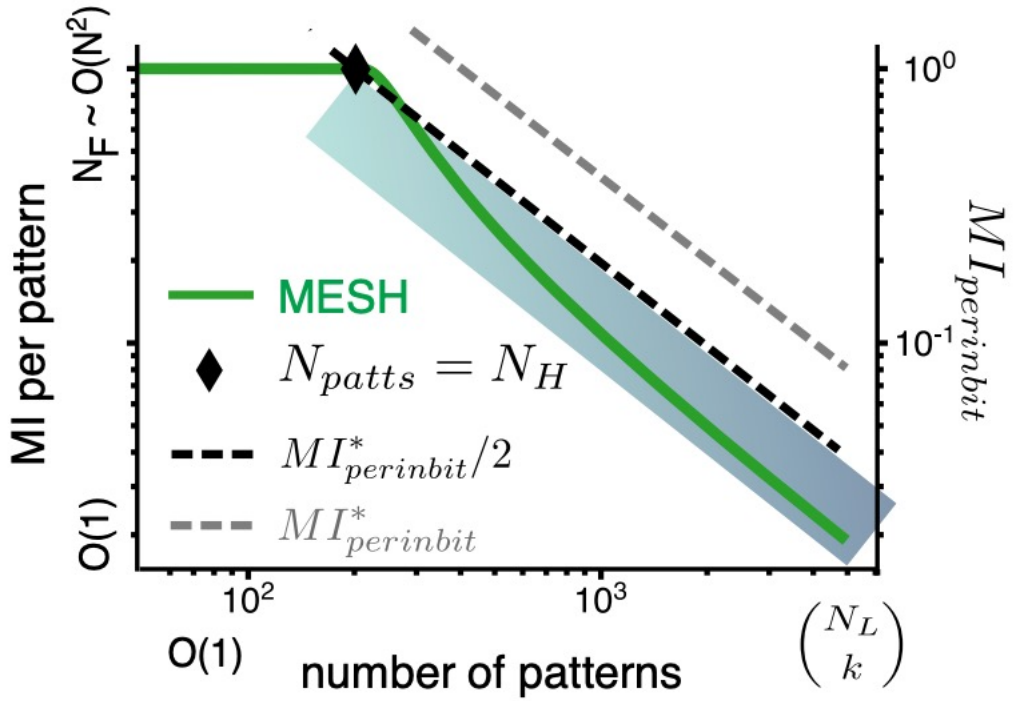
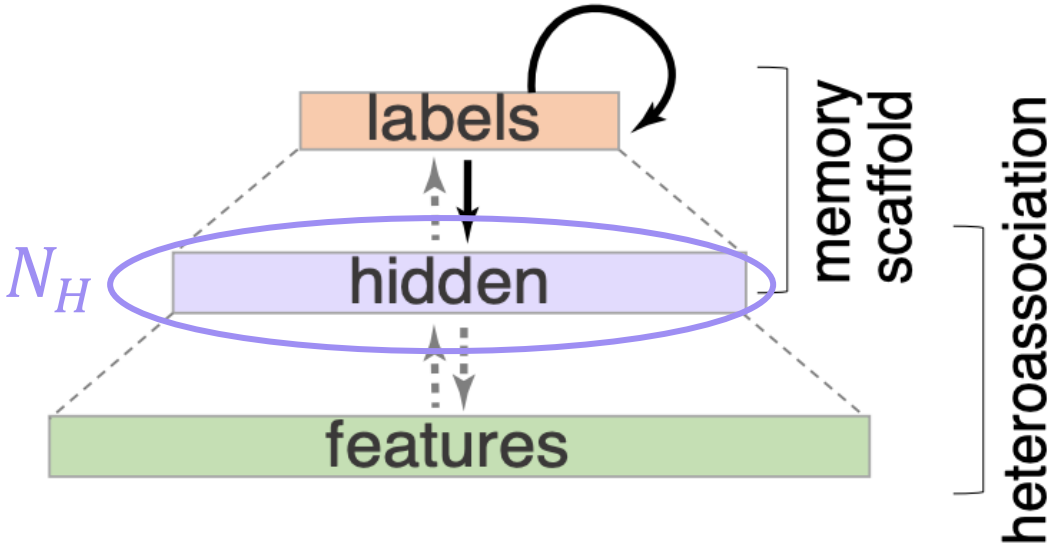
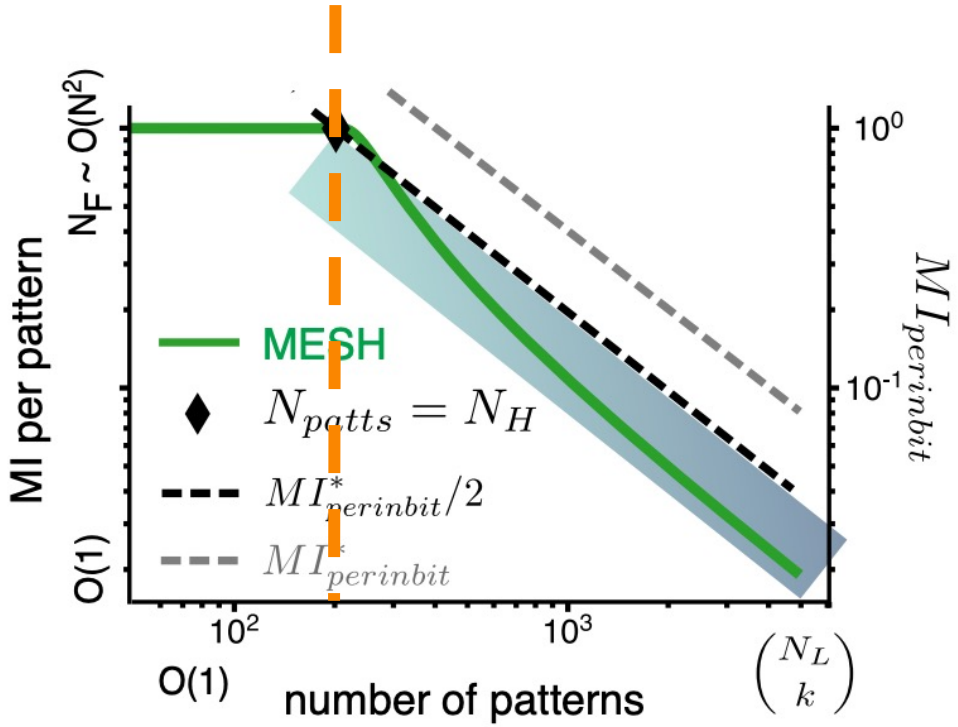
