Associative Memory Cells: Basic Units of Memory Trace

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Springer

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ISBN 978-981-13-9500-0 ISBN 978-981-13-9501-7 (eBook)
https://doi.org/10.1007/978-981-13-9501-7

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Preface

Associative learning is a common approach to acquire multiple associated signals including knowledge, experiences, and skills from the natural environment or social interaction. Associative memory stands for the integrative storage and reciprocal retrieval of these associated signals, which are essential for cognitive processes, emotional reactions, and behaviors. The revelation of cellular and molecular mechanism underlying associative memory is important for us to understand the principles of memory formation and memory-relevant behaviors as well as to develop the therapeutic strategies that enhance memory capacity in health individuals and improve memory deficit in patients suffering from neurological disease and psychiatric disorders. Neural substrates for associative memory have been studied for centuries. A series of hypotheses is given, such as memory traces, engrams, cell assemblies, and neural plasticity for short-term memory and long-term memory consolidation. However, numerous questions need to be addressed, especially basic units and their working principles in engram circuit specifically for various memory patterns. In addition to memories to the associated signals learned from natural and social environments, the contents about associative thinking, logical reasoning, imagination, computation, and emotional reactions can be memorized for subsequent recall and recollection. Two sets of basic units in memory traces have been proposed for memories to exogenous signals from environments and endogenous signals generated from cognitions and emotions. By a series of experiments, basic units in memory traces have been discovered to be recruited during associative learning. These basic units in engram circuits include primary associative memory cells in sensory cortices, secondary associative memory cells in brain areas in relevance to cognition, emotion, and behaviors, as well as memory output cells in the motor cortex. Their characters include the following. The coactivation of cortical neurons recruits them as associative memory cells through the formation of their mutual synapse innervation. These associative memory cells receive new synapse innervation from coactivated brain areas alongside innate synapse input. Associative memory cells can encode new and innate associated signals for their integrative storage and reciprocal retrieval. Their axons innervate brain areas relevant to cognition, emotion, and behaviors to recruit secondary associative memory cells. The number and functional upregulation of associative memory cells influence memory strength and maintenance. The activation of associative memory cells grants logical reasoning and associative thinking. Their recruitment is influenced by epigenetics-regulated genes and proteins that manage axon prolongation and synapse formation. The working principle of these associative memory cells is based on their mutual synapse innervation, their reception strength of synapse innervations, their ability to convert synaptic analogue signals into digital spikes for encoding associated signals, as well as their ability to output sequential spikes for driving behavior and cognition. The synapse innervations to associative memory cells determine the specificity of memory contents. The number and activity level of associative memory cells and the number and activity strength of synapse innervations set up the power and persistence of memory and memory-relevant behaviors.

In this book, the author expects to provide comprehensive diagrams about associative memory cells and their working principles that may be applied to associative memories and memory-relevant cognitions for neuroscientists, psychologists, and students, based on historical and current literatures in memoriology. In the meantime, the author will present personal perspectives about pathology and therapeutic strategies for memory deficits in patients suffering from neurological diseases and psychiatric disorders.

Beijing, China Jin-Hui Wang
05-31-2019

Acknowledgement

This study is funded by the National Key R&D Program of China (2016YFC1307100) and the National Natural Science Foundation of China (81671071) to JHW. The author thanks Shan Cui for drawing some illustrations.

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About the Author

Wang Jin-Hui received his PhD from Shanghai Institute of Physiology, Chinese Academy of Sciences. After his postdoctoral training in the State University of New York and the University of Texas, he joined the University of Kansas as tenure-track assistant professor. Subsequently, he is appointed by the Chinese Academy of Sciences as a distinguished professor. After being an independent researcher, he has found working principles of neurons and synapses about the conversion of inactive into active synapses, the conversion of irregular to regular transmission pattern at unitary synapse, homeostatic plasticity among subcellular compartments, spike amplification at axons, as well as the functional compatibility between axonal branches and their postsynaptic partners. In terms of cellular architecture for learning and memory, his group has discovered and identified associative memory cells as basic units in memory trace.