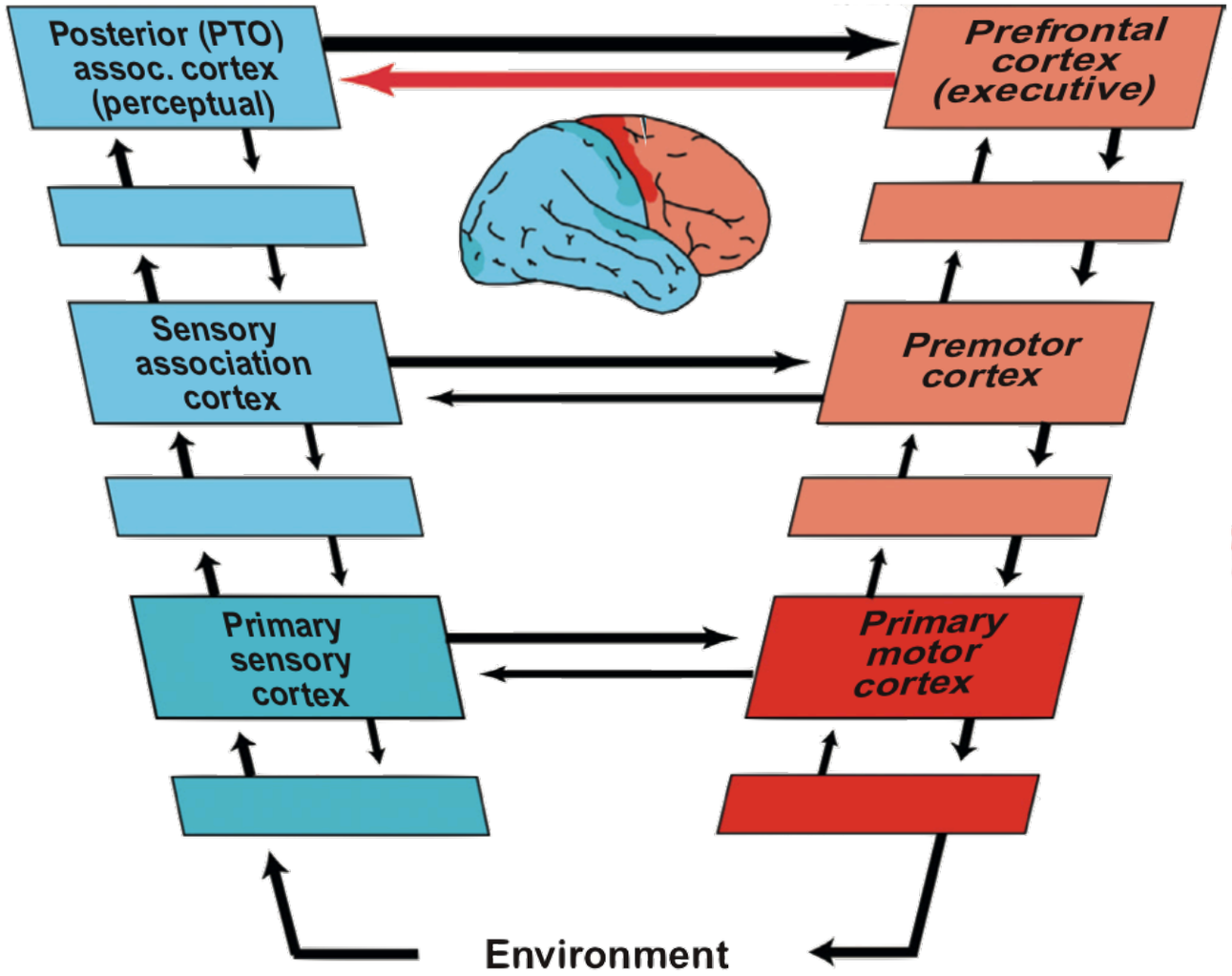
Fuster’s Hierarchy Revisited & Reinvented