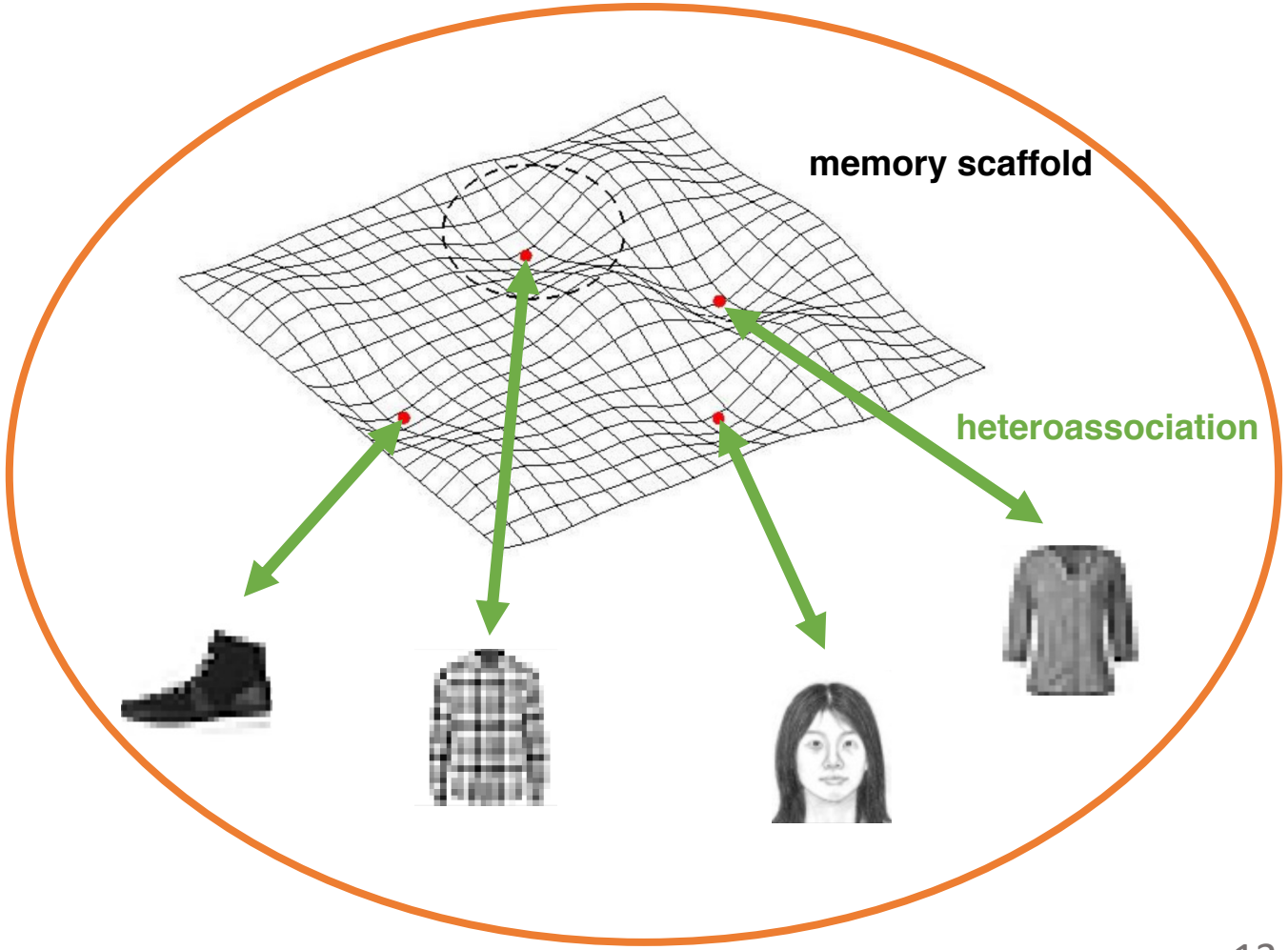
MESH exhibits a near-optimal CAM continuum



