PRESS RELEASE

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Elucidating the Double Duty of Sleep in Memory Processing

Researchers uncover mechanisms by which sleep not only consolidates past memories but also prepares the brain for future learning

Sleep is essential for memory consolidation, but could it also prepare the brain for future learning? Researchers from Japan investigated this dual role, using advanced imaging to track neuronal activity in mice. They identified a distinct population of brain cells that became active during post-learning sleep and later encoded new experiences. Their findings, supported by neural network modeling, reveal that sleep not only preserves past memories but also primes the brain for forming future memories.

Memory formation, storage, and retrieval are fundamental processes that define who we are and how we interact with the world. At the cellular level, these processes rely on specialized neurons called engram cells—neuronal populations that physically encode our experiences and allow us to recall them later. Over the past few decades, scientists have made significant progress in identifying these neuronal ensembles and understanding some aspects of memory allocation.

Although sleep is widely known to be essential for memory processing and consolidation, many of its underlying mechanisms and functions are unclear. Traditional views have largely focused on sleep as a backward-looking process that serves to strengthen past experiences, but could it simultaneously help prepare the brain for new learning?

In a recent effort to tackle this question, a research team from Japan, led by Distinguished Professor Kaoru Inokuchi from the University of Toyama, uncovered a dual role for sleep in memory processing. Their paper, which will be published in *Nature Communications* on April 28, 2025, explores how the brain simultaneously preserves past memories while preparing for future ones during sleep periods. The study was co-authored by Specially Appointed Assistant Professor Khaled Ghandour, also from the University of Toyama; Dr. Tatsuya Haga from the National Institute of Information and Communications Technology; Dr. Noriaki Ohkawa from Dokkyo Medical University; and Prof. Tomoki Fukai from OIST.

The researchers employed an advanced imaging system that combines live calcium imaging with engram cell labeling, allowing them to track neuronal activity in mice before, during, and after learning experiences. This approach gave them unprecedented insights into how specific populations of neurons behave across different cognitive states, including during sleep periods before and after learning events.

Their findings revealed that two parallel processes occur during post-learning sleep. First, engram cells that encoded an initial learning experience showed reactivation patterns—confirming the well-established consolidation process. Remarkably, they also identified a separate population of neurons, which they termed 'engram-to-be cells,' that became increasingly synchronized during post-learning sleep. These cells were later shown to encode a new, different learning experience. "*Engram-to-be cells exhibited increased coactivity with existing engram cells during sleep, suggesting that this interaction helps shape new memory networks*," explains Prof. Inokuchi.

To understand the mechanisms behind this phenomenon, the team developed a neural network model simulating hippocampal activity. The model suggested that synaptic depression and scaling, which are mechanisms that adjust connection strengths between neurons during sleep, are essential for the emergence of engram-to-be cells. When these processes were disabled in the model, the preparation of neurons for future learning was significantly impaired.

The study also revealed interesting dynamics between existing engram cells and engram-to-be cells, showing increased co-activation during post-learning sleep. This hints at some form of information transfer or coordination between neural networks representing past and future memories.

These findings have significant implications for our understanding of learning and memory. They suggest that the quality of sleep between learning sessions may determine not only how well we remember what we've already learned, but also how effectively we can learn new information. This could influence approaches to education, cognitive enhancement, and the treatment of memory disorders.

Additionally, the research opens new avenues for exploring how sleep disturbances might impact not just memory consolidation but also the brain's preparedness for future learning challenges. "*We believe that manipulating brain activity during sleep or sleep patterns may uncover methods to enhance memory by unlocking the brain's latent potential*," says Prof. Inokuchi.

