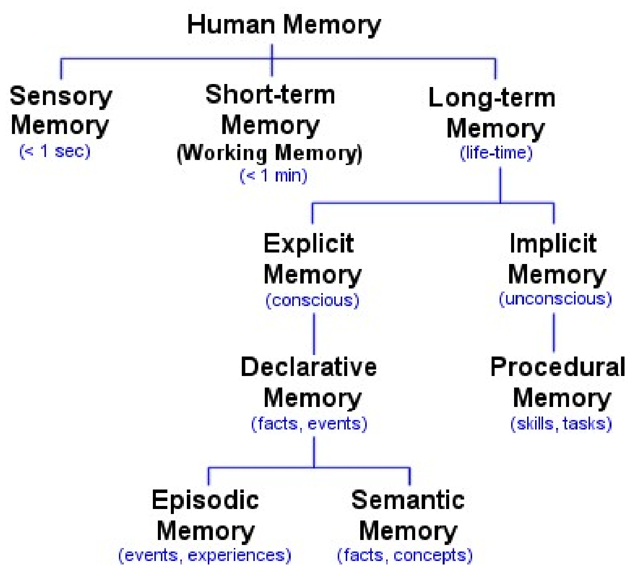
TYPES OF MEMORY

http://www.human-memory.net/types.html

What we usually think of as "memory" in day-to-day usage is actually long-term memory, but there are also important short-term and sensory memory processes, which must be worked through before a long-term memory can be established. The **different types of memory** each have their own particular mode of operation, but they all cooperate in the process of memorization, and can be seen as **three necessary steps** in forming a lasting memory.

This model of memory as a sequence of three stages, from sensory to short-term to long-term memory, rather than as a unitary process, is known as the **modal or multi-store or Atkinson-Shiffrin model**, after Richard Atkinson and Richard Shiffrin who developed it in 1968, and it remains the most popular model for studying memory. It is often also described as the **process of memory**, but I have used this description for the processes of **encoding, consolidation, storage and recall** in the separate Memory Processes section.

It should be noted that an **alternative model, known as the levels-of-processing model** was proposed by Fergus Craik and Robert Lockhart in **1972,** and posits that memory recall, and the extent to which something is memorized, is a **function of the depth of mental processing,** on a continuous scale from shallow (perceptual) to deep (semantic). Under this model, there is no real structure to memory and no distinction between short-term and long-term memory.



Sensory memory

Sensory memory is the shortest-term element of memory. It is the ability to retain impressions of sensory information after the original stimuli have ended. It acts as a kind of **buffer for stimuli received through the five senses** of sight, hearing, smell, taste and touch, which are retained accurately, but very briefly. For example, the ability to look at something and remember what it looked like with just a second of observation is an example of sensory memory.

The stimuli detected by our senses can be **either deliberately ignored**, in which case they disappear almost instantaneously, or **perceived**, in which case they enter our sensory memory. This does not require any conscious attention and, indeed, is usually considered to be totally outside of conscious control. The brain is designed to only process information that will be useful at a later date, and to allow the rest to pass by unnoted. As information is perceived, it is therefore stored in sensory memory **automatically** and unbidden. Unlike other types of memory, the **sensory memory cannot be prolonged via rehearsal**.

Sensory memory is an **ultra-short-term memory and decays** or degrades very quickly, typically in the region of 200 - 500 milliseconds (1/5 - 1/2 second) after the perception of an item, and certainly less than a second (although echoic memory is now thought to last a little longer, up to perhaps three or four seconds). Indeed, it lasts for such a short time that it is often considered part of the process of **perception**, but it nevertheless represents an essential step for storing information in short-term memory.