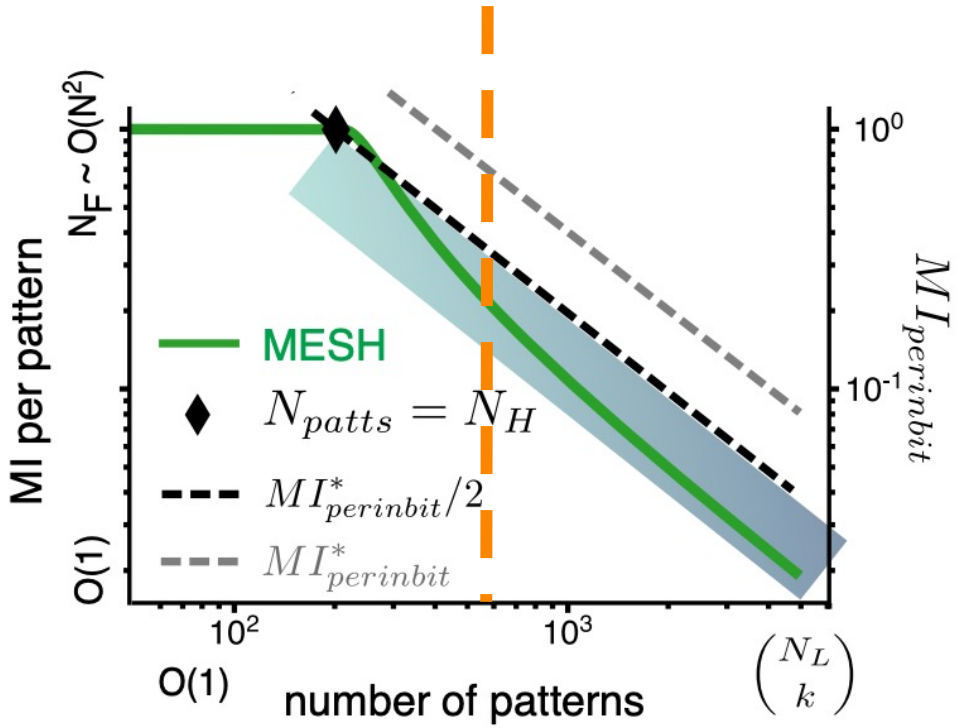


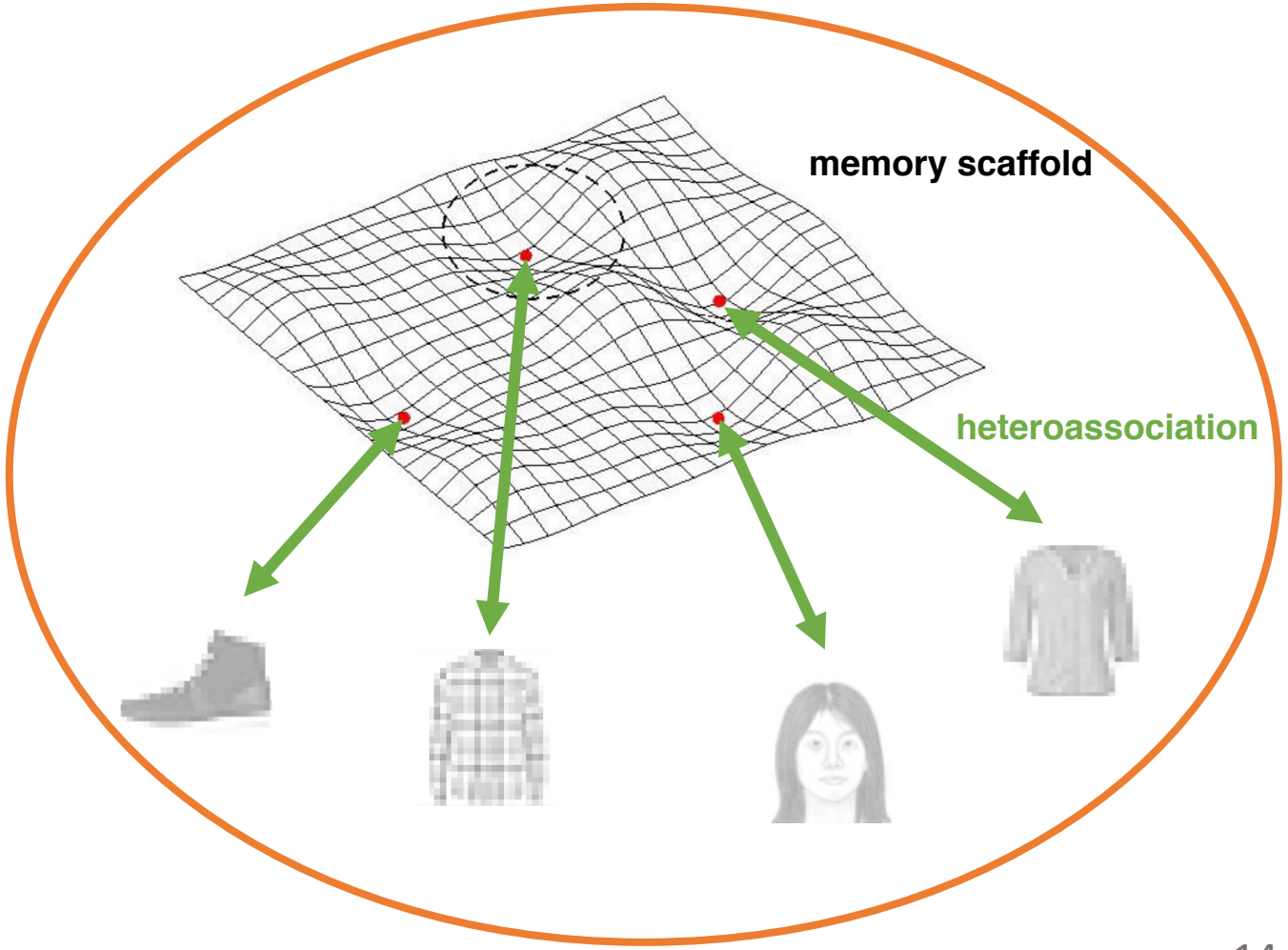
Complete recovery of up to N_H memories



