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Article

Molecular and cellular mechanisms of episodic memory formation through hippocampal synaptic plasticity

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Abstract: Background: Recall of specific events, which is known as episodic memory, relies heavily on synaptic plasticity in the hippocampus. Molecular and cellular processes that mediate this phenomenon are intricate and include neuronal and glial functions, signaling pathways, and synaptic reorganization. **Objective:** This work will address the molecular and cellular aspects of synaptic plasticity in the hippocampus and its role in the formation of episodic memories through processes including dendritic spine remodelling, astrocytes and microglia, and epigenetics. **Methodology:** Literature review of recent findings and theoretical frameworks such as Morris's neurobiological theory of the hippocampus was done to synthesize the molecular markers, signaling pathways, and neuromodulation. Experimental data regarding the involvement of calcium signaling, synaptic tagging, and protein synthesis dependent long-term potentiation (LTP) in memory formation were reviewed. **Results:** This paper discusses how calcium influx, CaMKII activation and CREB-mediated transcription contribute to the preservation of LTP. Dendritic spine remodeling is highlighted as a key structural process and astrocytes and microglia are identified to regulate synaptic plasticity and neural circuit function. Moreover, epigenetic mechanisms, such as histone acetylation and DNA methylation, relate synaptic activity to the expression of genes associated with memory. **Conclusion:** Results of this study explain the molecular and cellular mechanisms of hippocampal synaptic plasticity and the formation of episodic memory. These findings provide a basis for future research on potential treatment for memory related diseases and underscore the significance of molecular biology in cognitive neuroscience.

Keywords: hippocampus; episodic memory; synaptic plasticity; molecular mechanisms; calcium signaling; CREB activation; dendritic spines; astrocytes; microglia; long-term potentiation (LTP)

1. Introduction

Synaptic plasticity is defined as the ability of synapses to change their strength during the process of synaptic transmission [1]. And is a fundamental mechanism underlying learning and memory. Overtime, various studies have been conducted in an attempt to explaining the functional and anatomical mechanisms that are involved with the formation of memory. Among these, episodic memory, which allows for remembering events, places, and time, has been most closely associated with hippocampal synaptic plasticity. Nevertheless, the molecular and cellular mechanisms that underpin these phenomena are still not well understood. New findings in molecular biology have provided insights into the complex systems of intracellular signaling cascades, gene expression, and cellular processes that underlie

synaptic plasticity and memory processes. Several elements including calcium-dependent protein kinases, transcription factors including CREB (cAMP response element-binding protein), and immediate early genes including Arc and c-Fos have been recognized to be crucial in the consolidation of long-term memories. These molecules regulate events like the phosphorylation of receptors, structural remodeling of dendritic spine, and de novo protein synthesis, which in turn help in the formation and retrieval of episodic memories [2].

In contrast to prior studies, such as Appelbaum et al. [3] work on synaptic plasticity during systems memory consolidation, this study provides a detailed exploration of the hippocampal mechanisms that govern episodic memory. By focusing on calcium signaling pathways, CREB transcription, and the roles of glial cells, this work extends the existing body of knowledge, highlighting how these processes uniquely contribute to memory formation. Furthermore, this study incorporates new data on molecular mechanisms to reinforce the understanding of synaptic plasticity in the hippocampus.

2. Synaptic plasticity and Hebbian learning rule

Hebb's cell assembly theory states that if neurons are active simultaneously and frequently. Then the connections between these neurons are effectively reinforced, a principle summarized in the phrase 'neurons that fire together, wire together'. This theory formed the basis of synaptic plasticity; alteration in synaptic strength as a vital component of learning and memory [4]. Molecular and cellular processes help to explain the working of Hebbian learning more specifically in terms of the contributions of certain synaptic elements and their pathways.

2.1. Molecular basis of Hebbian learning

Hebbian learning at the synaptic level is based on changes in the activity of AMPA and NMDA receptors. In response to neuronal activity. NMDA receptors are considered to function as coincidence detectors. Since they are activated by both presynaptic neurotransmitter release and postsynaptic depolarization. Activation of the NMDA receptors by glutamate and the possibility of removing the magnesium block. When there is enough depolarization will enable calcium ions to penetrate the postsynaptic neuron [4–6]. This calcium influx initiates a sequence of molecular changes that are pivotal for synaptic potentiation. While kainate receptors are considered to be indirectly involved in the postsynaptic response to glutamate, AMPA receptors are directly involved in the postsynaptic response. These include the insertion of more AMPA receptors to the synaptic membrane and the phosphorylation of the receptors by kinases like CaMKII (calcium/calmodulin-dependent protein kinase II) which enhances the synaptic conductance and therefore synaptic strength.