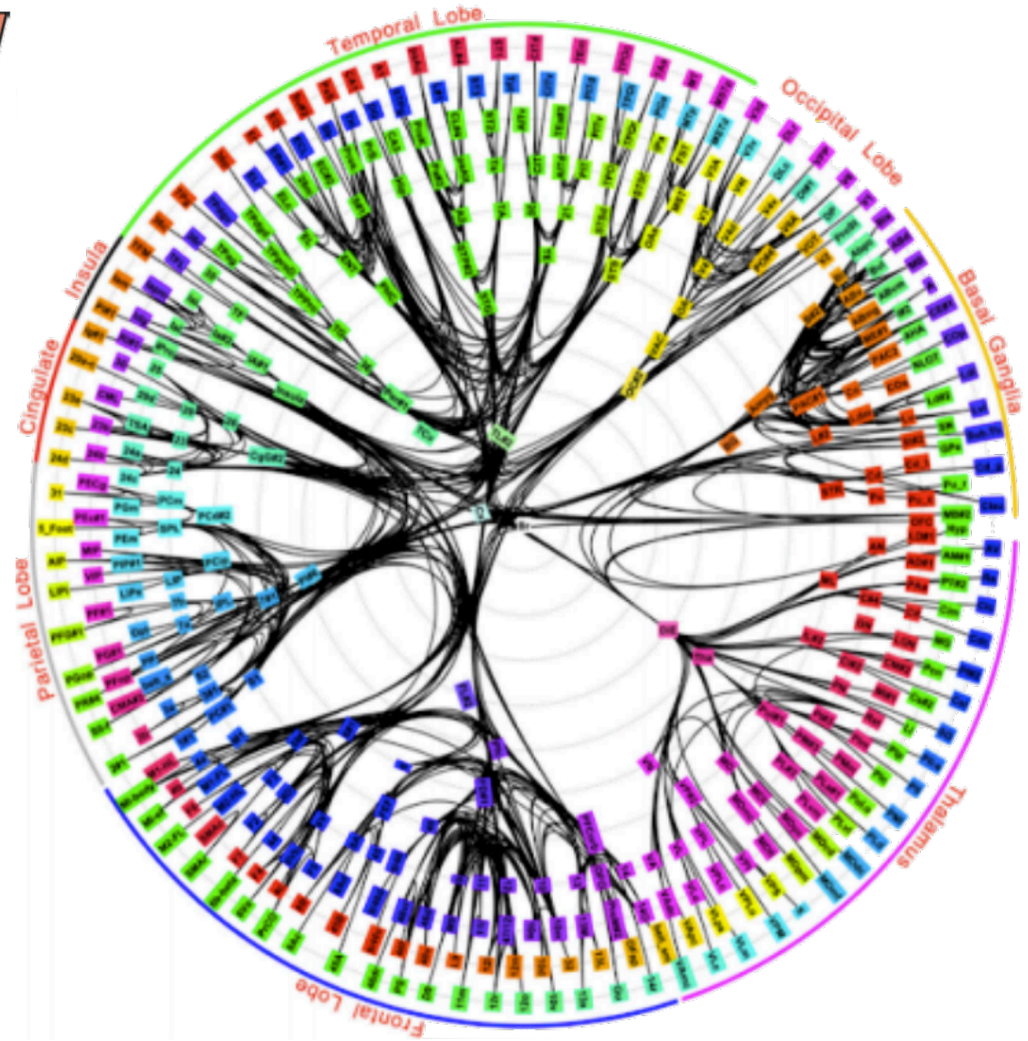
Tom Dean, Stanford, May 20, 2021

Acknowledgements: Francis Eugene Lewis, Yash Savani, Chaofei Fan, Randy O’Reilly, Jay McClelland, Dharshan Kumaran