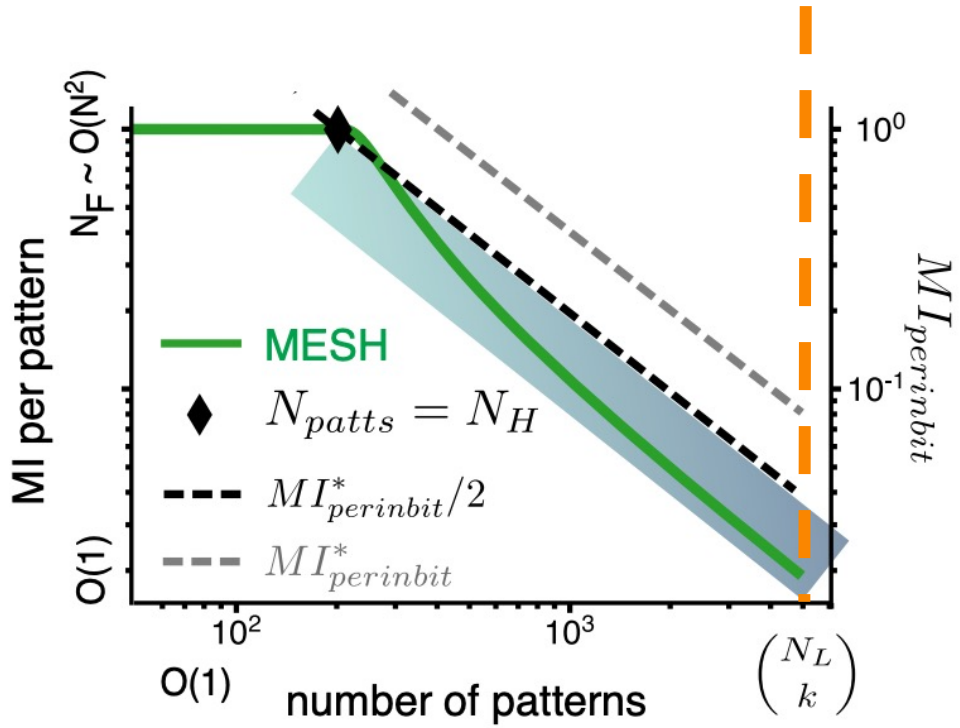


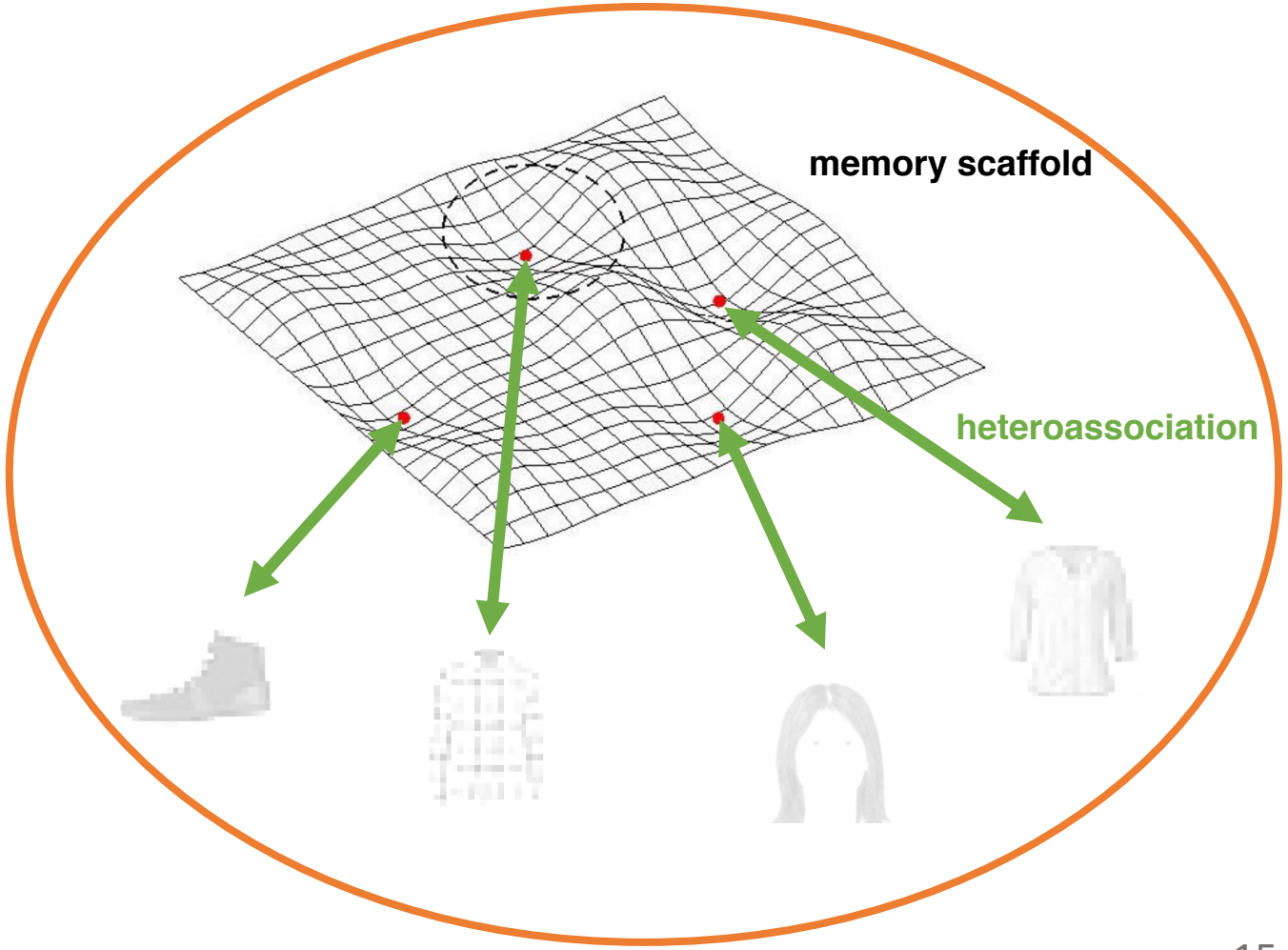
Partial recovery of each of the memories > N_H