Overall, this study underscores the critical role of sleep in maintaining cognitive function and overall well-being. "*We want people to understand that sleep is not just about rest—it plays a crucial role in how the brain processes information,*" Prof. Inokuchi concludes, "*With that in mind, we hope everyone will begin to value sleep more and use it as a way to improve their overall quality of life.*"

Video

https://youtu.be/9ir0pT8grfI

Title: Overview of the study

Caption: Distinguished Professor Kaoru Inokuchi and Specially Appointed Assistant Professor Khaled Ghandour explain the rationale, goals, and main findings of this research, which focuses on the importance of sleep to both consolidate past memories and prime the brain for future memories.
Credit: Kaoru Inokuchi from the University of Toyama, Japan
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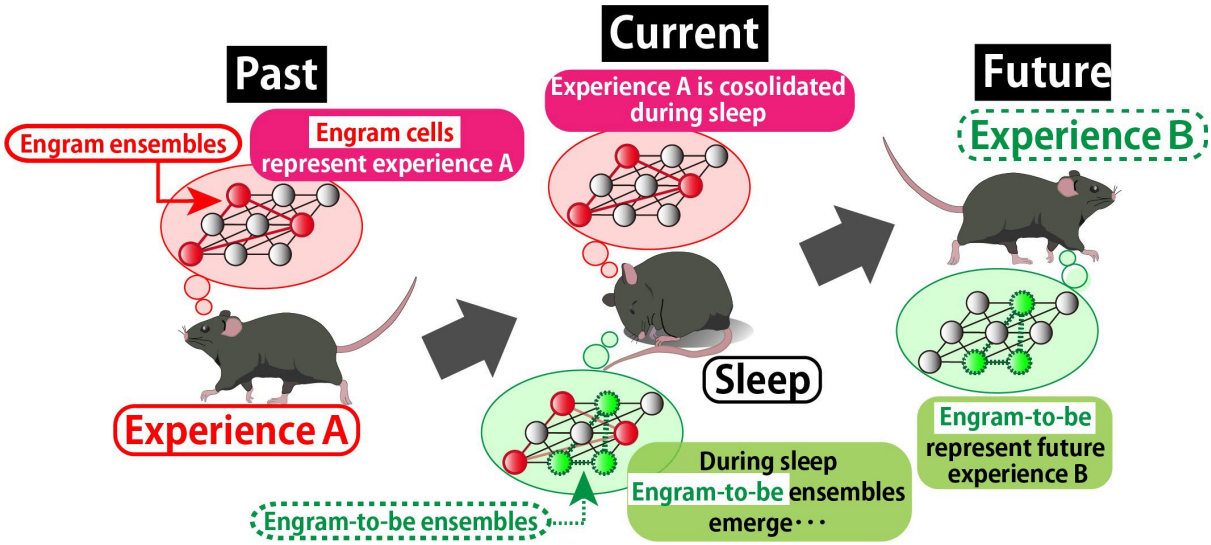
Image



Title: Sleep's Dual Role in Memory Processing
Caption: Through behavioral experiments in mice coupled with advanced neuronal imaging, researchers found how sleep helps consolidate past experiences in engram cells and prepare engram-to-be cells to store future experiences.
Credit: Kaoru Inokuchi from the University of Toyama, Japan
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Reference

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About University of Toyama, Japan

University of Toyama is a leading national university located in Toyama Prefecture, Japan, with campuses in Toyama City and Takaoka City. Formed in 2005 through the integration of

three former national institutions, the university brings together a broad spectrum of disciplines across its 9 undergraduate schools, 8 graduate schools, and a range of specialized institutes. With more than 9,000 students, including a growing international cohort, the university is dedicated to high-quality education, cutting-edge research, and meaningful social contribution. Guided by the mission to cultivate individuals with creativity, ethical awareness, and a strong sense of purpose, the University of Toyama fosters learning that integrates the humanities, social sciences, natural sciences, and life sciences. The university emphasizes a global standard of education while remaining deeply engaged with the local community.

Website: https://www.u-toyama.ac.jp/en/

About Distinguished Professor Kaoru Inokuchi from the University of Toyama, Japan
Kaoru Inokuchi obtained a PhD degree from the Graduate School of Agriculture, Nagoya University, in 1984. He joined University of Toyama as full Professor in 2009 and was awarded the title of Distinguished Professor in 2019. Since 2020, he also served as the Director of the Research Center for Idling Brain Science. His current research specializes in the underlying mechanisms of memory at the molecular, cellular, and system levels. He has received multiple awards, including the Medal of Honor with Purple Ribbon from the Japanese Emperor, the Naito Memorial Award for the Advancement of Science, and Prizes for Science and Technology from the Minister of MEXT, among others.

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