

Chapter 2

Storing and Keeping Memories

Forming Memories

How memories are formed in the brain is an extremely complex process that is only partly understood. Memories are fundamental for learning and being able to interact with our environment. There is a sequence of events that are involved in forming memories. These events include the acquisition and storage of something one wishes to remember and after retaining this information, being able to retrieve it when there is a need to use it. There are two types of memories that the brain uses to store and retrieve a memory for brief or long durations. The first type is **short-term memory**. Short-term memory, as the name implies, is holding a small amount of information that is acquired (typical about 7 items or less), briefly storing it and then usually forgetting it after about 30 s. Short-term memory can be retained by repetition that is how one is able to retain a telephone number that is important to recall. Short-term memory information can be transferred to long-term memory within seconds, but the mechanisms involved in this transformation remain controversial.

The second type of memory is called long-term. Long-term memory is acquired and stored permanently. The storage and retrieval of long-term memories can last a few days too many years. How well one remembers memories that are heard, seen, smelled, felt or tasted depends on how precise the brain can record them. Weak memories only come to mind when prompting or reminding.

Procedural, episodic, and semantic memory is part of long-term memory.

Procedural memory is involved in knowing how to do things, such as riding a bicycle or putting your shoes on. It does not require a conscious component and can be performed without thinking.

Episodic memory is a part of the long-term memory responsible for acquiring and storing events (episodes) that have been experienced in life, such as cutting your hand with a knife or the first time you wore eyeglasses. Most adults in the nation recall what they were doing on 9/11 when the xxx Towers went down.

Semantic memory also participates in long-term memory and is the ability to store information that includes general knowledge and the meaning of words.

Episodic and semantic memories but not procedural memory are declarative or explicit, that is, they require conscious thought, for example, recalling facts and events such as Napoleon's war in Russia or solving quadratic equations. Procedural memories are implicit, they include memories for skills and habit. Pavlovian conditioning is an example of procedural memory where a dog learns to salivate at the ringing of a bell that signifies food is coming.

Creating a Memory

A memory perceived by the senses is said to be **encoded**, a process that constitutes the first step in creating and storing a memory. Encoding takes place in various areas of the frontal cortex and other cortical regions of the brain where they are decoded (Fig. 2.1).

Following decoding, the memory travels to a part of the brain called the **hippocampus**, a structure deep within the medial temporal lobe of the brain responsible for **learning and memory**. Learning is described as the process by which new information about the environment is acquired and memory as the mechanism by which that knowledge is retained. As memories arrive at the hippocampus, a decision is made as to whether or not the memory is worthy of being permanently stored in the cortex for potential recall. It is generally believed that the cortex is capable of supporting various types of memories acquired from visual, hearing, olfactory, tactile, and auditory stimuli. This notion is supported by many studies using functional neuroimaging techniques that light up the screen following neuron activation in different parts of the cortex when the brain is exposed to various sensory or mental stimuli.

For long-term storage, memories undergo a process called **consolidation**. Memory consolidation is the means by which a memory is stabilized after its initial acquisition. Following consolidation of a memory, **long-term potentiation** (LTP) may take place. LTP is believed to prolong the strengthening mechanism of synaptic transmission and to maintain memories in the brain for long durations (Fig. 2.1).

This process involved in memory is highly complex and incompletely understood. Memory storage and retrieval involves thousands of neural connections, neurotransmitter release, protein synthesis and the participation of a variety of chemical molecules. The role of the hippocampus in humans was studied in Henry Molaison (known in neuroscience as "H.M."). Molaison was a man, who due to intractable seizures, had his hippocampus surgically removed bilaterally. After the operation, he was seizure free, but it was noted that he had great difficulty in forming new memories, learning new words, and remembering what had happened a short time before. However, older memories of facts and events formed before his operation could be recalled, a detail that suggested storage of long-term memories

FORMATION OF A MEMORY



MEMORY ACQUISITION

ENCODING

CONSOLIDATION

LONG TERM POTENTIATION

SYNAPTIC STORAGE

Fig. 2.1 Memories are acquired from sensory stimuli derived from the 5 senses, seeing, smelling, hearing, feeling, and tasting. The first step in creating a memory involves encoding, a process where the perceived item of interest is converted into a construct that can be stored in the brain. After encoding, the memory trace is decoded in different regions of the sensory cortex where it is eventually sent to the hippocampus, a small region of the brain that elects whether the memory will be stored long-term or discarded. Long-term storage of the memory involves consolidation, where the memory is stabilized and stored using a process called long-term potentiation. Retrieval or recall of a memory in long-term storage is based on cues that prompt the act of remembering. Short-term memory undergoes a similar process as long-term memory but differs essentially due to its brief duration and limited capacity of items to be stored. Short-term memory quickly decays within 30 s unless a conscious effort is made to retain the information

did not reside in the hippocampus. Where in the brain is memory stored has been a topic of much research and considerable debate. Evidence indicates that long-term memory is processed in the prefrontal cortex and then flows to different regions of the brain by neural circuits and networks ending up in the synapse, the connecting point between neurons.

This long-held belief has been challenged recently by **Dr. David Glanzman**, a professor of Integrative Biology and Physiology at UCLA whose work with the 5-inch long *Aplysia* snail, suggests that long-term memory is not stored in synapses. Glanzman's research has reported that although synapses participate in long-term memory that is not where memories are stored [1]. Glanzman suspects that memories instead may be stored in the nucleus of neurons, although this has not been proven [1]. Knowing where long-term memory is stored is of key importance in research because it can provide targets for restorative therapy in neurons or synapses that have not been killed by trauma or neurodegeneration. That is the advantage of using a simple organism like *Aplysia* which have only about

20,000 neurons when doing experiment involving long-term memory compared to the human brain which has about 100,000 billion neurons and 100 trillion synapses.

How Alzheimer's and other dementias destroy short- and long-term memory has been the subject of heated controversy in recent years. It may be assumed that hippocampal damage and death of neurons from the neurodegenerative process involved in Alzheimer's and other dementias is an important contributor of short-term memory loss and eventually of long-term memory.

Rodent experiments in our laboratory have shown that hippocampal neurons are the first cells in the brain to perish several weeks following reduced cerebral blood flow induced by occluding the common carotid arteries that supply about 60 % of the blood flow to the brain (Fig. 4.1). The death of these hippocampal neurons in rodents was associated with progressive memory impairment, reduced ATP, and eventual atrophy of the cortex, particularly in older rats [2]. The delicate sensitivity of hippocampal neurons to mild, but chronic brain hypoperfusion remains unclear.

It is known that a memory item may not be retained once damage to neurons that encode or decode a memory from sensory stimuli has occurred. It follows that tests involving the degree of sensory damage may offer a clue that a dementia process may be forthcoming. For example, a poor sense of smell may be one of the earliest signs of Alzheimer's, especially when it correlates with other mental and cognitive deficits characteristic of this dementia.

For now, it is intriguing to know that memory loss can occur not only from dementia but also from physical, physiological, and psychological trauma to the brain. These very different memory-robbing mechanisms imply that a disturbed common element may explain the damage to neurons, their connections, and their function. That common element may involve inadequate blood flow to the brain, among other things. I will present this argument throughout the balance of this book.

References

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