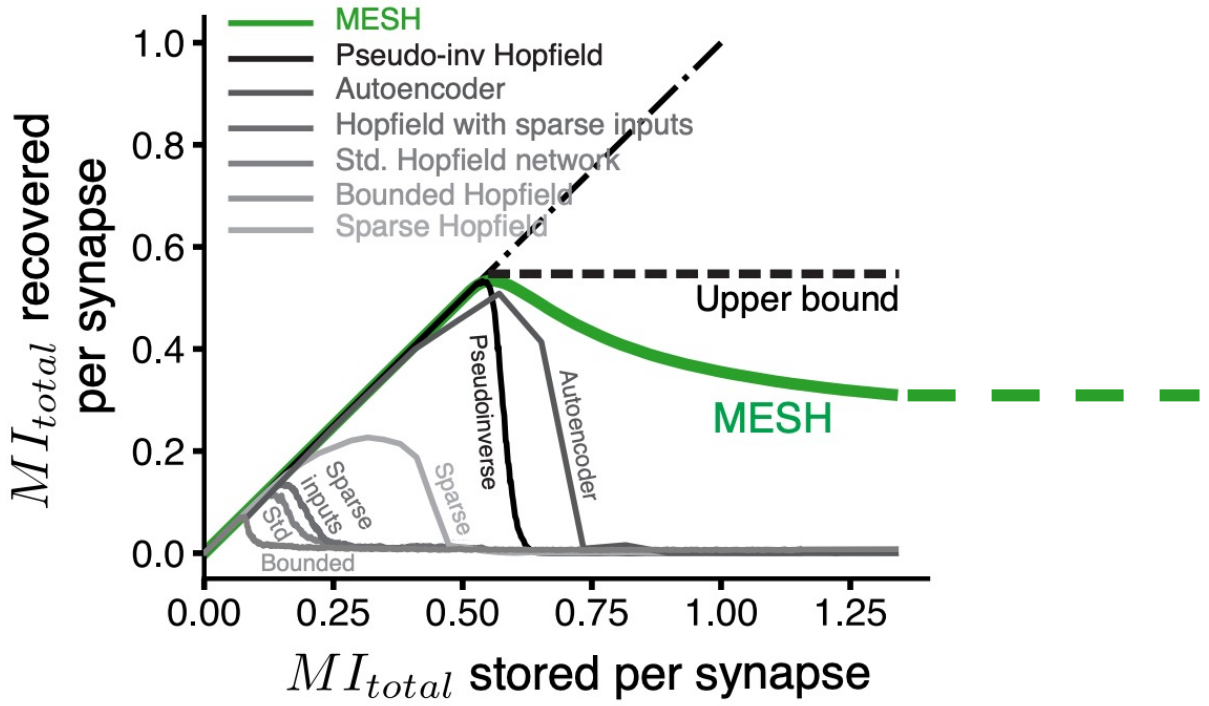
Gradual degradation of information per memory