The sensory memory for visual stimuli is sometimes known as the iconic memory, the memory for aural stimuli is known as the echoic memory, and that for touch as the haptic memory. **Smell may actally be even more closely linked to memory than the other senses, possibly because the olfactory bulb and olfactory cortex (where smell sensations are processed) are physically very close - separated by just 2 or 3 synapses - to the hippocampus and amygdala** (which are involved in memory processes). Thus, smells may be more quickly and more strongly associated with memories and their associated emotions than the other senses, and memories of a smell may persist for longer, even without constant re-consolidation.

Experiments by **George Sperling** in the early 1960s involving the flashing of a grid of letters for a very short period of time (50 milliseconds) suggest that the upper limit of sensory memory (as distinct from short-term memory) is approximately **12 items**, although participants often reported that they seemed to "see" more than they could actually report.

Information is passed from the sensory memory into short-term memory via the process of **attention** (the cognitive process of selectively concentrating on one aspect of the environment while ignoring other things), which effectively filters the stimuli to only those which are of interest at any given time.

SHORT-TERM (WORKING) MEMORY

Short-term memory acts as a kind of **“scratch-pad” for temporary recall** of the information which is being processed at any point in time, and has been refered to as "the brain's Post-it note". It can be thought of as the ability to **remember and process information at the same time.** It holds a small amount of information (typically around 7 items or even less) in mind in an active, **readily-available** state for a short period of time (typically from 10 to 15 seconds, or sometimes up to a minute).

For example, in order to understand this sentence, the beginning of the sentence needs to be held in mind while the rest is read, a task which is carried out by the short-term memory. **Other common examples of short-term memory in action are the holding on to a piece of information temporarily in order to complete a task** (e.g. “carrying over” a number in a subtraction sum, or remembering a persuasive argument until another person finishes talking), and simultaneous translation (where the interpreter must store information in one language while orally translating it into another). What is actually held in short-term memory, though, is not complete concepts,but rather links or pointers (such as words, for example) which the brain can flesh out from it's other accumulated knowledge.

However, this **information will quickly disappear forever unless we make a conscious effort to retain it,** and short-term memory is a necessary step toward the next stage of retention, long-term memory. The transfer of information to long-term memory for more permanent storage can be facilitated or improved by **mental repetition** of the information or, even more effectively, by **giving it a meaning and associating** it with other previously acquired knowledge. **Motivation** is also a consideration, in that information relating to a subject of strong interest to a person, is more likely to be retained in long-term memory.

The term **working memory** is often used interchangeably with short-term memory, although technically working memory refers more to the whole theoretical framework of structures and processes used for the temporary storage and manipulation of information, of which short-term memory is just one component.

The **central executive part of the prefrontal cortex** at the front of the brain appears to play a fundamental role in short-term and working memory. It both serves as a temporary store for short-term memory, where information is kept available while it is needed for current reasoning processes, but it also "calls up" information from elsewhere in the brain. The **central executive controls two neural loops**, one for **visual data** (which activates areas near the visual cortex of the brain and acts as a visual scratch pad), and one for **language** (the "phonological loop", which uses **Broca's area as a kind of "inner voice"** that repeats word sounds to keep them in mind). These two scratch pads temporarily hold data until it is erased by the next job.

Although the **prefrontal cortex** is not the only part of the brain involved **-** it must also cooperate with other parts of the **cortex** from which it extracts information for brief periods - it is the most important, and Carlyle Jacobsen reported, as early as 1935, that damage to the prefrontal cortex in primates caused short-term memory deficits.

The **short-term memory** has a **limited capacity**, which can be readily illustrated by the simple experiment of trying to remember a list of random items (without allowing repetition or reinforcement) and seeing when errors begin to creep in. The often-cited experiments by George Miller in 1956 suggest that the **number of objects an average human can hold in working memory (known as memory span) is between 5 and 9** (7 ± 2, which Miller described as the “magical number”, and which is sometimes referred to as **Miller's Law**). However, although this may be approximately true for a population of college students, for example, memory span varies widely with populations tested, and modern estimates are typically lower, of the order of just 4 or 5 items.