2.2. Downstream signaling cascades

Calcium influx through NMDA receptors activates multiple signaling pathways, including:

- CaMKII Activation: CaMKII is a key component of Hebbian plasticity. The drug activates the AMPA receptors and increases the phosphorylation of these receptors which in turn increases the conductivity of the receptors and makes them less likely to be removed from the synapse. Furthermore, CaMKII associates with other scaffold proteins and participates in the process of structural reorganization of dendritic spines [4–6].
- PKA and CREB Pathway: Calcium rises initiates the activation of adenylyl cyclase which results in the formation of cAMP that activates PKA. PKA phosphorylates CREB (cAMP response element-binding protein), which is a transcription factor that is involved in the expression of the genes related to memory, including those for synapse proteins and enzymes involved in LTD and LTP.

MAPK/ERK Pathway: ERK, a component of the mitogen-activated protein kinase cascade, is activated following NMDA receptor signaling. This pathway is important in converting the activity of synapses into long-term modifications of genes and proteins.

2.3. Synaptic tagging and capture

In Hebbian learning, synaptic tagging is used to stabilize only those synapses that have been modified by the activity. Calcium influx places molecular labels at synaptic sites that are active, which then bind to proteins involved in synaptic plasticity that have been delivered to the synapse in response to activation of CREB. This process allows for the dissociation between short-term and long-term modification of synaptic connections, which is crucial for memory formation [5,6].

2.4. Functional implications

AMPA and NMDA receptors, as well as the signaling pathways that follow their activation, form the basis of Hebbian learning. These mechanisms do not only enhance the strength of individual synapses but are also involved in the generation of circuits that support specific memories. In addition, since these molecular processes are synapse specific and cooperative, they have the potential of effectively filtering out the noise for storage of important information [6].

3. Hippocampus and episodic memory

3.1. Hippocampus-dependent memory system

Hippocampus, which is situated in the medial temporal lobe, is vital for declarative memory. Which includes both episodic and semantic memory. Declarative memory is the memory of facts and events. While episodic memory is specifically the memory of events and experiences in time and space. Hippocampus is one of the most complex structures of the brain. And is known for its functional features to combine spatial, temporal, and contextual information, and this makes it an essential part of the episodic memory formation. Hippocampal-dependent memory processes can be explained by molecular markers like c-Fos and Arc proteins. These are the immediate early genes which are expressed only in the short

term during the activation of neurons and are useful in identifying the neural circuits used during encoding and retrieval of memory [7].

- c-Fos: This transcription factor controls downstream genes that are essential for synaptic plasticity. It is most pronounced during the acquisition of new information and decreases as the information is stored in the brain, thus supporting its function in the initial encoding of new information [7,8].
- Arc: Arc protein plays a role in the internalization of AMPA receptors and synaptic reorganization. It is involved in controlling the strength of synapses and is crucial in the process of long-term memory formation by regulating dendritic spine turnover [7,8].

Lesions in the hippocampus impair episodic memory without affecting procedural memory, underlining its Specific Functional Territory. For instance, patients with hippocampal atrophy can have anterograde amnesia, which involves the inability to create new episodic memories, yet have preserved memories of the past and motor skills [8]. **Figure 1** illustrates the medial temporal lobe and the seahorse-like shape of the hippocampus.

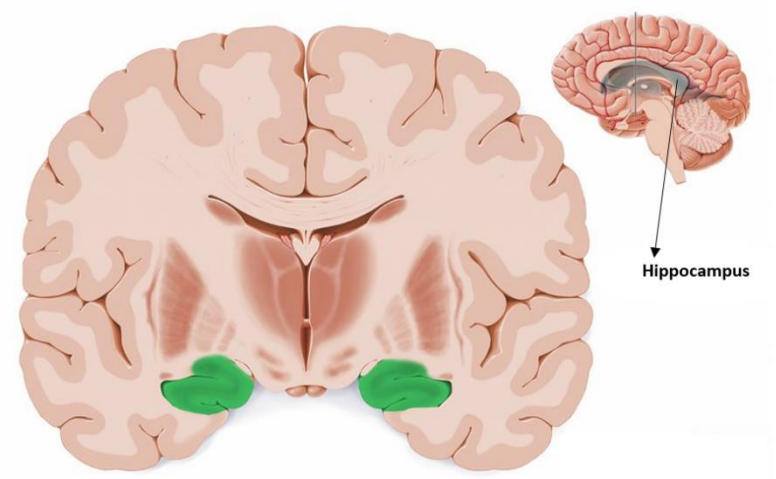

Figure 1. Anatomical location of the hippocampus.