Fuster's Hierarchy Covers the Neocortex Including the Global Workspace



Fuster's Hierarchy

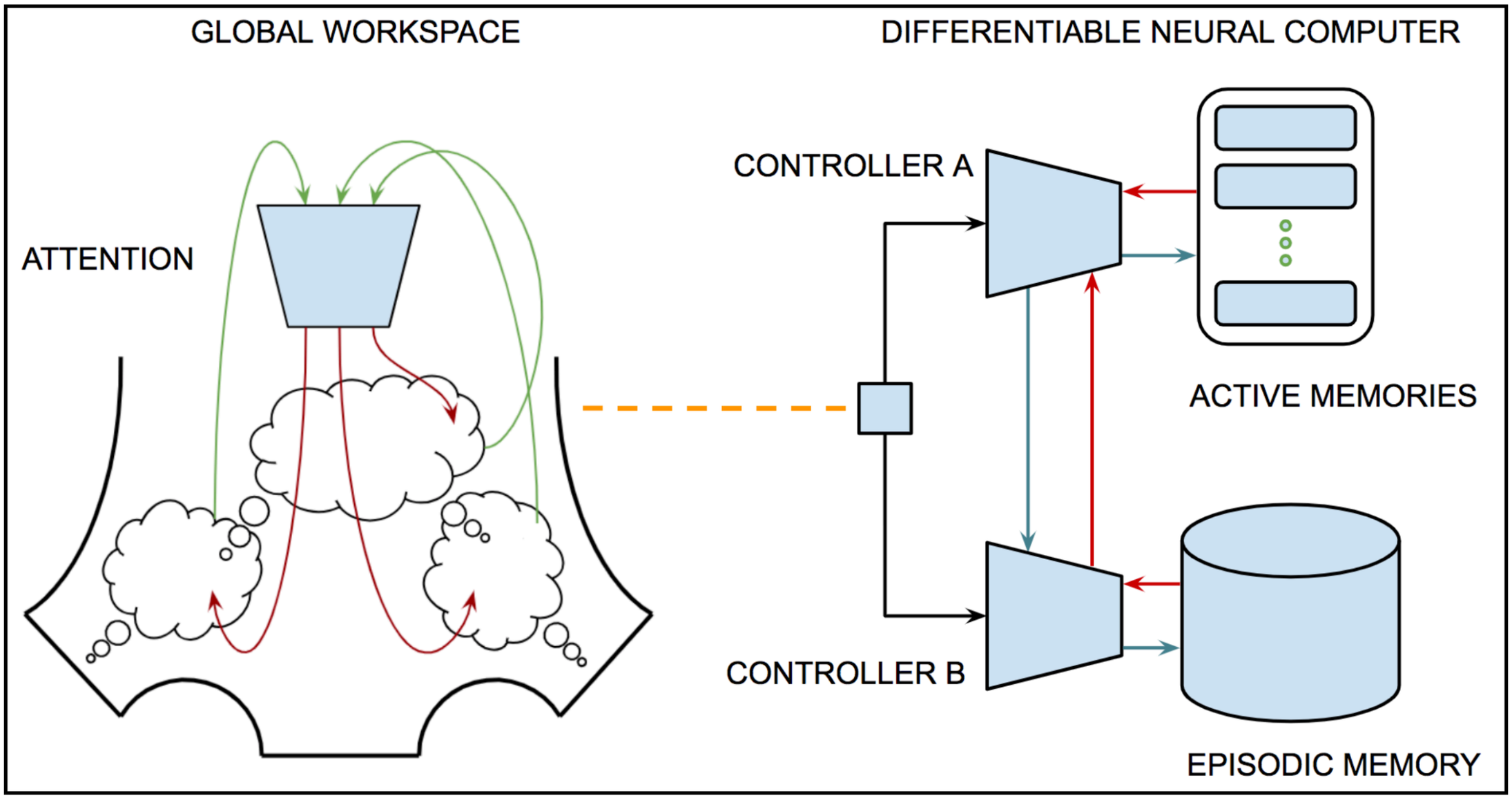


Global Workspace

Complementary Memory Systems - Hippocampus and Neocortex

> The hippocampus sits on "top" of the cortical hierarchy and can encode information from all over the brain, binding it together into an episodic memory. [. . .] The hippocampus seems to be particularly good at rapidly learning new information, in a way that doesn't interfere too much with previously learned information. When you need to remember the name associated with a person you recently met, you're relying on this rapid learning ability of the hippocampus.
>
> All people with a functioning hippocampus have this remarkable "tape recorder" constantly encoding everything that happens during our waking lives – we don't have to exert particular effort to recall what happened 20 minutes or a few hours ago – it is just automatically there. Most people end up forgetting the vast majority of the daily flux of our lives, retaining only the particularly salient or meaningful events.
>
> The hippocampus does introduce one critical innovation beyond what is present in the basal ganglia and cerebellum: it has attractor dynamics. Specifically the recurrent connections between CA3 neurons are important for retrieving previously-encoded memories, via pattern completion. The price for this innovation is that the balance between excitation and inhibition must be precisely maintained, to prevent epileptic activity dynamics.
>
> – *Computational Cognitive Neuroscience.* Randall C. O'Reilly, Yuko Munakata, Michael J. Frank, Thomas E. Hazy. 2020.

Complementary Memory Systems - Different Neural Architectures



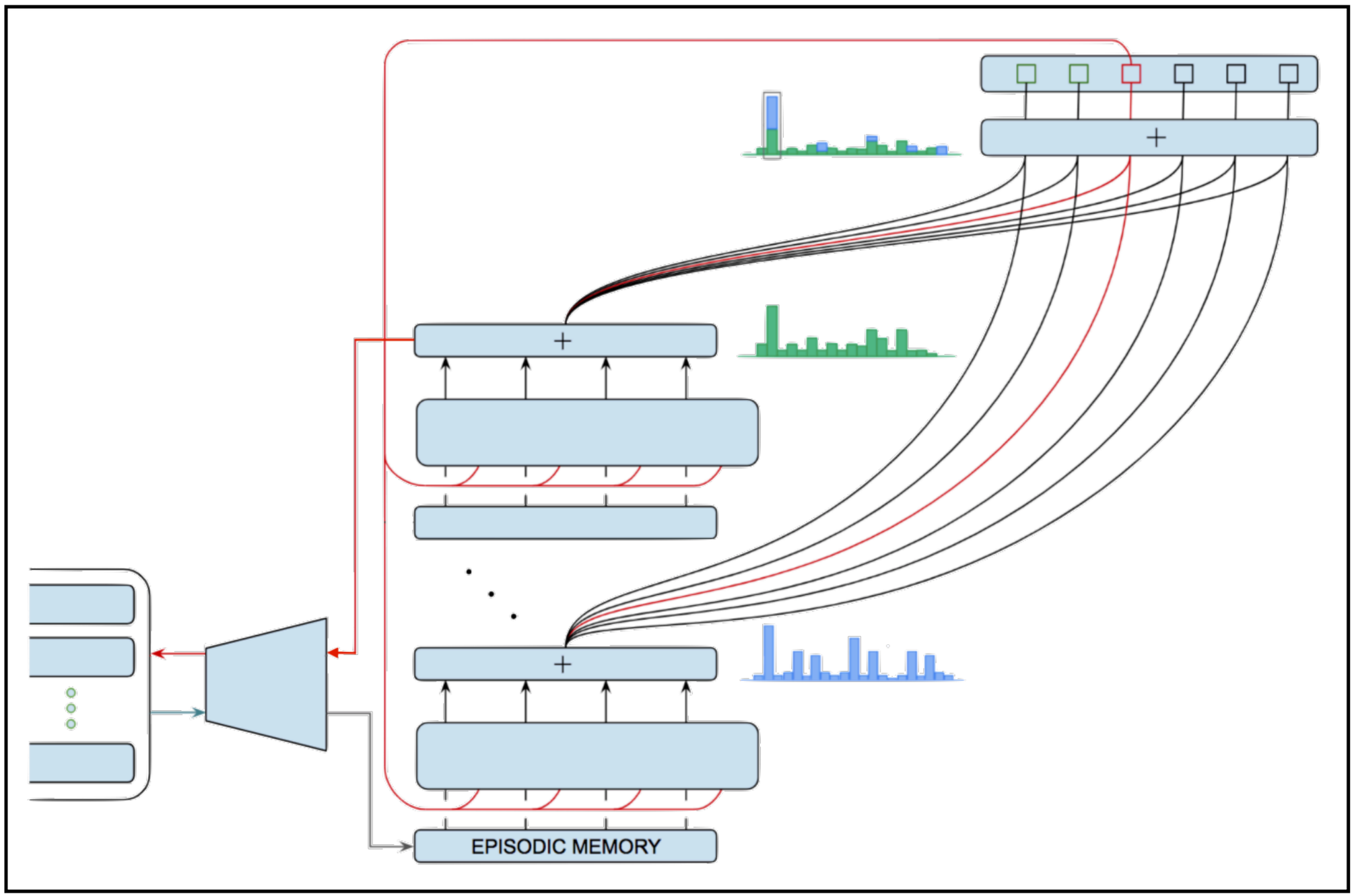
Words are Signs - Signs are Affordances - Affordances Facilitate Behavior

Words are signs in the sense defined by semiotic theory. As signs go, words are relatively well defined in terms of human usage since they were intended for articulation by the human vocal apparatus and identification by human ears. Their meaning however is not so well defined – two individual humans may differ with regard to the meaning of a word. However, convention as prescribed by human development, subsequent formal education, and social norms does encourage shared meaning in so far as that is possible by shared grounding in the experience of same physical environment and social milieu.

Words are not the only signs that humans use. All signs are effectively affordances that facilitate behavior of one sort or another. Iconic traffic signs are one familiar example but nearly all animals make use of signs to mark their territory or return to locations they have hidden food or hidden their offspring so as to distract predators. It would seem that the human brain would naturally make use of internal signs if only as a memory aid. The stripe-like neural circuits in the frontal cortex that serve as working memory might have related signs that could be used to retrieve information set aside when agent is interrupted or is performing mental arithmetic.

