Adjourning Alzheimer's

Memory (Day 32)

Before we travel the road to diagnosing Alzheimer's, we need to talk about how memories are made. Yet before we discuss that, we need to introduce something called **emergence**.

An **emergent property** is one that arises as a result of the interactions among parts of a system, rather than the individual parts themselves. To understand the phenomenon of emergence, let's consider a couple of examples.

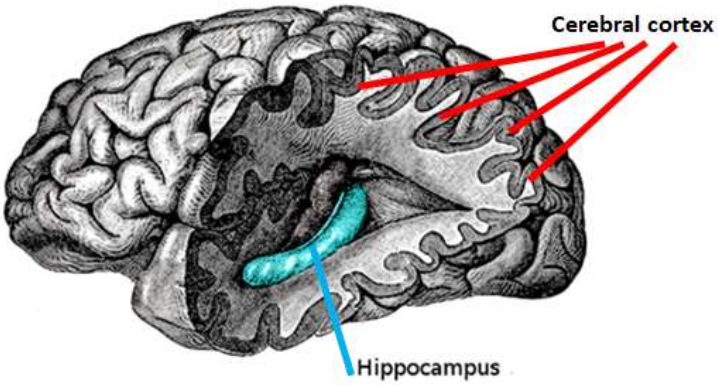
Alone, a fish swims in a wandering, haphazard manner. Yet when hundreds of fish are put together, they precisely space themselves from each other, synchronizing their swimming to move at the same speed, in the same direction. The **behaviour of a school of fish** is an emergent property that no individual fish can perform; this emergent behaviour arises from the **collective interactions between the fish**, not the individual fish.

Alone, an ant behaves erratically, virtually at random. Yet when millions of ants are put together, they organize themselves into incredibly long lines that march and work together to construct large, complex structures, such as ant hills and dams. The **behaviour of an ant colony** is an emergent property that no individual ant can perform; this emergent behaviour arises from the **collective interactions between the ants**, not the individual ants.

An ant hill, the result of emergent behaviour.

Similarly, a neuron alone can only fire signals, nothing more. Yet billions of neurons organized into a brain can make **memories**, emergent properties that arises out of the interactions between the neurons. Neurons do not "contain" memories; rather, the memories are emergent phenomena that arise from the **collective interactions between the neurons** as they send and receive signals to and from each other.

In general, a person's memories are necessary to let them survive and meaningfully interact within the world. The two brain structures most directly involved in making memories are the **hippocampus** and **cerebral cortex**. The hippocampus consists of a pair of small, seahorse-shaped structures that lies adjacent to the cerebral cortex, a much larger structure that envelops most of the brain (although much smaller in size, the hippocampus is quite a bit older in evolution than the cerebral cortex).

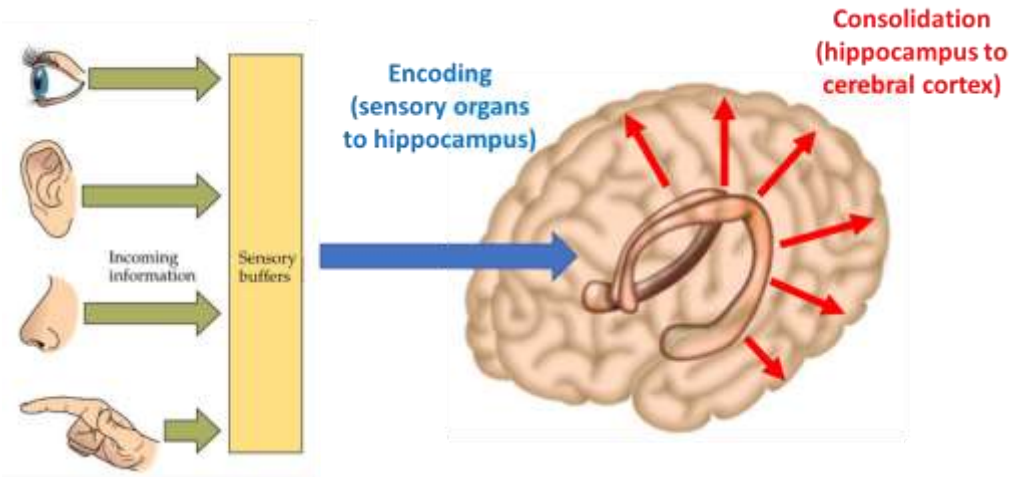


Small hippocampus, large cerebral cortex.