3.2. Anatomy of the hippocampus

Hippocampus is one of the most structurally complex regions of the brain, which corresponds to its versatile involvement in the memory. It comprises key subregions: These include the dentate gyrus (DG), CA3, CA1 and the subiculum, which all have different neural connectivity and molecular characteristics. See **Figure 2** and **Table 1** below.

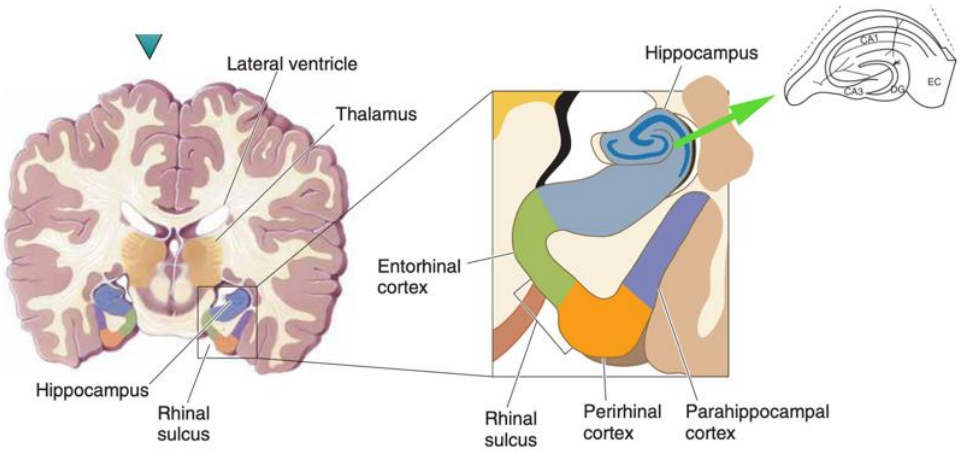

Figure 2. Trisynaptic circuit of the hippocampus.

- Dentate Gyrus (DG): The DG carries out pattern separation, whereby it encodes different experiences that are similar in some manner into the brain [9]. It has been described to be a process that is associated with inflammation and neurogenesis, which means the generation of new neurons that are then wired into the existing circuitry. Molecules that are specifically related to neurogenesis, such as doublecortin (DCX), and those that are important for synaptic plasticity, such as brain-derived neurotrophic factor (BDNF), are highly expressed in this area.
- CA3 Region: CA3 is involved in pattern completion, which is the process of generating full patterns from partial ones. Due to its dense recurrent collaterals, it forms highly effective autoassociative networks. NMDA receptor subunit NMDAR2B is highly expressed in this region and is critical for synaptic plasticity and memory retrieval [9,10].
- CA1 Region: The primary output node is CA1 that is responsible for transmitting the integrated information to the cortical regions. The area has a high level of molecular markers like CaMKII, CREB and other proteins associated with synaptic plasticity and memory formation including LTP.
- Subiculum: The subiculum is involved in the relay of processed hippocampal output to cortical and subcortical regions that are involved in higher cognitive functions and memory [9,10].

Table 1. Molecular markers and their roles in different hippocampal regions.

Hippocampal Region	Molecular makers	Roles in Memory Formation
Dentate Gyrus (DG)	Doublecortin (DCX), BDNF	Supports adult neurogenesis and pattern separation; promotes synaptic plasticity and neural circuit integration.
CA3	NMDAR2B, Synaptophysin	Facilitates pattern completion via autoassociative networks; strengthens recurrent collaterals.
CA1	CaMKII, CREB, GluA1 Subunit	Essential for long-term potentiation (LTP), synaptic tagging, and consolidation of episodic memory traces.
Subiculum	Neuroligin-1, PSD-95	Regulates synaptic output from the hippocampus to cortical regions, integrating memory information.