The human perceptual system seeks to turn perceptions and observations into signs that are unique enough that we can treat them as perceptual complexes that serve to uniquely identify individual affordances, but admit to some degree of flexibility to discount irrelevant cues and ignore physical characteristics that are likely to change. Alan Baddley and Joaquin Fuster view working memory as a form of attention: sustained attention focused on an executive cognitive network for the processing of prospective action. In so doing they place working memory at the center of supervisory attentive control.

Baddley and Fuster View Working Memory as a Form of Attention



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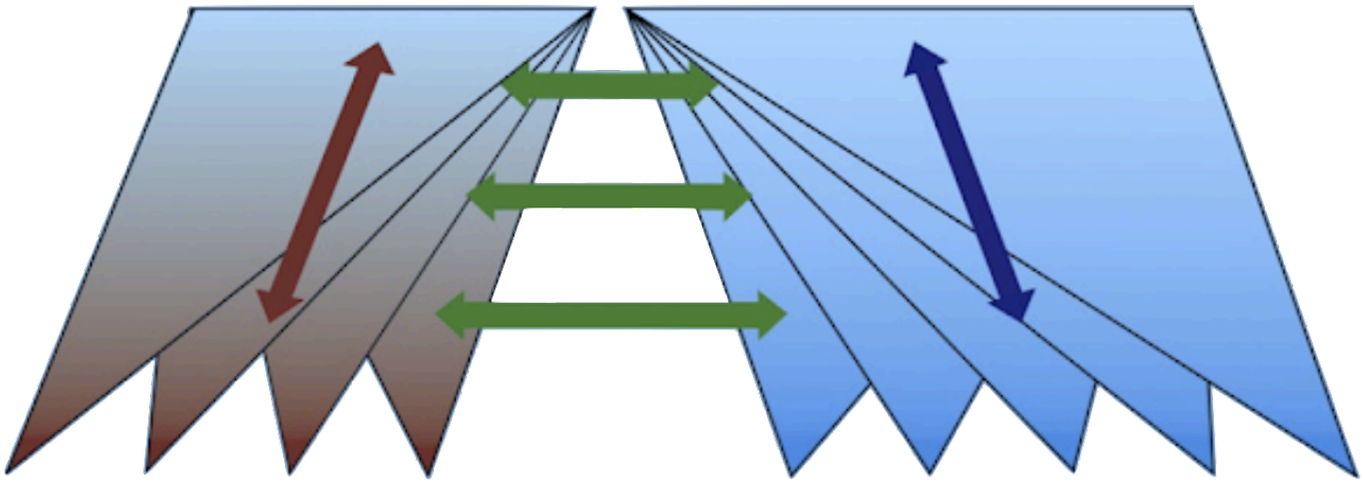
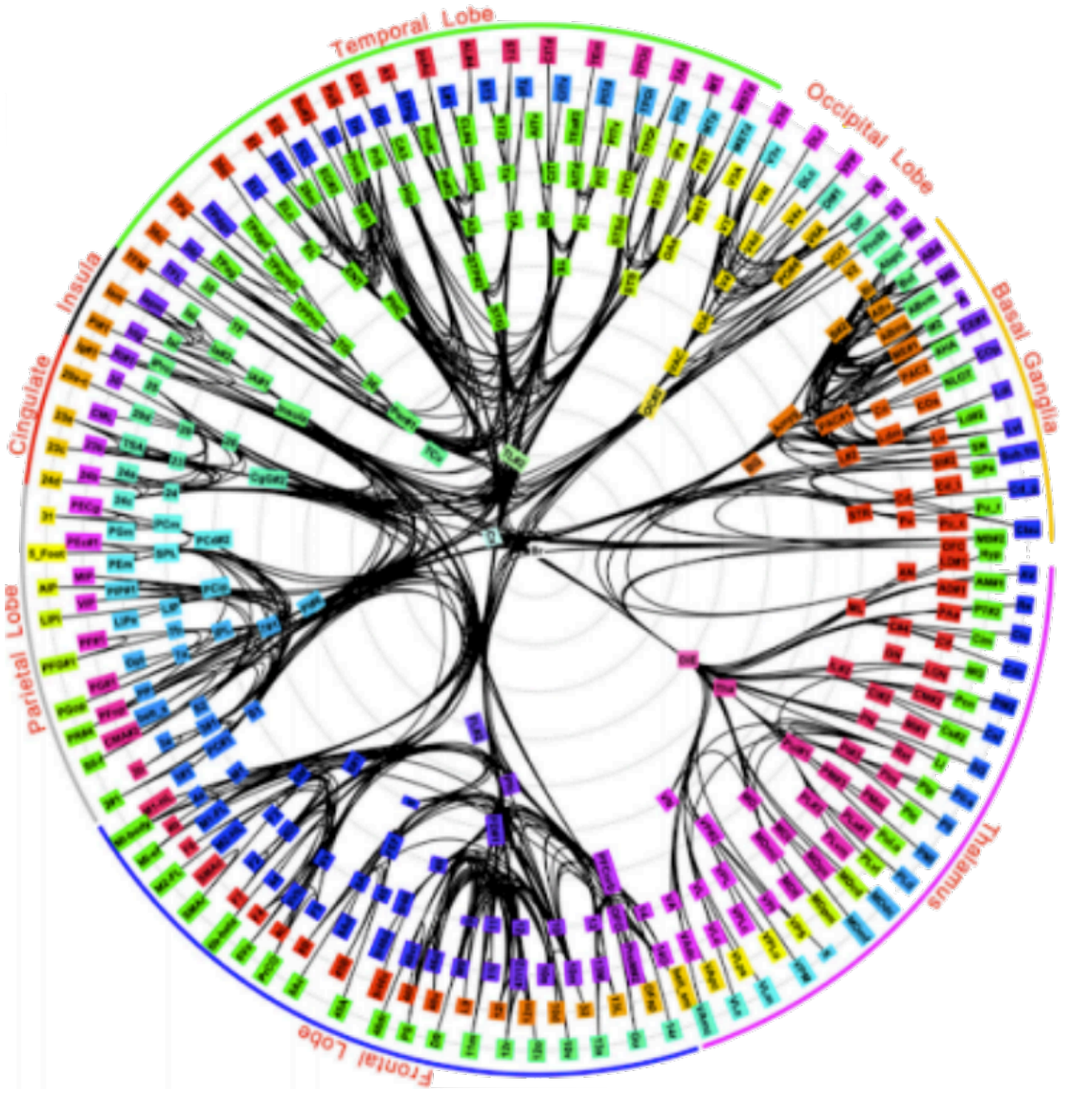
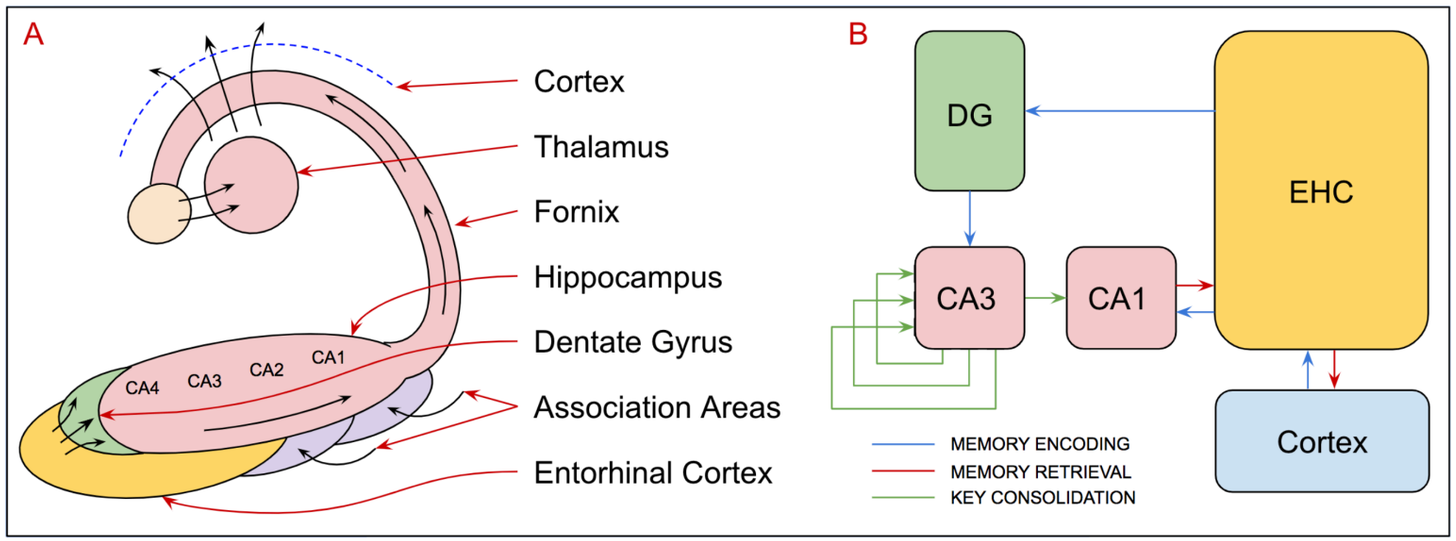
Fuster’s Hierarchy



