Memory Systems I
Where Stored

Reading:
BCP Chapter 24
Memory Systems

**Learning** is the acquisition of new knowledge or skills. **Memory** is the retention of learned information.

Many different kinds of information are learned and remembered (e.g., facts, events, skills). Evidence suggests that no single brain structure or cellular mechanism accounts for all learning. Moreover, the way in which information of a particular type is stored may change over time.

Where stored
- Types of Memory
- Cortical structures

How stored
- Engram
- Long-term potentiation
- Long-term depression
- Consolidation
Short-term and Long-term Memory

From daily experience, we know that some memories last longer than others.
• Short-term memories are those that last on the order of seconds to hours.
• Long-term memories are those that can be recalled days, months and years after they were stored.

Short-term but not (distant) long-term memory can be “erased” by interference (e.g., head trauma). These observations have led to the hypothesis that short-term memories are selectively converted into a permanent form via a process called memory consolidation.
Evidence suggests that there are two distinct types of long-term memory: declarative and non-declarative (procedural). Memory for facts and personal events that can be consciously recalled is called declarative (or explicit) memory; this is what we usually mean by the word “memory”. Long-term memory for skills, habits and behaviors that cannot be consciously recalled (but shown) is called non-declarative (or procedural or implicit) memory.
Much information re: where memories are stored in the brain has come from studies of individuals that have suffered brain injury.

In daily life, forgetting is nearly as common an occurrence as learning and remembering. However, certain diseases and injuries to the brain cause a serious loss of memory and/or ability to learn called amnesia. Concussion, chronic alcoholism, encephalitis, brain tumor and stroke can all disrupt memory.

Following trauma to the brain, amnesia can manifest itself in two ways (often a mixture of both):
• retrograde, memory loss for events before the trauma;
• anterograde, an inability to form new memories after the trauma.
Henry Molaison (1926-2008), widely known as H.M., was an epileptic who had his temporal lobes removed in 1953. His seizures were dramatically reduced—but so too was his long-term memory (LTM). H.M. experienced both mild retrograde amnesia and severe anterograde amnesia of his declarative memory; his implicit long-term and short-term (STM) memory was intact.

The effects of bilateral medial temporal lobectomy showed that:
- long-term memory has two components: declarative vs. procedural (e.g., mirror drawing test)
- short-term and long-term memory are distinctly separate types of memory (consolidation is required to move STM to LTM)
- the medial temporal lobes are involved in declarative memory
Patients with more restricted medial temporal lobe damage usually show incomplete long-term declarative memory deficits (as compared to H.M.). That is, differential damage to the medial temporal lobes suggest that declarative memory falls into two categories: semantic and episodic.

In particular, patients with damage to the anterior pole of the temporal lobe show deficits more-so in semantic memory (for general information).

In contrast, patients with damage further caudal tend to have far greater difficulties with episodic memory (events that one has experienced) than semantic memory.
Semantic memory refers to general world knowledge that we have accumulated throughout our lives. There are many different models as to how semantic memory is stored in the brain.

Most models suggest that semantic memory is stored in a distributed manner in cortex (e.g. dog bark in/around auditory cortex; dog form in inferotemporal cortex). The anterior pole of the temporal cortex may act as a hub for convergence of information.
There are three major structures in the part of medial temporal lobe caudal (behind) the anterior pole: the amygdala, hippocampus, and rhinal cortex.

Selective damage to both the hippocampus and rhinal cortex (which are strongly interconnected) produce deficits in declarative, episodic memory, although the loss is greater after damage to the rhinal cortex.
Evidence suggests that the hippocampus plays a key role in memory for spatial navigation.

In the Morris water maze test, rats placed at various locations in a circular pool of murky water rapidly learn to swim to a stationary platform hidden just below the surface. Rats with hippocampal lesions learn this task with great difficulty (if at all).

Many hippocampal cells acquire a place field after exposure to an environment. Place cells are neurons which respond best when a rat is in a given location within an environment (even in the dark).

Humans also show increased brain activity in the hippocampus for tasks involving spatial navigation.
Procedural Memory

Procedural memory is a type of long-term, non-declarative memory which aids in the performance of particular types of tasks without conscious awareness of these previous experiences. Procedural memory is created through procedural learning or, repeating a complex activity over and over again until all of the relevant neural systems work together to automatically produce the activity. Implicit procedural learning is essential for the development of any motor skill or cognitive activity. Evidence suggests that skill learning is dependent on activity within the basal ganglia and cerebellum.
Short-term memory (or "primary" or "active memory") is the capacity for holding a small amount of information in mind in a readily available state for a short period of time.

Evidence suggests that short-term memory is stored in numerous locations in the telencephalon, including the prefrontal and parietal cortex.

The Wisconsin card-sorting test reveals a role for the dorsolateral prefrontal cortex.

- Subjects are instructed to place a card in a holder; wherever it is placed, the subject is given feedback that this is correct.
- In the second trial, the subject uses the same rule and again receives positive feedback.
- In the third trial, the rule is followed, but the subject is told that the placement is in error.
- Patients with damage to the dorsolateral prefrontal cortex cannot change plans or ‘switch gears’ (i.e., use short-term information).
Neurons in prefrontal cortex have a variety of response types, some of which may reflect a role in short-term memory.

For example, when monkeys perform a delayed-response task (right), some neurons respond to visual cues only (A), whereas other neurons respond strongest during the delay period (B), when there is no visual stimulus.
Human brain imaging experiments suggest that numerous brain areas in the prefrontal cortex are involved in working memory.

Evidence suggests that spatial memory may be stored in the dorsolateral prefrontal cortex (red area; dorsal stream), whereas object identifiers may be stored in ventrolateral prefrontal cortex (blue areas; ventral stream).
Cortical areas outside the frontal lobe have also been found to contain neurons that appear to retain working memory information.

For example, lateral intraparietal cortex cortex (area LIP) is thought to guide eye movement to the locations (current or remembered) of objects of interest.
Patients who have suffered a concussion have permanent retrograde amnesia for events that led up to the blow, and permanent anterograde amnesia for events during the subsequent period of confusion. The length of the retrograde amnesia depends on the severity of the blow (more severe = longer periods), suggesting that older, long-term, memories are strengthened with time (consolidation).

Electroconvulsive shock testing (ECT) (an outdated treatment for epilepsy; a current treatment for depression) suggests that memory consolidation occurs over a period of years.
Summary: Structure-Function Relationships

Memory

Short-term
(Telencephalon)

Long-term

Declarative memory
(Medial temporal lobe)

Facts
(Anterior pole)

Events
(Rhinal cortex, hippocampus)

Procedural memory:
skills and habits
(Striatum)

Nondeclarative memory

Classical conditioning

Skeletal musculature
(Cerebellum)

Emotional responses
(Amygdala)