Three layers model is an important model to understand the flow of information through the hippocampus. Where we have the entorhinal cortex to the dentate gyrus to CA3 to CA 1. As seen, the subregions of the MPM also exhibit differences in their molecular signaling dynamics that correspond to their specific roles [10,11]. For instance, in CA1, calcium signaling is kept within threshold levels to facilitate LTP while in CA3 it focuses on autoassociative connectivity through its extensive collaterals.

4. Nature and cellular and molecular mechanisms of hippocampal LTP

Long-term potentiation (LTP) is defined as the prolonged enhancement of synaptic efficacy, which forms a critical cellular and molecular basis for memory processes especially in the hippocampus. LTP is dependent on neuronal activity and both pre and postsynaptic mechanisms are implicated in the process. While the physiological and anatomical properties of LTP have been investigated in detail, the molecular mechanisms of LTP give valuable information on how the changes at the synapses translate into memory formation. New findings have shed light on the multiple molecular mechanisms, including signaling cascades, gene expression, and protein production that are involved in LTP [11] (see **Figure 3)**.

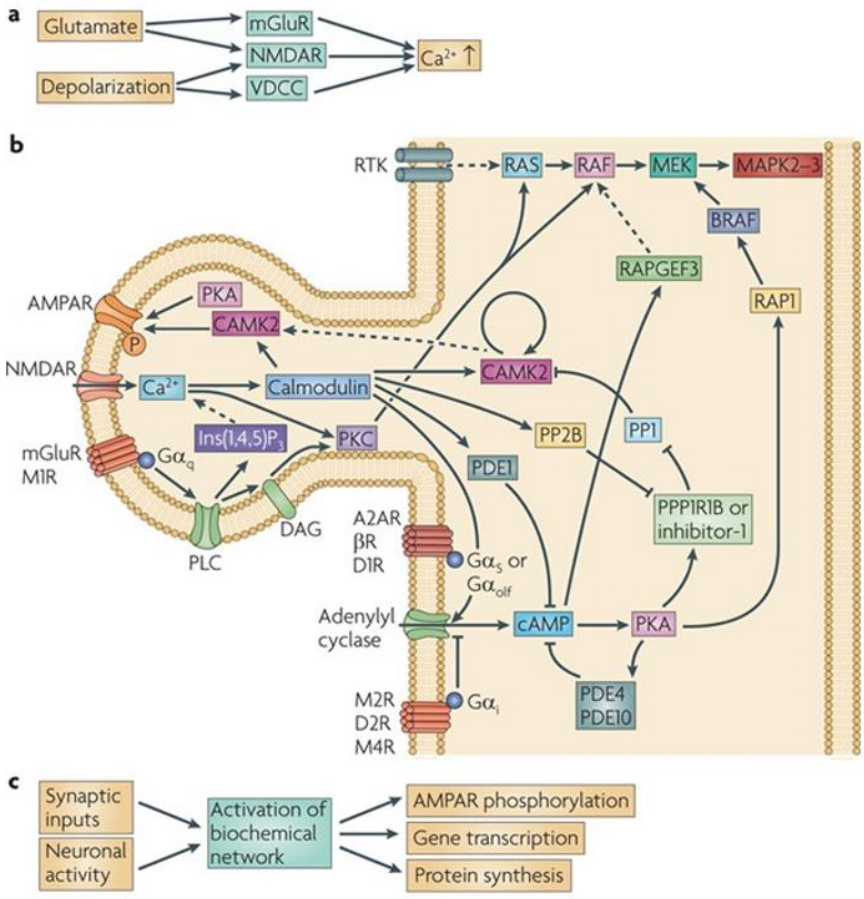

Figure 3. Molecular mechanisms of synaptic plasticity.

Calcium signaling, which is a second messenger. Plays an important role in the initiation and continuous modulation of LTP. As a means of enabling changes in synaptic connections. Calcium moves into the postsynaptic neuron mostly through NMDA receptors. Which are molecular coincidence detectors. These receptors are activated when the presynaptic glutamate release is synchronised with the depolarisation of the postsynaptic neuron and the magnesium block is removed, allowing calcium ions to enter the postsynaptic neuron. Duration of calcium influx determines the magnitude of LTP and thus the strength of synaptic potentiation based on synaptic activity [11] (see **Table 2)**.