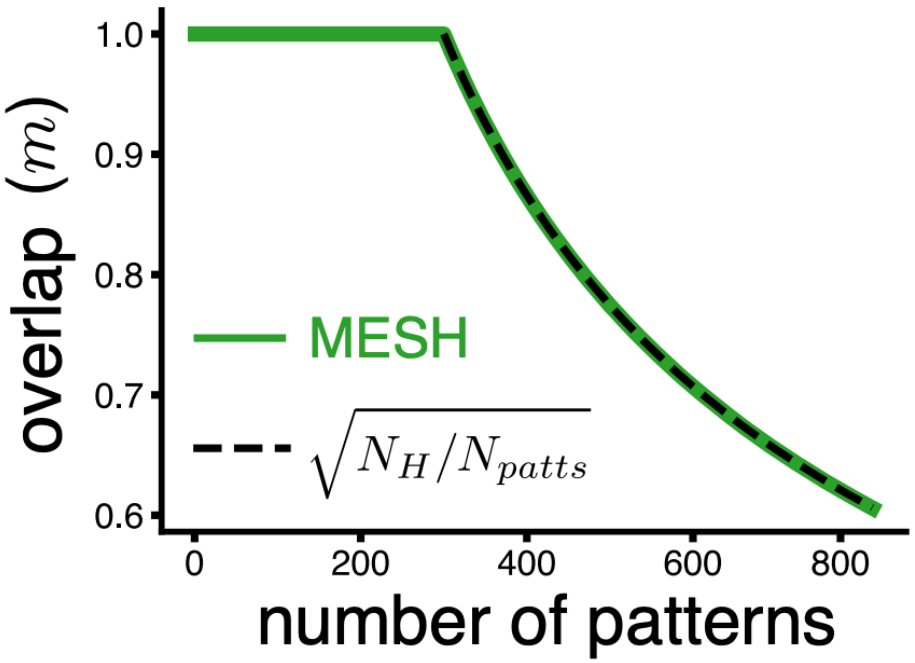
Constant total information per synapse in MESH

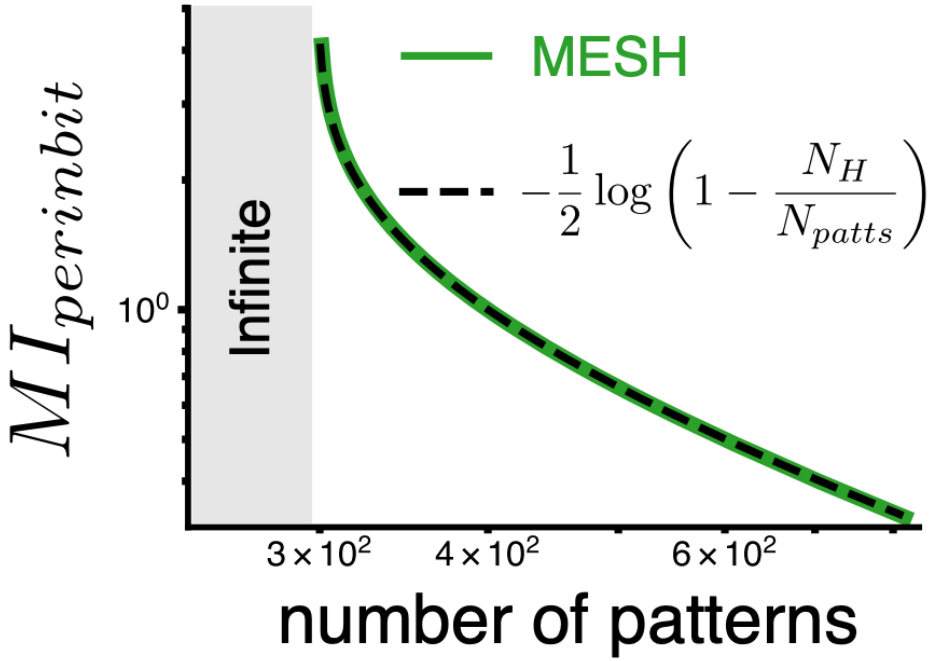
- Given a network of fixed size, the total information is invariant to the number of stored patterns
- Smooth trade-off between number of patterns and pattern richness.