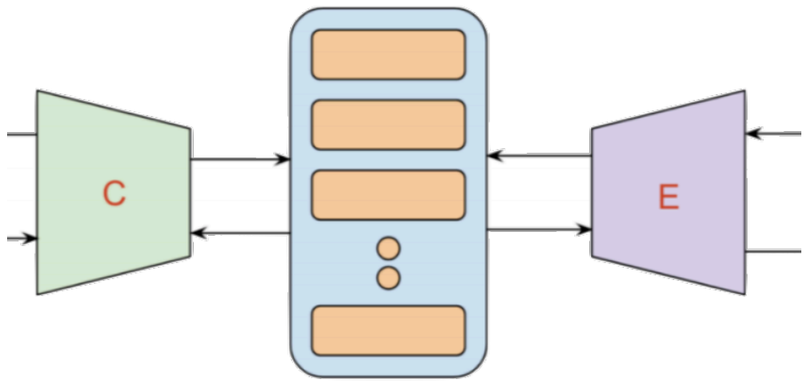


Global Workspace

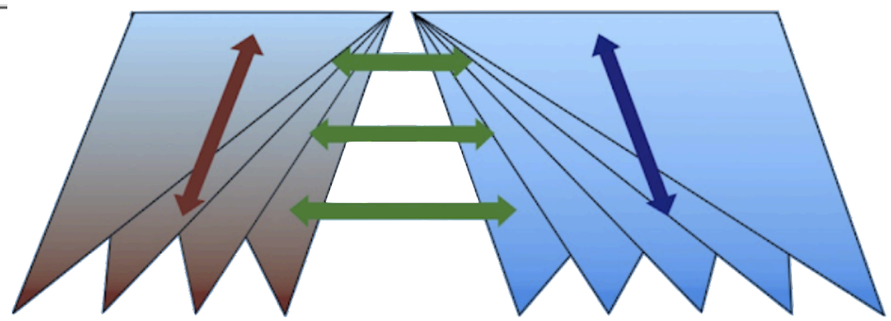
The Hippocampus is Responsible for Complementary Episodic Memory