The **creation of memories** involves the transfer of real-world sensory information, picked up by sensory organs such as the eyes and ears and sent in the form of signals, to the hippocampus and cerebral cortex. These memories can be **episodic** (personal experiences that occurred in a specific place and time; for example, remembering an enjoyable meal in a restaurant in Buenos Aires) or **semantic** (facts about the world learned independently of personal experience; for example, knowing that Buenos Aires is the capital of Argentina). Both kinds of memories are created during a two-step process that spans both wakefulness and sleep.

The initial step in memory creation occurs during **wakefulness** and involves the transfer of real-world sensory information to the neurons of the hippocampus; this is called **encoding**. In encoding, specific hippocampal neurons temporarily modify their signals to form an emergent representation of an experience or fact in the real world, resulting in the creation of a short-term episodic or semantic memory, respectively. However, if the newly-encoded memories remain within the hippocampus, then within a few hours to days, they will be forgotten.

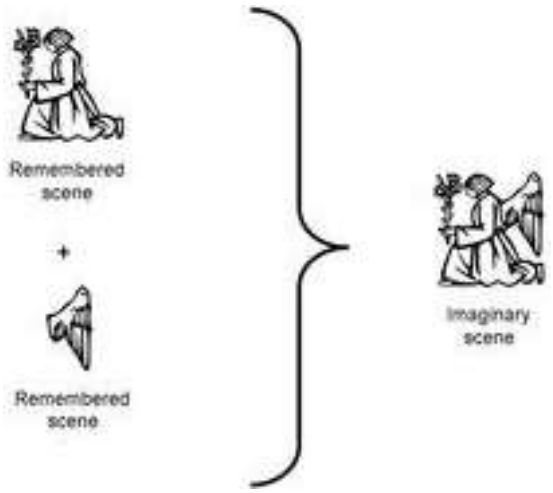
The latter step in memory creation occurs during **non-rapid eye movement (NREM) sleep** and involves the transfer of encoded hippocampal memories to the cerebral cortex; this is called **consolidation**. In consolidation, the hippocampus "replays" encoded memories back to the cerebral cortex in modified form, allowing the cerebral cortex neurons to store the "gist" of the encoded memories (rather than the details). This results in the creation of long-term memories; the more the memories are consolidated, the more permanent they become.



Memory creation - encoding involves the transfer of sensory information to the hippocampus during wakefulness, consolidation involves the transfer of encoded hippocampal memories to the cerebral cortex during NREM sleep.

The **utilization of memories** involves the relay of consolidated memories in the cerebral cortex back to the hippocampus. Like memory creation, memory utilization also spans wakefulness and sleep.

In memory **retrieval and reassembly**, which occurs during **wakefulness**, consolidated memories in the cerebral cortex are relayed to and reassembled by the hippocampus. This may occur in **realistic** ways that mirror the actual experience or fact the memories were based on - for example, when picturing an image of a person or bird. However, memories can also be relayed and reassembled in non-realistic, **imagined** ways that may not be directly relevant to the original experience or fact - for example, when picturing an image of an angel, which is reconstructed from the images of a person and bird. Once retrieved and reassembled, these memories are used to form our perspectives and guide our actions.



Memories can be retrieved and reassembled in realistic ways (such as when picturing a person or a bird wing), but also in imaginative ways (such as an angel).

In dreams, which largely occur during **rapid eye movement (REM) sleep**, consolidated memories in the cerebral cortex are **semi-randomly relayed** back to the hippocampus (there are also NREM dreams, but they are less random and likely related to hippocampal replay). Dreams represent the resurrected parts of a person's long-term memories that probably identify unresolved, often stressful issues requiring that person's real-world attention; they also form our perspectives and guide our actions, but in more subtle ways.

The creation and utilization of episodic and semantic memories relies on the constant back-and-forth transfer of those memories between hippocampus and cerebral cortex; a **cognitive dance**, one in which the memories are continuously refined and modified.

It is the dance between hippocampus and cerebral cortex that builds each person's **inner model of the world**, reality as seen through their eyes.

The dance that guides us, and more or less **defines** us.

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References

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