Continuous valued patterns successfully stored

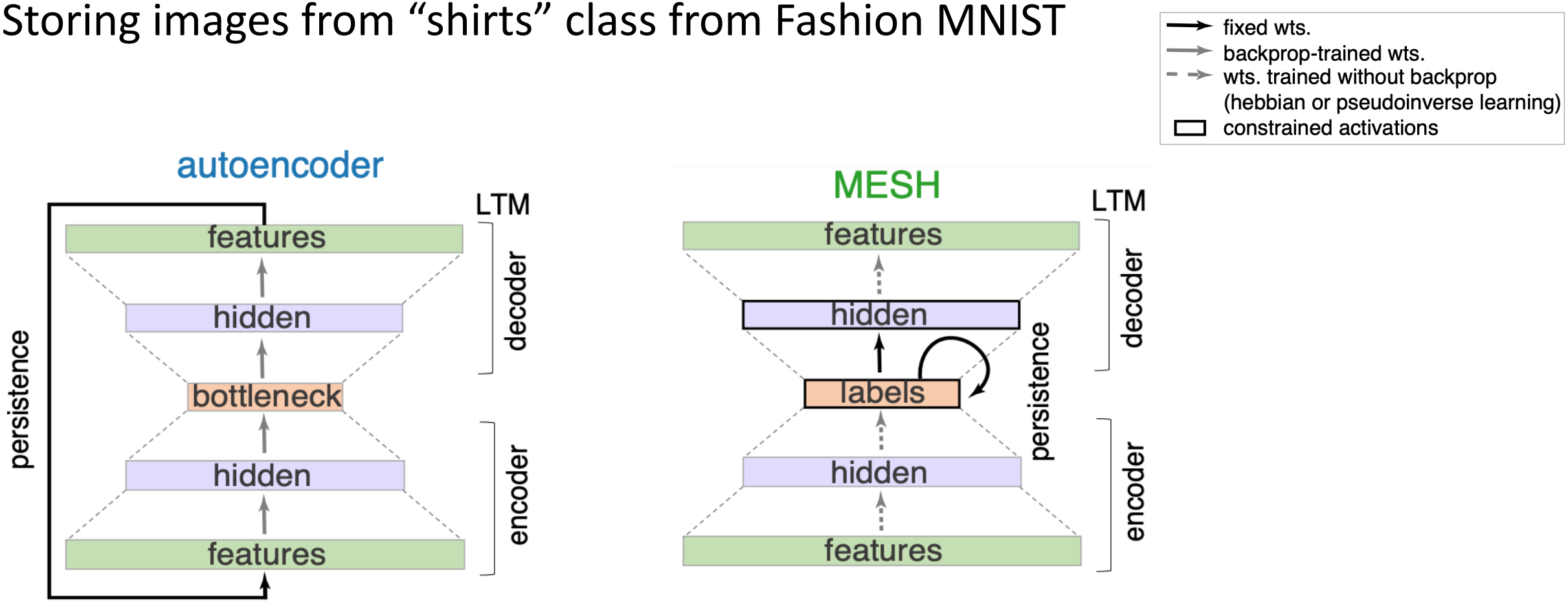
Random continuous valued patterns





Continuous valued patterns successfully stored

Storing images from “shirts” class from Fashion MNIST



Radhakrishnan, Belkin, Uhler (2020)

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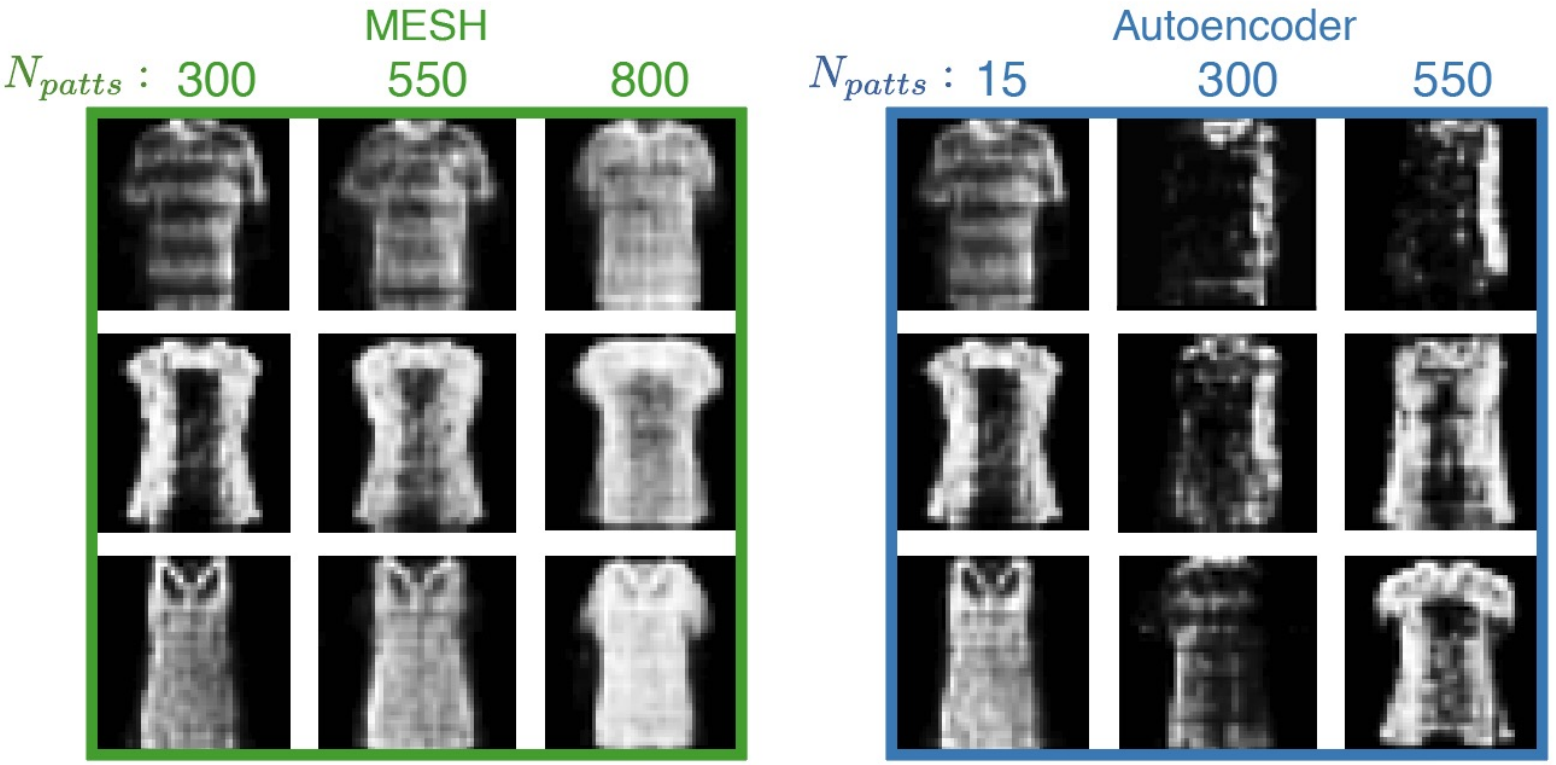

