

How Human Memory Works

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Human memory is a complex, brain-wide process that is essential to who we are. Learn about encoding, the brain, and short- and long-term memory. See more [brain pictures](#).

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How Human Memory Works Overview

The more you know about your memory, the better you'll understand how you can improve it. Here's a basic overview of how your memory works and how [aging](#) affects your ability to remember.

Your baby's first [cry](#)...the taste of your grandmother's molasses cookies...the scent of an ocean breeze. These are memories that make up the ongoing experience of your life -- they provide you with a sense of self. They're what make you feel comfortable with familiar people and surroundings, tie your past with your present, and provide a framework for the future. In a profound way, it is our collective set of memories -- our "memory" as a whole -- that makes us who we are.

Most people talk about memory as if it were a thing they have, like bad eyes or a good head of hair. But your memory doesn't exist in the way a part of your body exists -- it's not a "thing" you can touch. It's a concept that refers to the process of remembering.

In the past, many experts were fond of describing memory as a sort of tiny filing cabinet full of individual memory folders in which information is stored away. Others likened memory to a neural supercomputer wedged under the human scalp.

But today, experts believe that memory is far more complex and elusive than that -- and that it is located not in one particular place in the [brain](#) but is instead a brain-wide process.

Do you remember what you had for breakfast this morning? If the image of a big plate of fried eggs and bacon popped into your mind, you didn't dredge it up from some out-of-the-way neural alleyway. Instead, that memory was the result of an incredibly complex constructive power -- one that each of us possesses -- that reassembled disparate memory impressions from a web-like pattern of cells scattered throughout the brain. Your "memory" is really made up of a group of systems that each play a different role in creating, storing, and recalling your memories. When the brain processes information normally, all of these different systems work together perfectly to provide cohesive thought.

What seems to be a single memory is actually a complex construction. If you think of an object -- say, a pen -- your brain retrieves the object's name, its shape, its function, the sound when it scratches across the page. Each part of the memory of what a "pen" is comes from a different region of the brain. The entire image of "pen" is actively reconstructed by the brain from many different areas. Neurologists are only beginning to understand how the parts are reassembled into a coherent whole.

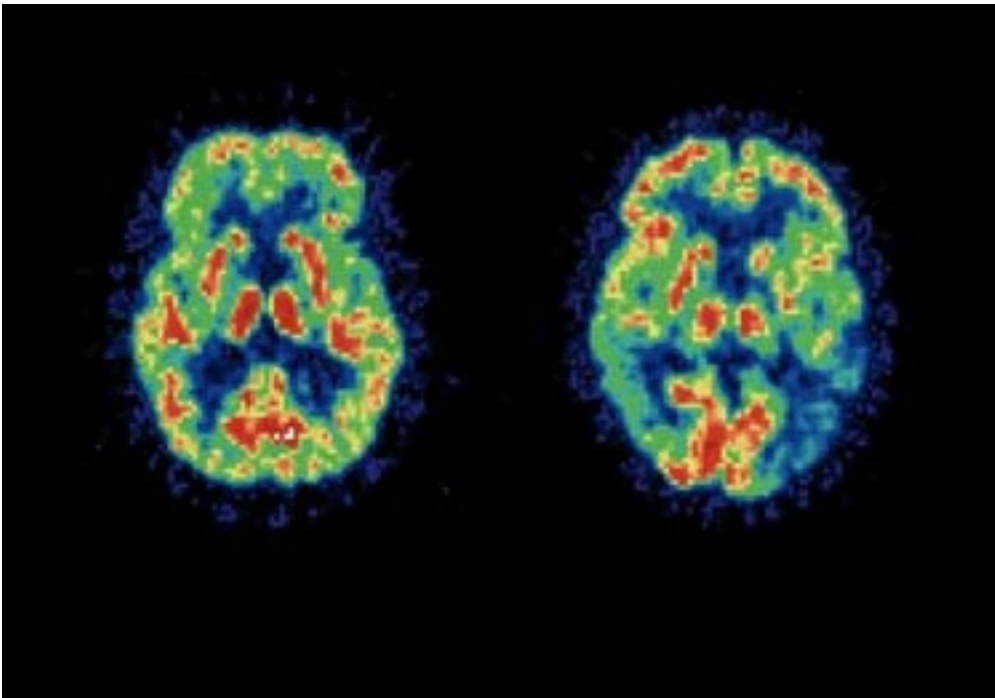
If you're riding a bike, the memory of how to operate the bike comes from one set of brain cells; the memory of how to get from here to the end of the block comes from another; the memory of biking safety rules from another; and that nervous feeling you get when a car veers dangerously close, from still another. Yet you're never aware of these separate mental experiences, nor that they're coming from all different parts of your brain, because they all work together so well. In fact, experts tell us there is no firm distinction between how you remember and how you think.