The **type or characteristics of the information also affects the number of items which can be retained in short-term memory.** For instance, more words can be recalled if they are shorter or more commonly used words, or if they are phonologically similar in sound, or if they are taken from a single **semantic category** (such as sports, for example) rather than from different categories, etc. There is also some evidence that short-term memory capacity and duration is increased if the words or digits are **articulated aloud** instead of being read sub-vocally (in the head).

The relatively **small capacity of the short-term memory**, compared to the huge capacity of long-term memory, has been attributed by some to the **evolutionary survival advantage** in paying attention to a relatively small number of important things (e.g. the approach of a dangerous predator, the proximity of a nearby safe haven, etc) and not to a plethora of other peripheral details which would only interfere with rapid decision-making.

"Chunking" of information can lead to an increase in the short-term memory capacity. Chunking is the organization of material into shorter meaningful groups to make them more manageable. For example, a hyphenated phone number, split into groups of 3 or 4 digits, tends to be easier to remember than a single long number. Experiments by **Herbert Simon** have shown that the ideal size for chunking of letters and numbers, whether meaningful or not, is three. However, meaningful groups may be longer (such as four numbers that make up a date within a longer list of numbers, for example). With chunking, each chunk represents just one of the 5 - 9 items that can be stored in short-term memory, thus extending the total number of items that can be held.

It is usually **assumed that the short-term memory spontaneously decays** over time, typically in the region of 10 - 15 seconds, **but items may be retained for up to a minute, depending on the content. However, it can be extended by repetition or rehearsal** (either by reading items out loud, or by mental simulation), so that the information re-enters the short-term store and is retained for a further period. When **several elements (such as digits, words or pictures) are held in short-term memory simultaneously, they effectively compete with each other for recall.** New content, therefore, gradually pushes out older content (known as **displacement**), unless the older content is actively protected against interference by rehearsal or by directing attention to it. Any outside **interference** tends to cause disturbances in short-term memory retention, and for this reason people often feel a distinct desire to complete the tasks held in short-term memory as soon as possible.

The **forgetting of short-term memories involves a different process to the forgetting of long-term memories**. When something in **short-term memory is forgotten, it means that a nerve impulse has merely ceased being transmitted through a particular neural network**. In general, unless an impulse is reactivated, it stops flowing through a network after just a few seconds.

Typically, **information is transferred from the short-term or working memory to the long-term memory** within just a few seconds, although the exact mechanisms by which this transfer takes place, and whether all or only some memories are retained permanently, remain controversial topics among experts. Richard Schiffrin, in particular, is well known for his work in the 1960s suggesting that ALL memories automatically pass from a short-term to a long-term store after a short time (known as the **modal** or **multi-store** or **Atkinson-Schiffrin** model).

However, this is disputed, and it now seems increasingly likely that some kind of vetting or editing procedure takes place. Some researchers (e.g. Eugen Tarnow) have proposed that there is no real distinction between short-term and long-term memory at all, and certainly it is difficult to demarcate a clear boundary between them. However, the evidence of patients with some kinds of anterograde amnesia, and experiments on the way distraction affect the short-term recall of lists, suggest that there are in fact two more or less separate systems.

Long Term Memory

Long-term memory is, obviously enough, intended for storage of information over a long period of time. Despite our everyday impressions of forgetting, it seems likely that **long-term memory actually decays very little over time**, and can store a seemingly **unlimited** amount of information **almost indefinitely**. Indeed, there is some debate as to whether we actually ever “forget” anything at all, or whether **it just becomes increasingly difficult to access or retrieve certain items from memory.**

Short-term memories can become long-term memory through the process of consolidation, involving **rehearsal** and **meaningful association**. Unlike short-term memory (which relies mostly on an **acoustic**, and to a lesser extent a **visual**, code for storing information), **long-term memory encodes information for storage semantically** (i.e. based on meaning and association). However, there is also some evidence that long-term memory does also encode to some extent by **sound**. For example, when we cannot quite remember a word but it is “on the **tip of the tongue**”, this is usually based on the sound of a word, not its meaning.