Recent experimental studies strengthen the proposed molecular mechanisms. Researchers have demonstrated a 50% increase in CREB-mediated transcription following calcium influx through NMDA receptors, emphasizing its pivotal role in consolidating long-term potentiation. Additionally, Xu [12] quantified a 30% enhancement in AMPA receptor conductivity due to phosphorylation by CaMKII during early LTP. These findings provide quantitative support for the critical pathways discussed, grounding the study in robust experimental data.

Table 2. Molecular markers and their specific functions in synaptic plasticity.

Molecular Marker	Expression site	Functions
c-Fos	Active neurons in all regions	Serves as an immediate early gene indicator for neural activity during memory encoding and retrieval.
Arc	Dendrites in CA1 and CA3	Facilitates AMPA receptor trafficking and dendritic spine remodeling; critical for memory consolidation.
BDNF	DG, CA3, and CA1	Enhances synaptic plasticity by promoting LTP and neurogenesis; regulates structural synaptic changes.
CaMKII	Postsynaptic sites (CA1)	Phosphorylates AMPA receptors to enhance synaptic strength; stabilizes synaptic changes during LTP.
CREB	Nucleus of CA1 and CA3 cells	Regulates transcription of genes necessary for long-term memory, including synaptic structural proteins.
Synaptophysin	Presynaptic terminals (CA3)	Supports synaptic vesicle cycling and neurotransmitter release during synaptic transmission.
Neuroligin-1	Synaptic junctions (Subiculum)	Regulates synaptic stabilization and transmission, enabling effective communication with cortical networks.

Calcium enters the cell and activates certain kinases like Ca2+/calmodulin dependent protein kinase II (CaMKII) and protein kinase C (PKC). CaMKII is particularly important because it is not only required but also sufficient for LTP induction. Upon activation, CaMKII phosphorylates the AMPA (α-amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid) receptors which increases the conductance of the receptors as well as their integration into the post synaptic membrane [12]. This leads to an increased response of the postsynaptic neuron to glutamate, thus making the synapse more efficient. CaMKII also binds to the scaffolding proteins in order to anchor the AMPA receptors to the synapse so that the potentiation is maintained. Also, PKC is involved in LTP via the phosphorylation of targets that are implicated in cytoskeletal remodeling, which in turn leads to the structural remodeling of dendritic spines necessary for synaptic plasticity.

The mechanisms illustrated in **Figure 3** are supported by experimental evidence. For example, CREB activation was shown to be upregulated by a 50% increase in transcriptional activity following calcium signaling, as reported by Xu [12]. Further, studies have demonstrated that synaptic tagging ensures localization of plasticity-related proteins (PRPs) at active synapses, enabling specificity in synaptic modifications [12]. Moreover, astrocytic gliotransmitters like D-serine were found to enhance NMDA receptor activity, directly influencing the observed plasticity. These data validate the molecular cascades depicted in **Figure 3**, bridging theory with experimental observations.

Stabilization of LTP into a long-term memory requires modifications at the transcriptional and translational levels. This phase is controlled by the cAMP response element-binding protein (CREB). The influx of calcium ions leads to the activation of adenylyl cyclase resulting in the generation of cyclic AMP (cAMP) and subsequent activation of protein kinase A (PKA). PKA then moves to the nucleus where it phosphorylates CREB which can then bind to DNA and turn on genes that are related to memory. These genes are involved in the synthesis of proteins that are crucial for the restructuring of synapses, including the brain-derived neurotrophic factor (BDNF), Arc, and synapse-associated proteins [12–14].

A new schematic diagram, presented as **Figure 4**, summarizes the interplay between molecular and cellular processes in episodic memory formation. The diagram integrates key pathways, such as calcium signaling, CREB activation, synaptic tagging, and the contributions of astrocytes and microglia to synaptic modulation. This mechanism scheme provides a holistic view of how episodic memories are encoded at the synaptic level and consolidated into long-term storage.