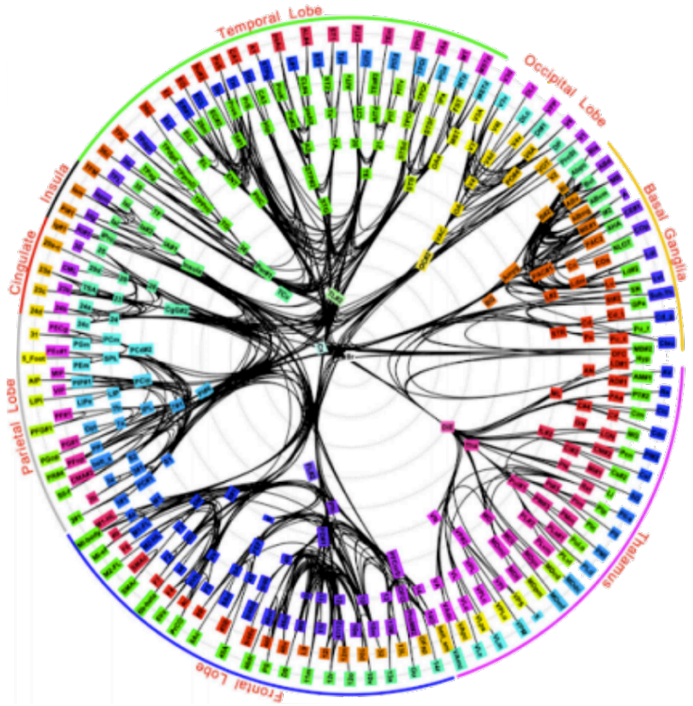


Hippocampal Formation

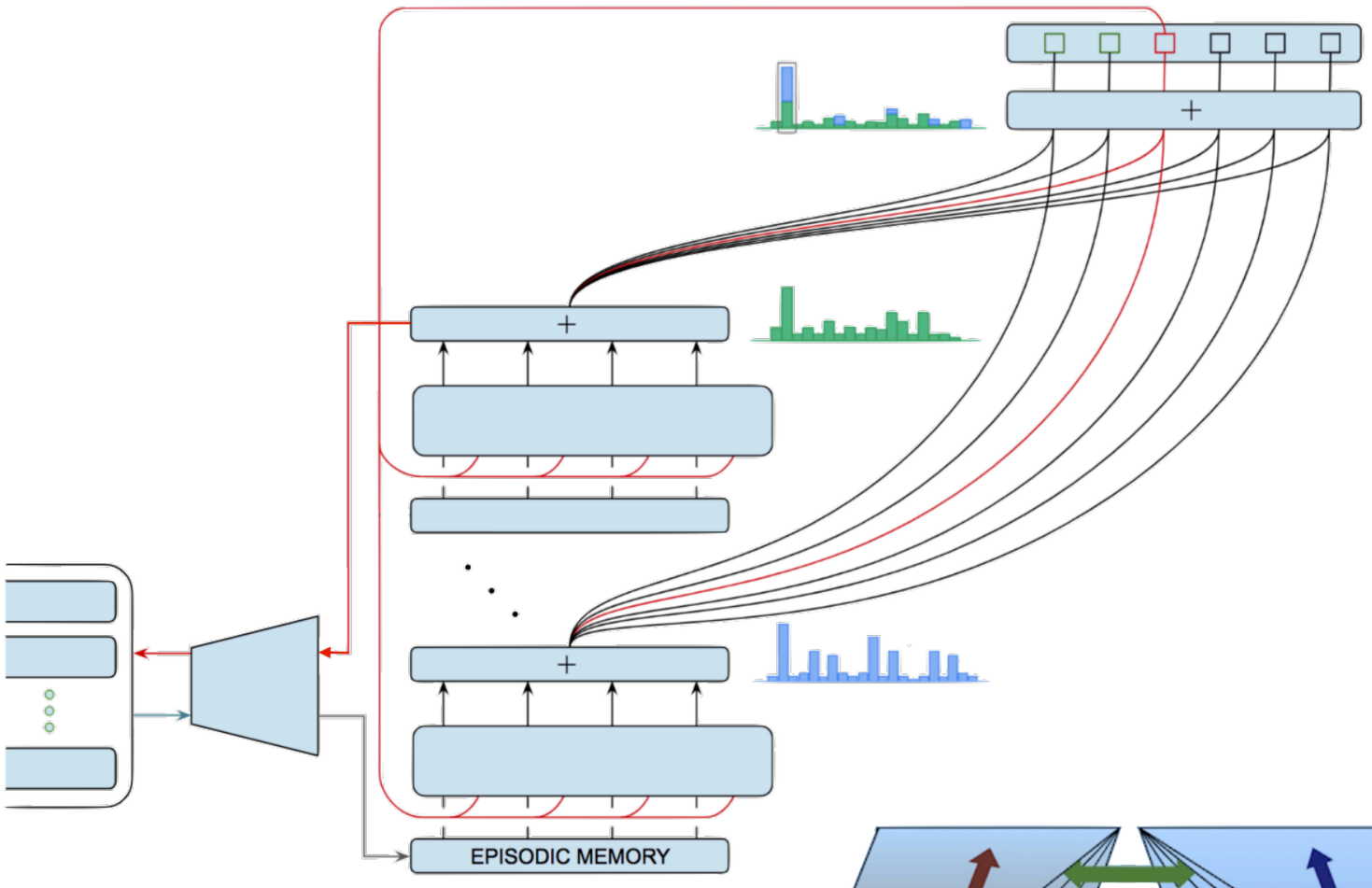


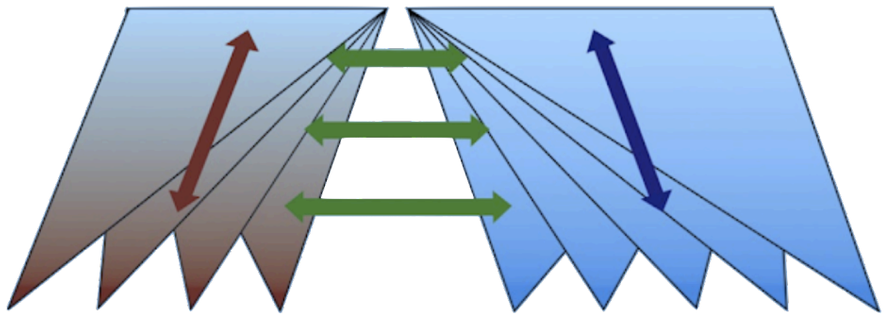
External Key Value Memory

