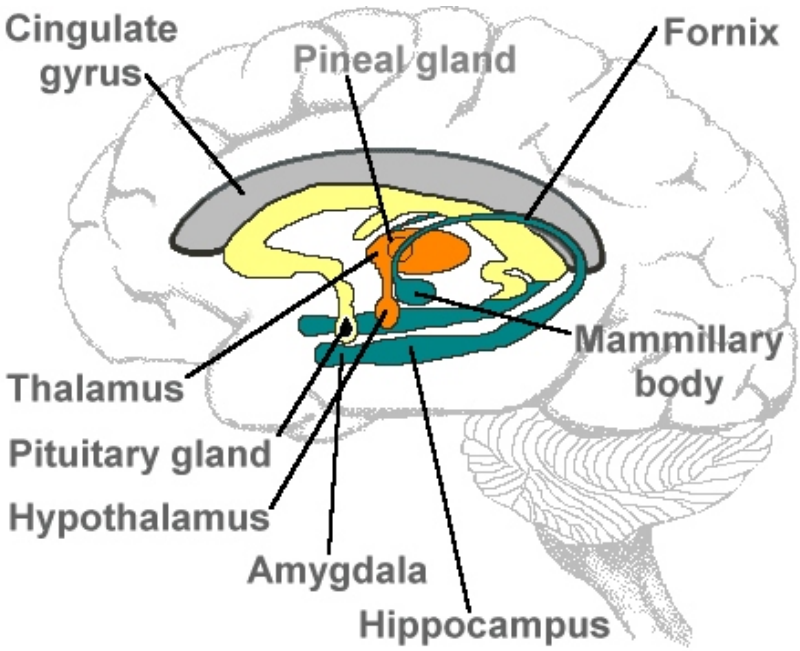


The Limbic System

The amygdala:

If you remember only one word about the amygdala, the word is FEAR. The amygdala is the nucleus responsible for the lurch you feel in your stomach when you turn around in a dark alley and notice someone following you. It couples a learned sensory stimulus (man in ski mask in alley = danger) to an adaptive response (fight or flight). On the basis of this information, you should be able to guess the primary inputs to and outputs from the amygdala.

Inputs: the amygdala must get sensory input, and it must be fairly highly processed input to recognize the elements of a scene that signal danger. The association areas of visual, auditory, and somatosensory cortices are the main inputs to the amygdala.

Outputs: the amygdala must be able to control the autonomic system, to provoke such an instant sympathetic response. The main outputs of the amygdala are to the hypothalamus and brainstem autonomic centers, including the vagal nuclei and the sympathetic neurons.

The amygdala is also involved with mood and the conscious emotional response to an event, whether positive or negative. To this end, the amygdala is also extensively interconnected with frontal cortex, mediodorsal thalamus, and the medial striatum.

The hippocampus and memory:

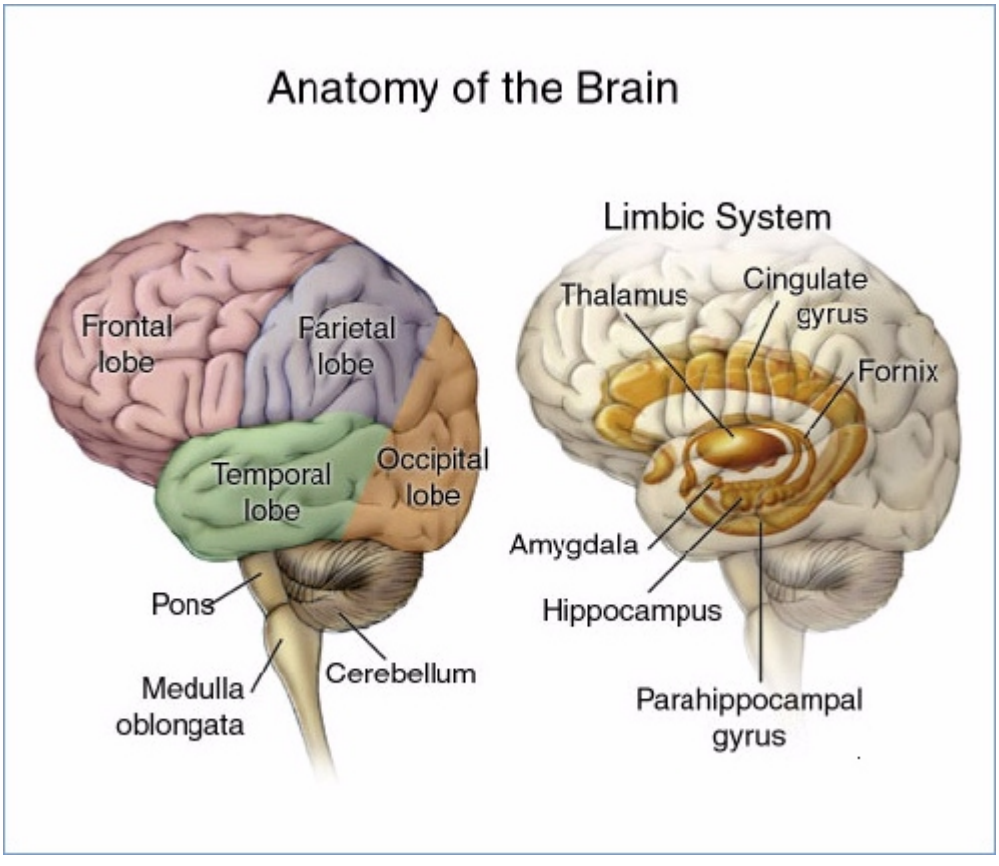
If the amygdala is FEAR, then the hippocampus is MEMORY. To understand exactly how the hippocampus is involved in memory, however, you must first know a little about memory.

There are at least three different types of memory. The most short term is working memory. Working memory is like the RAM of a computer. It is the type of memory that enables you to spit back the last sentence of a coversation when someone accuses you of not listening. Like the RAM of a computer, it is crucial for performing some common operations in your head: adding numbers, composing a sentence, following directions, etc. Also like a computer, the space devoted to that operation is recycled as soon as you turn to something else. It does not become a permanent memory. Working memory does not require the hippocampus; it is probably a cortical phenomenon.

The second type is what we most commonly associate with "memory". This is long-term or declarative memory, and is composed of all the facts, figures, and names you have ever learned. All of your experiences and conscious memory fall into this category. It is analogous to the hard drive of a computer. Although no one knows exactly where this enormous database is stored, it is clear that the hippocampus is necessary to file away new memories as they occur.

The third type is procedural memory, and is probably the most durable form of memory. These are actions, habits, or skills that are learned simply by repetition. Examples include playing tennis, playing an instrument, solving a puzzle, etc. The hippocampus is not involved in procedural memory, but it is likely that the cerebellum plays a role in some instances.

The significance of the hippocampus is driven home by a famous patient named H.M. As part of an epilepsy surgery, doctors removed most of his medial temporal lobes. Since that surgery, in 1953, he has formed no new memories. He can remember his childhood and everything before the surgery, and he still has working memory and the ability to form procedural memories. You can have a normal, lucid conversation with him, but if you leave the room for a moment, when you return he will not remember you or the conversation. He has completely lost the ability to lay down declarative memory.



Therefore, the hippocampus is critical in laying down declarative memory, but is not necessary for working memory, procedural memory, or memory storage. Damage to the hippocampus will only affect the formation of new declarative memories.

The mechanisms of the hippocampus are not entirely understood. The formation of memories probably involves long term potentiation, or LTP. This is a molecular process which strengthens groups of synapses that are repeatedly used. LTP is not sufficient to explain the storage of memory, though.