Physiologically, the establishment of **long-term memory involves a process of physical changes in the structure of neurons** (or nerve cells) in the brain, a process known as **long-term potentiation**, although there is still much that is not completely understood about the process. At its simplest, whenever **something is learned, circuits of neurons in the brain, known as neural networks**, are created, altered or strengthened. These neural circuits are composed of a number of neurons that **communicate with one another through special junctions called synapses**. Through a process involving the **creation of new proteins within the body of neurons**, and the electrochemical transfer of **neurotransmitters** across synapse gaps to **receptors**, the communicative strength of certain circuits of neurons in the brain is reinforced. With repeated use, the efficiency of these synapse connections increases, facilitating the passage of nerve impulses along particular neural circuits, which may involve many connections to the **visual cortex**, the **auditory cortex**, the **associative regions** of the cortex, etc.

This process differs both structurally and functionally from the creation of working or short-term memory. Although the **short-term memory is supported by transient patterns of neuronal communication in the regions of the frontal, prefrontal and parietal lobes of the brain, long-term memories are maintained by more stable and permanent changes in neural connections widely spread throughout the brain**.

The **hippocampus** area of the brain essentially acts as a kind of **temporary transit point for long-term memories**, and is not itself used to store information. However, it is essential to the consolidation of information from short-term to long-term memory, and is thought to be involved in changing neural connections for a period of three months or more after the initial learning.

Unlike with short-term memory, **forgetting** occurs in long-term memory when the formerly strengthened synaptic connections among the neurons in a neural network become weakened, or when the activation of a new network is superimposed over an older one, thus causing **interference** in the older memory.

Over the years, several **different types of long-term memory** have been distinguished, including **explicit and implicit memory, declarative and procedural memory** (with a further sub-division of declarative memory into episodic and semantic memory) and retrospective and prospective

DECLARATIVE (EXPLICIT) & PROCEDURAL (IMPLICIT) MEMORY

Long-term memory is often divided into two further main types: **explicit (or declarative) memory and implicit (or procedural) memory.**

Declarative memory (“knowing what”) is memory of facts and events, and refers to those memories that can be **consciously recalled** (or "declared"). It is sometimes called **explicit memory**, since it consists of information that is explicitly stored and retrieved, although it is more properly a subset of explicit memory. Declarative memory can be **further sub-divided into episodic memory and semantic memory.**

Procedural memory (“knowing how”) is the **unconscious memory** of skills and how to do things, particularly the use of objects or movements of the body, such as tying a shoelace, playing a guitar or riding a bike. These memories are typically acquired through repetition and practice, and are composed of automatic sensorimotor behaviours that are so deeply embedded that we are no longer aware of them. Once learned, these "body memories" allow us to carry out ordinary motor actions more or less automatically. Procedural memory is sometimes referred to as **implicit**

memory, because previous experiences aid in the performance of a task without explicit and conscious awareness of these previous experiences, although it is more properly a subset of implicit memory.

These **different types of long-term memory are stored in different regions of the brain** and undergo quite different processes. **Declarative memories are encoded by the hippocampus**, **entorhinal cortex and perirhinal cortex (all within the medial temporal lobe** of the brain), but are **consolidated and stored in the temporal cortex and elsewhere**.

Procedural memories, on the other hand, do not appear to involve the hippocampus at all, and are **encoded and stored by the cerebellum, putamen, caudate nucleus and the motor cortex**, all of which are involved in motor control. Learned skills such as riding a bike are stored in the putamen; instinctive actions such as grooming are stored in the caudate nucleus; and the cerebellum is involved with timing and coordination of body skills. Thus, **without the medial temporal lobe (the structure that includes the hippocampus), a person is still able to form new procedural memories** (such as playing the piano, for example), but cannot remember the events during which they happened or were learned.

