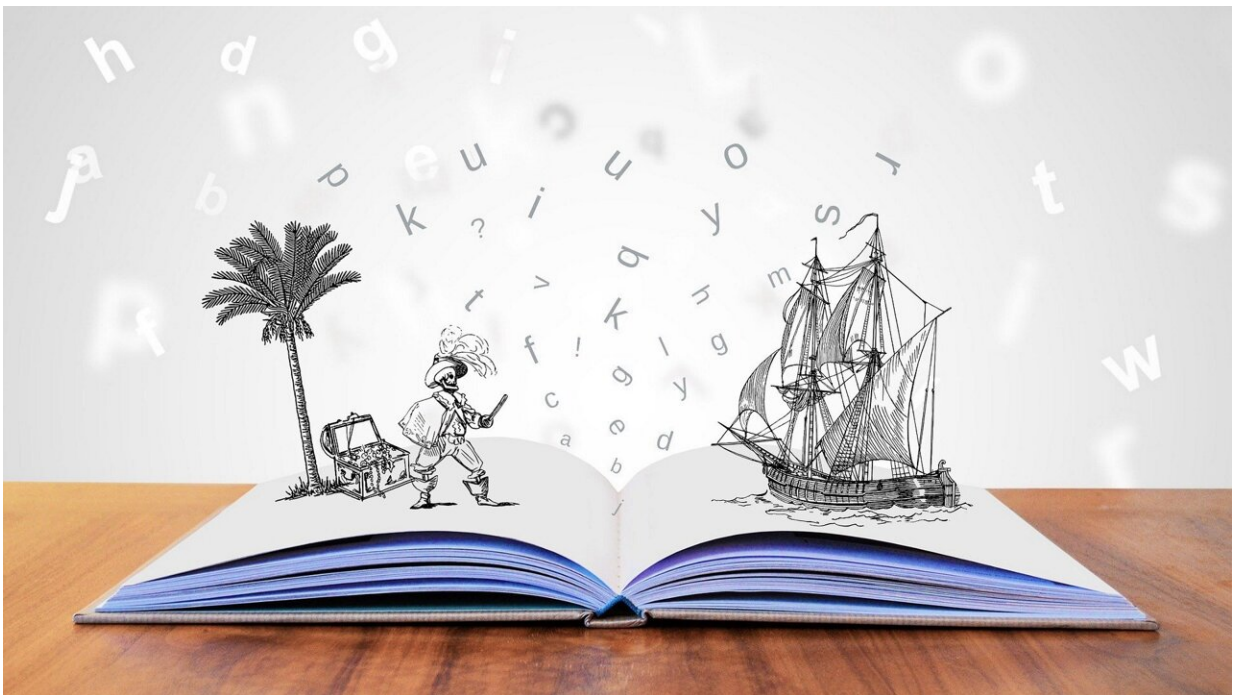


# Imagination makes us human—this unique ability to envision what doesn't exist has a long evolutionary history

February 23 2023, by Andrey Vyshedskiy

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You can easily picture yourself riding a bicycle across the sky even though that's not something that can actually happen. You can envision yourself doing something you've never done before—like water skiing—and maybe even imagine a better way to do it than anyone else.

Imagination involves creating a mental image of something that is not present for your senses to detect, or even something that isn't out there in reality somewhere. Imagination is one of the key abilities that make us human. But where did it come from?

[I'm a neuroscientist](#) who studies how children acquire [imagination](#). I'm especially interested in the neurological mechanisms of imagination. Once we identify what brain structures and connections are necessary to mentally construct new objects and scenes, scientists like me can look back over the course of evolution to see when these [brain areas](#) emerged—and potentially gave birth to the first kinds of imagination.

## From bacteria to mammals

After [life emerged on Earth](#) around 3.4 billion years ago, organisms gradually became more complex. Around 700 million years ago, neurons organized into [simple neural nets](#) that then [evolved into the brain and spinal cord](#) around 525 million years ago.

[Eventually dinosaurs evolved around 240 million](#) years ago, with [mammals emerging a few million years later](#). While they shared the landscape, dinosaurs were very good at catching and [eating small, furry mammals](#). Dinosaurs were cold-blooded, though, and, like modern cold-blooded reptiles, could only move and hunt effectively [during the daytime when it was warm](#). To avoid predation by dinosaurs, [mammals](#) stumbled upon a solution: [hide underground during the daytime](#).

Not much food, though, grows underground. To eat, mammals had to travel above the ground—but the safest time to forage was at night, when dinosaurs were less of a threat. [Evolving to be warm-blooded](#) meant mammals could move at night. That solution came with a trade-off, though: Mammals had to eat a lot more food than dinosaurs per unit of weight [in order to maintain their high metabolism](#) and to support their

constant inner body temperature around 99 degrees Fahrenheit (37 degrees Celsius).