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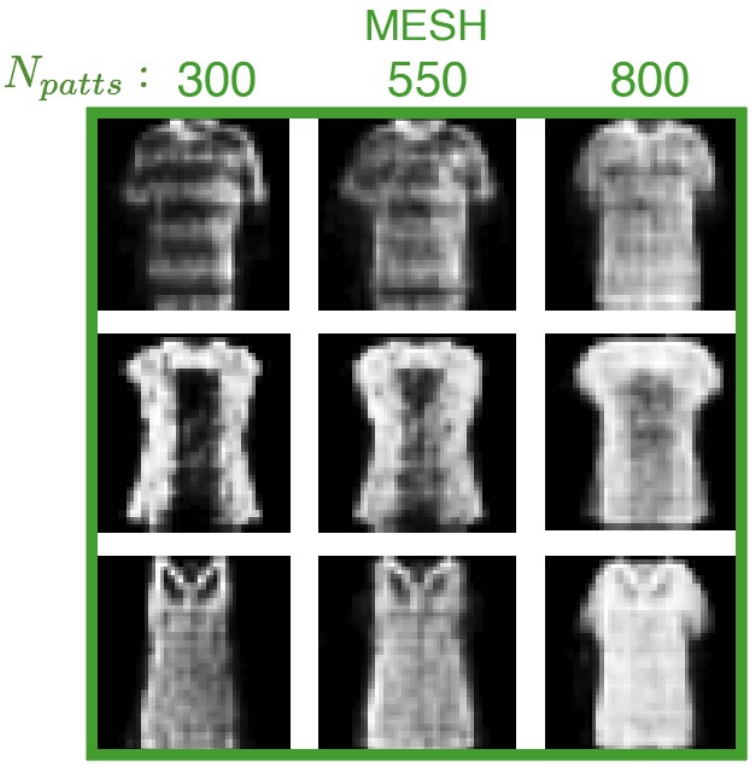

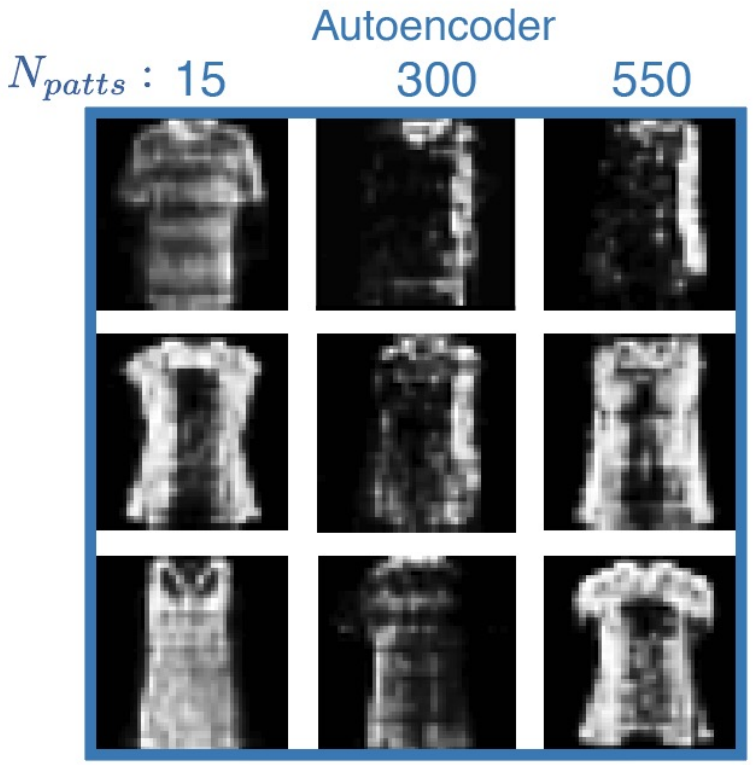

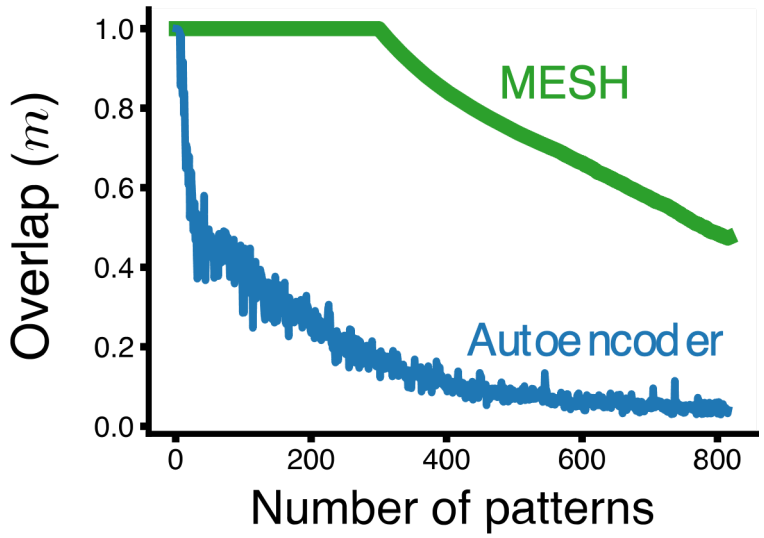

Conclusions

- MESH is a biologically plausible **associative memory model without a catastrophic memory cliff** (maps onto the entorhinal-hippocampal system in the brain)
- **Memory scaffold** generates an exponentially large number of fixed points; **Heteroassociation** labels arbitrary patterns to these fixed points
- MESH can be used for the storage, lookup, and retrieval of memory states through a **factorized key-value structure**; recognition/familiarity detection, locality sensitive hashing.