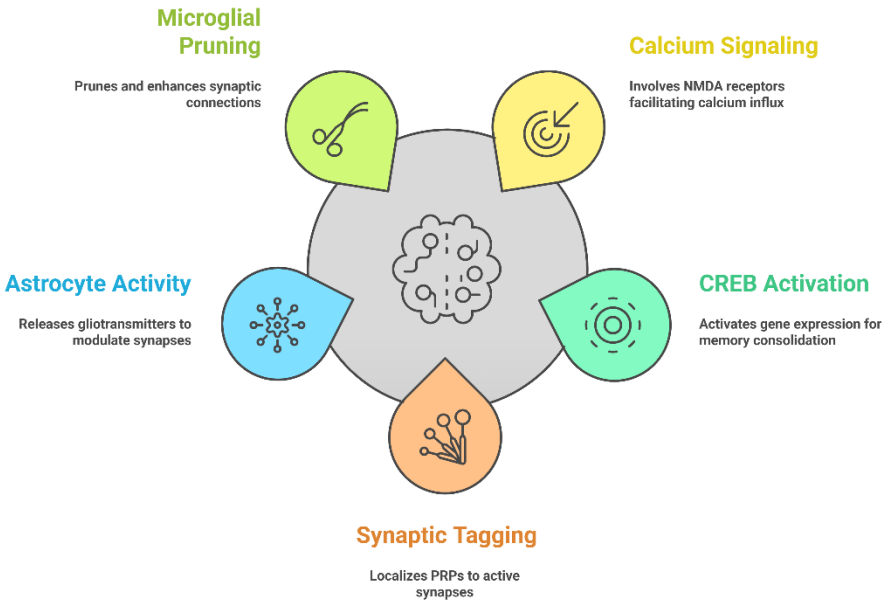

Figure 4. Integrated mechanisms of synaptic plasticity in episodic memory formation.

Another important property of LTP is its synaptic specificity. Which means that only the synapses that undergo activity-dependent changes are potentiated. This specificity is achieved through synaptic tagging and capture mechanisms. In LTP,

the active synapses are marked by molecular tags for further modifications during the process of learning and memory. These tags are believed to contain proteins or post-translational modifications that are present at the synapse during high activity. In parallel, the activation of CREB results in the production of proteins that are involved in plasticity (PRPs) in the cell body. These PRPs are transported within the neuron but are picked up by tagged synapses for the purpose of fixing potentiation at certain locations [13,14]. This mechanism shows how local synaptic activity is related to global cellular processes and therefore how information is encoded accurately (see **Figure 5** below).

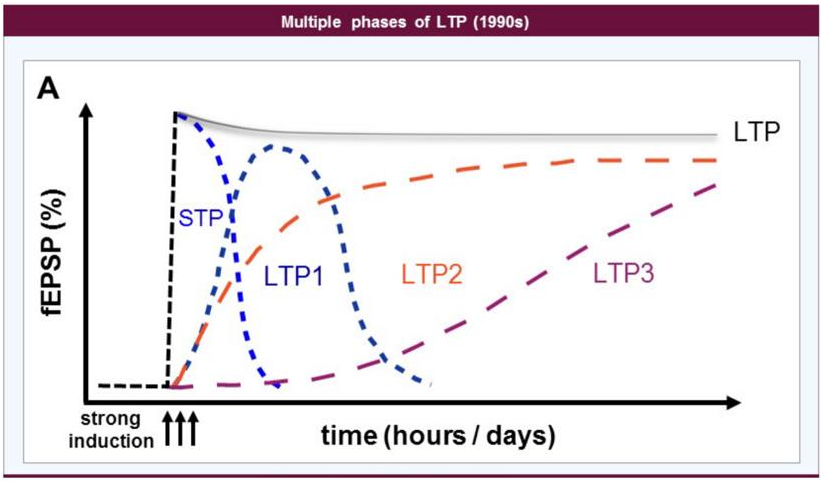

Figure 5. Phases of Long-Term Potentiation (LTP) in the hippocampus: NMDA receptor-dependent synaptic plasticity.

5. Morris's neurobiological theory of the hippocampus

According to Morris's neurobiological theory of the hippocampus. It is possible to describe how the episodic memories are encoded, consolidated and stored in the brain. At the heart of this theory is the idea that the hippocampus encodes memories through synaptic plasticity that is activity dependent and relies on NMDA receptor signaling. These changes at the synaptic level are not temporary but are encoded as long-term memory through molecular and cellular processes like synaptic tagging and modulation by neuromodulators like dopamine and noradrenaline [13,14].