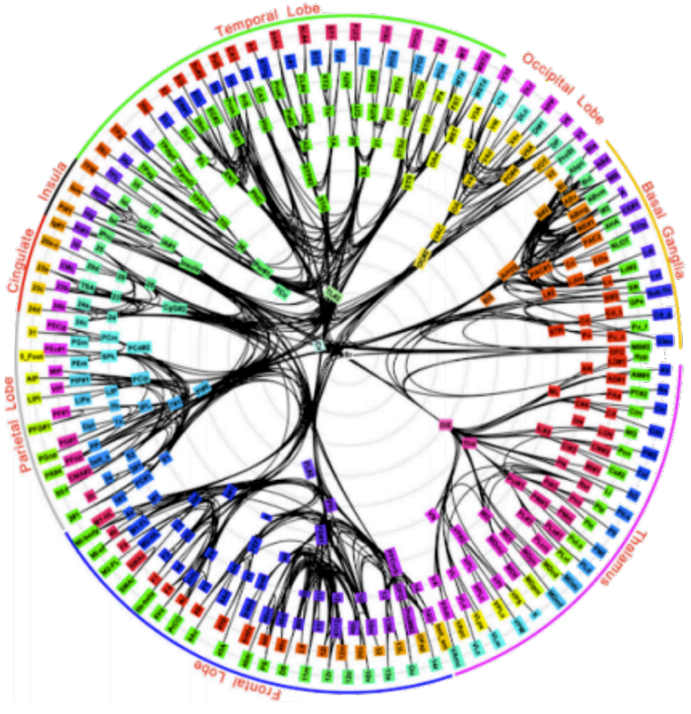




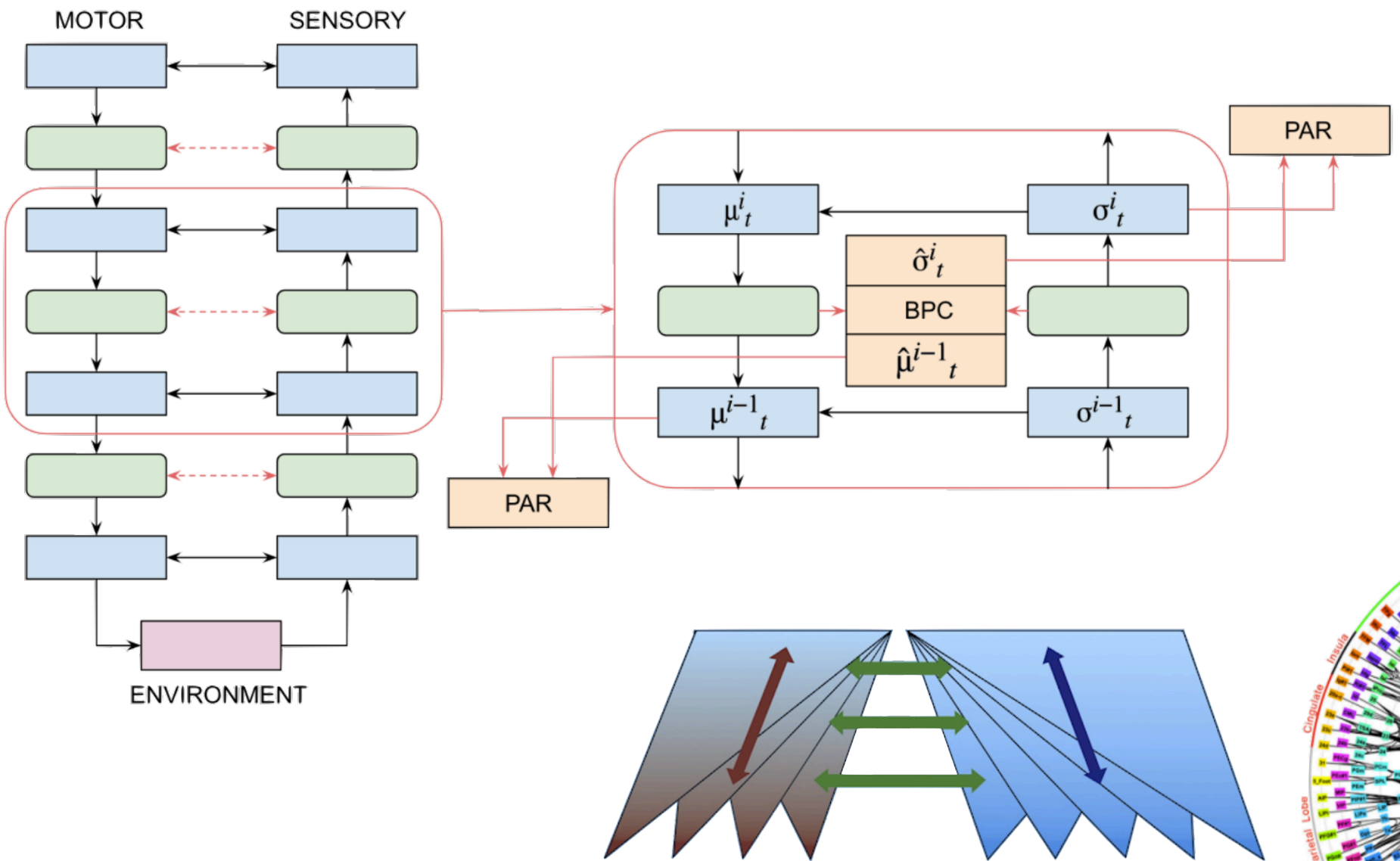
Attention Serves to Integrate the Complementary Episodic Memories