Perhaps the **most famous study demonstrating the separation of the declarative and procedural memories** is that of a **patient known as "H.M."**, who had parts of his medial temporal lobe, hippocampus and amygdala removed in 1953 in an attempt to cure his intractable epilepsy. After the surgery, H.M. **could still form new procedural memories and short-term memories, but long-lasting declarative memories could no longer be formed**.

The nature of the exact brain surgery he underwent, and the types of amnesia he experienced, allowed a good understanding of how particular areas of the brain are linked to specific processes in memory formation. In particular, his ability to recall memories from well **before** his surgery, but his inability to create **new** long-term memories, **suggests that encoding and retrieval of long-term memory information is mediated by distinct systems within the medial temporal lobe, particularly the hippocampus**.

The fact that **"HM" was able to learn hand-eye coordination skills such as mirror drawing**, despite **having absolutely no memory of having learned or practised the task before,** also suggested the existence **different types** of long-term memory, which are now known as declarative and procedural memories

There is strong evidence, notably by studying **amnesic** patients and the effect of **priming**, to suggest that **implicit memory is largely distinct from explicit memory,** and **operates through a different process in the brain.** Studies of the effects of amnesia have shown that it is quite possible to have an intact **implicit** memory despite a severely impaired **explicit** memory. Priming is the effect in which exposure to a stimulus influences response to a subsequent stimulus, so that, for instance, if a person reads a list of words including the word "concert", and is later asked to complete a word starting with "con", there is a higher probability that they will answer "concert" than, say, "contact", "connect", etc. Studies from amnesic patients indicate that priming is controlled by a brain system separate from the medial temporal system that supports explicit memory.

RETROSPECTIVE & PROSPECTIVE MEMORY

An important **alternative classification** of long-term memory used by some researchers is based on the **temporal direction** of the memories.

Retrospective memory is where the content to be remembered (people, words, events, etc) is in the past, i.e. the recollection of past episodes. It includes semantic, episodic and autobiographical memory, and declarative memory in general, although it can be either explicit or implicit.

Prospective memory is where the content is to be remembered in the future, and may be defined as **"remembering to remember"** or remembering to perform an intended action. It may be either event-based or time-based, often triggered by a **cue**, such as going to the doctor (action) at 4pm (cue), or remembering to post a letter (action) after seeing a mailbox (cue).

Clearly, though, retrospective and prospective memory are not entirely **independent** entities, and certain aspects of retrospective memory are usually required for prospective memory. Thus, there have been case studies where an impaired retrospective memory has caused a definite impact on prospective memory. However, there have also been studies where patients with an impaired prospective memory had an intact retrospective memory, suggesting that to some extent the two types of memory involve **separate processes**.

A recent study at the University of Michigan suggests that attention and short-term memory processing are directly affected by a person's surroundings and environment.
Two groups of individuals were tested on their attention and working memory performance, one group after a relaxed walk in a quiet park and the other group after navigating busy city streets. Those who had been walking the city streets scored far lower on the tests.

Short-term working memory appears to operate phonologically. For instance, whereas English speakers can typically hold seven digits in short-term memory, Chinese speakers can typically remember ten digits. This is because Chinese number words are all single syllables, whereas English are not.

The use of mnemonic devices can significantly increase memory, particularly the recall of long lists of names, numbers, etc. One case, known as "S.F.", was able to increase his digit span (the longest list of number that a person can repeat back in correct order) from 7 to 79 with the use of mnemonic strategies. Akira Haraguchi and Lu Chao's record-breaking recitations of the digits of the number Pi (100,000 and 67,890 digits respectively) also make use of mnemonic systems.

Children under the age of about seven pick up new languages easily without giving it much conscious thought, using procedural (or implicit) memory. Adults, on the other hand, actively learn the rules and vocabulary of a new language using declarative (or explicit) memory.