Our mammalian ancestors had to find [10 times more food](#) during their short waking time, and they had to find it in the dark of night. How did they accomplish this task?

To optimize their foraging, mammals developed a new system to efficiently memorize places where they'd found food: linking the part of the brain that records sensory aspects of the landscape—how a place looks or smells—to the part of the brain that controls navigation. They encoded features of the landscape in the neocortex, the outermost layer of the brain. They encoded navigation in the entorhinal cortex. And the [whole system was interconnected](#) by the brain structure called the hippocampus. [Humans still use this memory system](#) for remembering objects and past events, such as your car and where you parked it.

[Groups of neurons](#) in the neocortex encode these memories of objects and past events. Remembering a thing or an episode [reactivates the same neurons](#) that initially encoded it. All mammals likely can recall and re-experience previously encoded objects and events by reactivating these groups of neurons. This neocortex-hippocampus-based [memory system](#) that evolved 200 million years ago became the first key step toward imagination.

The next building block is the capability to construct a "memory" that hasn't really happened.

## **Involuntary made-up 'memories'**

The simplest form of imagining new objects and scenes happens in dreams. These vivid, bizarre involuntary fantasies are associated in people with the [rapid eye movement](#) (REM) stage of sleep.

Scientists hypothesize that species whose rest includes periods of REM sleep [also experience dreams](#). Marsupial and placental mammals do have REM sleep, but the egg-laying [mammal](#) the echidna does not, suggesting that this stage of the sleep cycle [evolved after these evolutionary lines diverged](#) 140 million years ago. In fact, recording from specialized neurons in the brain called [place cells](#) demonstrated that animals can "dream" of going [places they've never visited before](#).

In humans, solutions found during dreaming can [help solve problems](#). There are numerous examples of scientific and engineering solutions spontaneously visualized during sleep.

The neuroscientist Otto Loewi dreamed of an experiment that proved nerve impulses are [transmitted chemically](#). He immediately went to his lab to perform the experiment—later receiving the Nobel Prize for this discovery.

Elias Howe, the inventor of the first sewing machine, claimed that the main innovation, placing the thread hole near the tip of the needle, [came to him in a dream](#).

Dmitri Mendeleev described seeing in a dream "[a table where all the elements fell into place as required](#). Awakening, I immediately wrote it down on a piece of paper." And that was the periodic table.

These discoveries were enabled by the same mechanism of involuntary imagination first acquired by mammals 140 million years ago.

## **Imagining on purpose**

The difference between voluntary imagination and involuntary imagination is analogous to the difference between voluntary muscle control and muscle spasm. Voluntary muscle control allows people to

deliberately combine muscle movements. Spasm occurs spontaneously and cannot be controlled.

Similarly, voluntary imagination allows people to deliberately combine thoughts. When asked to mentally combine two identical right triangles along their long edges, or hypotenuses, you envision a square. When asked to mentally cut a round pizza by two perpendicular lines, you visualize four identical slices.

This deliberate, responsive and reliable capacity to combine and recombine mental objects is called prefrontal synthesis. It relies on the ability of the prefrontal cortex located at the very front of the brain to control the rest of the neocortex.

When did our species acquire the ability of prefrontal synthesis? Every artifact dated before 70,000 years ago could have been made by a creator who lacked this ability. On the other hand, starting about that time there are various archeological artifacts unambiguously indicating its presence: composite figurative objects, such as [lion-man](#); [bone needles with an eye](#); [bows and arrows](#); [musical instruments](#); [constructed dwellings](#); [adorned burials suggesting the beliefs in afterlife](#), and many more.

Multiple types of archaeological artifacts unambiguously associated with prefrontal synthesis appear simultaneously around 65,000 years ago in multiple geographical locations. This [abrupt change](#) in imagination has been characterized by historian Yuval Harari as the "[cognitive revolution](#) ." Notably, [it approximately coincides with](#) the largest [Homo sapiens' migration out of Africa](#).

[Genetic analyses suggest](#) that a few individuals acquired this prefrontal synthesis ability and then spread their genes far and wide by eliminating other contemporaneous males with the use of an imagination-enabled

strategy and newly developed weapons.

So it's been a journey of many millions of years of evolution for our species to become equipped with imagination. Most nonhuman mammals have potential for imagining what doesn't exist or hasn't happened involuntarily during REM sleep; only humans can voluntarily conjure new objects and events in our minds using prefrontal synthesis.

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