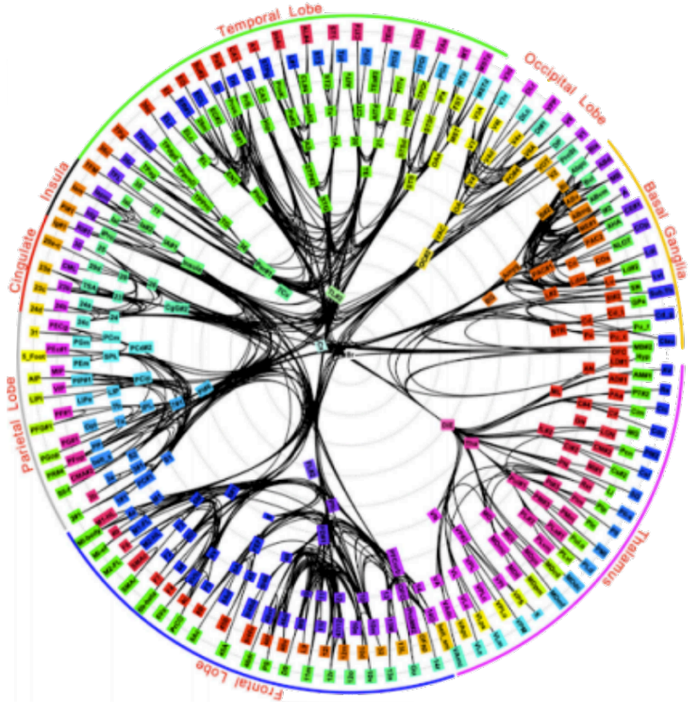




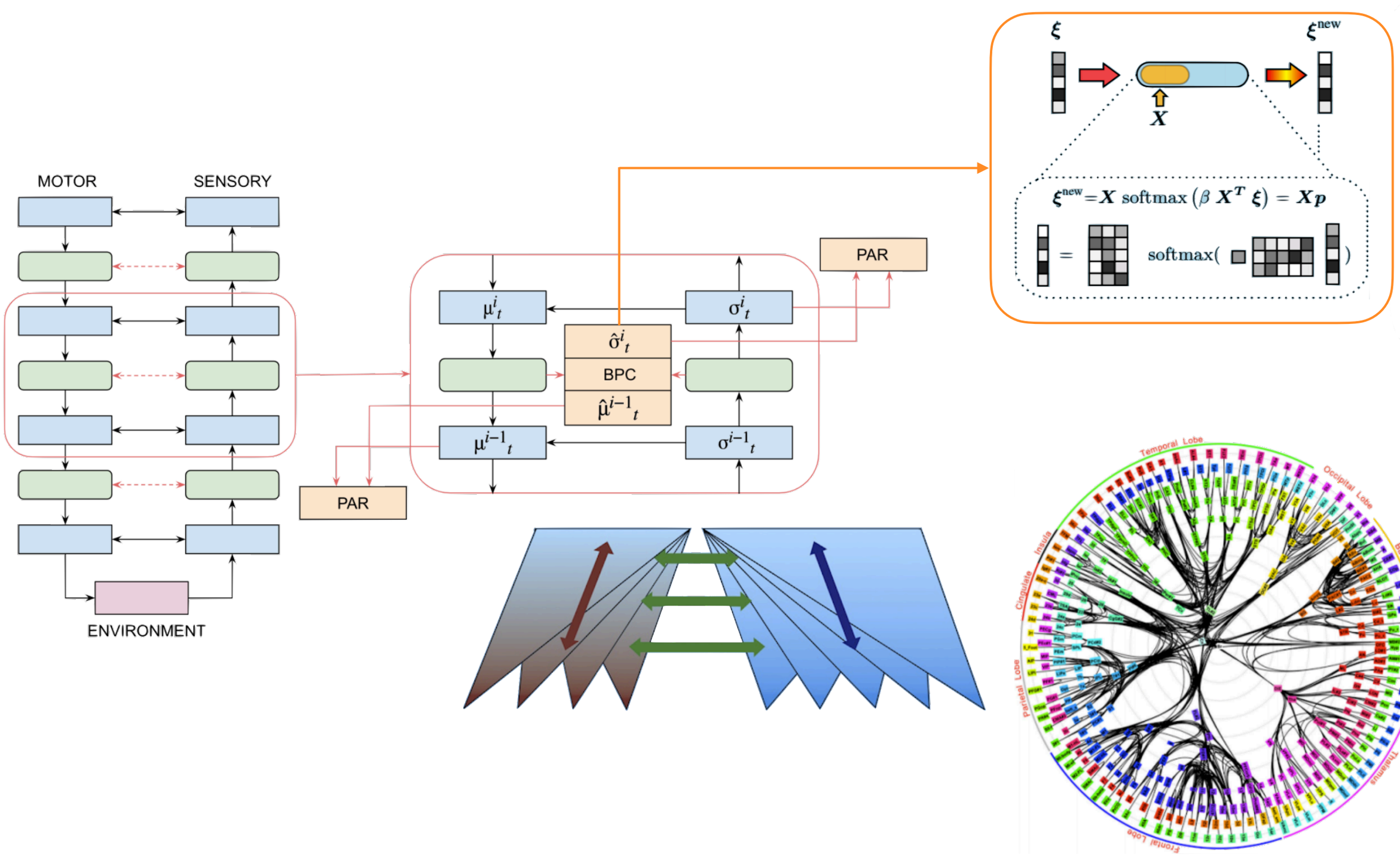


Reciprocal Connections Implement Contrastive Predictive Encoding





Hopfield Update Equivalence Explains Support for Flexible Composition



Detail of Fuster's Hierarchy Illustrating Level-Specific Procedural Memory