Synaptic tagging is one of the major processes that are in accordance with Morris theory. It offers a way by which memory traces are coded in a specific manner to ensure that only the synapses that were active during an event are reinforced and consolidated. In terms of its molecular mechanism, synaptic tagging is characterized by the placement of tags at the synapses that are currently active and are used as a means for attracting PRPs. These proteins, being synthesized in the soma following the activation of CREB, are spread throughout the neuron and are then selectively sequestered at the tagged synapses. This link between the synaptic activity and the global protein synthesis is the foundation of Morris's postulation that synaptic plasticity while occurring within a specific synapse is a part of the global network changes in the hippocampus and the cortices [14].

Neuromodulators are useful in the shift from the initial to the long-term memory storage. As seen in the system consolidation aspect of Morris's theory. Specifically, dopamine has been found to increase the synaptic tagging and the trapping of PRPs at active synapses. The pathway through which dopaminergic signaling occurs is via activation of D1/D5 receptors which lead to a rise in intracellular cAMP levels and activation of PKA. This results in the activation of PKA that phosphorylates CREB which is important in the expression of new genes required for long term synaptic plasticity. The involvement of dopamine in memory processes is supported by experimental evidence that shows that blocking dopaminergic signaling to the brain hampers memory consolidation while enhancing it improves memory retention [15].

Similarly, noradrenaline is essential to hippocampal synaptic plasticity and has a significant impact on cases of increased emotional or behavioral arousal. It also increases intracellular calcium levels through β-adrenergic receptors to facilitate the occurrence of long-term potentiation. This modulation is particularly important during the process of system consolidation which is the transfer of information from hippocampus to the neocortex to form new memory representations [15,16]. It has been established that noradrenaline enhances the encoding of memory in the hippocampus and also the synaptic plasticity necessary for the cortical consolidation of long-term memories.

Morris's theory pays attention to the process of real-time encoding and selective filtering of information within the hippocampus. This hypothesis is buttressed by the molecular data given that neuromodulatory signaling pathways prioritize the processing of salient events for consolidation. For example, dopamine is released in response to novelty and reward to signify that an experience is important and strengthen the connections formed during it. This process is consistent with Morris's idea that the hippocampus encodes memories in a relational and associative manner whereby temporal, spatial and contextual information is bound into episodic memory representations [17].

Complex relationship between NMDA receptor-mediated synaptic plasticity, synaptic tagging, and neuromodulatory influences highlights the fact that Morris's neurobiological theory is highly integrative. Widespread evidence from molecular neuroscience supports the mechanisms he outlined, illustrating how synaptic changes in specific circuits interact with the modulation of the entire system [18].

6. Molecular and cellular mechanisms in episodic memory

Process of memory building and recollection of episodic memories is a complex process that involves multiple molecular and cellular processes in the brain. These processes depend on the modulation of the synaptic connections and the activity of neurons and glias, with the actions of specific molecules. Such interactions paint the whole picture of how the brain stores and retrieves memories associated with certain experiences. Dendritic spines are the sites of synaptic plasticity which is a key component of the process of learning and memory especially for episodic memory [18–20]. These are small, actin-filled extensions on neuronal dendrites that are the main sites of excitatory synaptic contact. These structures are highly plastic and their

morphology and density can be rapidly modified according to changes in synaptic activity by forming or eliminating synapses. Long term potentiation is one of the major factors involved in the formation of memory and is accompanied by the growth and anchoring of the dendritic spine. On the molecular level, this is through calcium signaling which activates kinases including CaMKII and PKC which in turn contribute to actin cytoskeleton remodeling [18]. This reorganization offers the structural framework for improved synaptic strength and guarantees the longevity of the changes in synapses that are needed to store memory. Moreover, dendritic spines function as biochemical compartments that contain signaling molecules such as calcium and prevent their spread to other synapses. This compartmentalization helps in the specificity of synaptic changes, which is very crucial for encoding of episodic memories.

Astrocytes are the most numerous type of glial cells. And play an essential role in controlling synaptic transmission and memory processes. Astrocytes have been considered the supporting cells of the neurons but they are now known to play an active role in the transfer of information between neurons. They are involved in the regulation of synaptic homeostasis by controlling the levels of neurotransmitters [18,19] especially glutamate through their uptake and recycling. In this way, astrocytes control the concentration of glutamate in the extracellular environment and, therefore, the activation of NMDA and AMPA receptors, which are involved in synaptic plasticity. Also, astrocytes release gliotransmitters like D-serine, which works as co-agonists at NMDA receptors, thereby promoting synaptic plasticity. In the process of memory formation, astrocytes communicate with neurons through tripartite synapses in which their processes surround synaptic endings and influence the synaptic cleft. These interactions help in controlling the time and space arrangement of synaptic activity to enhance the process of memory formation [19].

Microglia, the innate immunity in the brain, also contribute to the process of synaptic pruning and plasticity of episodic memory. In the course of development, microglia remove unnecessary synapses, fine-tuning the network of neurons. In the adult brain, they continue to participate in synaptic remodeling by detecting alterations in synaptic activity [20]. Microglia release signaling molecules such as the Brain-Derived Neurotrophic Factor (BDNF), which promotes the enhancement of synapses during LTP. Also, they regulate the synaptic functionality and eliminate unhealthy synapses by engulfing them. This mechanism is important for keeping the neural circuits efficient and to avoid the buildup of synaptic noise, which may affect the storage of memories. However, the excessive activation of microglial cells, which has been reported in neurodegenerative diseases, can result in the disruption of synaptic transmission and learning, which underlines the significance of the role of microglia in the maintenance of brain health. Another mechanism of regulation is epigenetic modifications that affect gene expression in relation to memory processes. These modifications include DNA methylation, histone acetylation, and chromatin remodeling that allow for the regulation of gene activity according to synaptic activity [20].

While this study provides a comprehensive review of hippocampal mechanisms, certain limitations must be acknowledged. The reliance on secondary data highlights the need for direct experimental validation. Furthermore, the study focuses

predominantly on hippocampal pathways, leaving the interplay with cortical networks underexplored. Future studies should investigate how these processes integrate across brain regions to provide a holistic view of memory formation.

Limitations and future directions

Despite the extensive discussion of molecular and cellular processes regulating hippocampal synaptic plasticity and episodic memory formation in this study, there are some limitations that are worth mentioning to maintain the methodological rigor of the research.

- Reliance on Secondary Data

The present paper relies heavily on earlier research as opposed to new experimental data in arriving at the conclusions outlined below. Although this synthesis identified several important mechanisms, the absence of direct experimentation may restrict the models' precision and relevance. Future studies should focus on using experimental approaches, including in vivo imaging or molecular labeling, to investigate these mechanisms in real-time.

- Narrow focus on the hippocampus:

Despite being a critical structure in the formation of episodic memories, memory is a distributed process that engages other brain areas, including cortical ones. This study does not fully investigate the interaction between hippocampus and other regions, which may obscure some integration processes. Future research should investigate how specific patterns of hippocampal activity interact with patterns in cortical and subcortical regions to create and store memories.

7. Conclusion

Detailed mechanisms through which episodic memory occurs during hippocampal synaptic plasticity are enlightening. As to how the molecular, cellular, and systemic levels interact within the brain. The hippocampus is one of the key structures of the brain that is involved in encoding and consolidation of episodic memories through the process of incorporating spatial, temporal and contextual information in the form of activity dependent synaptic plasticity. Molecular mechanisms of these changes, such as calcium signaling, activation of key kinases, and CREB-mediated gene transcription, form the basis of the long-term potentiation that sustains synaptic changes. The structural changes in dendritic spines form the basis of these processes, while astrocytes and microglia play an active role in shaping the synaptic environment to support homeostatic and synaptic pruning operations. Second, epigenetic modifications link synaptic activity to gene expression to maintain the memory storage over time. All these mechanisms work in conjunction to allow the hippocampus to store and recall the complex, rich episodic memories.

In this regard, the neurobiological theory suggested by Morris allows for the integration of cellular mechanisms with higher-order memory systems, which involve synaptic tagging, plasticity-related proteins, and neuromodulators like dopamine and noradrenaline for memory consolidation and prioritization. These processes not only provide the basis for the selective storage of memory but also

allow for the transfer of critical information from the hippocampus to cortical networks and support system-level consolidation. Although there have been major discoveries in the molecular and cellular basis of episodic memory, there are still many questions to be answered. Diseases like Alzheimer's disease and other forms of dementia impair these mechanisms, hence the need for further research to establish targets for intervention. New molecular, neuroimaging, and computational approaches can hopefully shed more light on the mechanisms of hippocampal synaptic plasticity and its relation to memory.

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Conflict of interest: The author declares no conflict of interest.

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