This doesn't mean that scientists have figured out exactly how the system works. They still don't fully understand exactly how you remember or what occurs during recall. The search for how the brain organizes memories and where those memories are acquired and stored has been a never-ending quest among brain researchers for decades. Still, there is enough information to make some educated guesses. The process of memory begins with encoding, then proceeds to storage and, eventually, retrieval.

On the next page, you'll learn how encoding works and the brain activity involved in retrieving a memory.



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The typical brain has about 100 trillion synapses, which are the points where nerve cells in the human brain connect with other cells.

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Memory Encoding

Encoding is the first step in creating a memory. It's a biological phenomenon, rooted in the senses, that begins with perception. Consider, for example, the memory of the first person you ever [fell in love](#) with. When you met that person, your visual system likely registered physical features, such as the color of their eyes and hair. Your auditory system may have picked up the sound of their laugh. You probably noticed the scent of their perfume or cologne. You may even have felt the [touch](#) of their hand. Each of these separate sensations traveled to the part of your brain called the hippocampus, which integrated these perceptions as they were occurring into one single experience -- your experience of that specific person.

Experts believe that the hippocampus, along with another part of the [brain](#) called the frontal cortex, is responsible for analyzing these various sensory inputs and deciding if they're worth remembering. If they are, they may become part of your long-term memory. As indicated earlier, these various bits of information are then stored in different parts of the brain. How these bits and pieces are later identified and retrieved to form a cohesive memory, however, is not yet known.

Although a memory begins with perception, it is encoded and stored using the language of electricity and chemicals. Here's how it works: Nerve cells connect with other cells at a point called a synapse. All the action in your brain occurs at these synapses, where electrical pulses carrying messages leap across gaps between cells.

The electrical firing of a pulse across the gap triggers the release of chemical messengers called neurotransmitters. These neurotransmitters diffuse across the spaces between cells, attaching themselves to neighboring cells. Each brain cell can form thousands of links like this, giving a typical brain about 100 trillion synapses. The parts of the brain cells that receive these electric impulses are called dendrites, feathery tips of brain cells that reach out to neighboring brain cells.

The connections between brain cells aren't set in concrete -- they change all the time. Brain cells work together in a network, organizing themselves into groups that specialize in different kinds of information processing. As one brain cell sends signals to another, the synapse between the two gets stronger. The more signals sent between them, the stronger the connection grows. Thus, with each new experience, your brain slightly rewires its physical structure. In fact, how you use your brain helps determine how your brain is organized. It is this flexibility, which scientists call plasticity, that can help your brain rewire itself if it is ever damaged.

As you learn and experience the world and changes occur at the synapses and dendrites, more connections in your brain are created. The brain organizes and

reorganizes itself in response to your experiences, forming memories triggered by the effects of outside input prompted by experience, education, or training.

These changes are reinforced with use, so that as you learn and practice new information, intricate circuits of knowledge and memory are built in the brain. If you play a piece of music over and over, for example, the repeated firing of certain cells in a certain order in your brain makes it easier to repeat this firing later on. The result: You get better at playing the music. You can play it faster, with fewer mistakes. Practice it long enough and you will play it perfectly. Yet if you stop practicing for several weeks and then try to play the piece, you may notice that the result is no longer perfect. Your brain has already begun to forget what you once knew so well.

To properly encode a memory, you must first be paying attention. Since you cannot pay attention to everything all the time, most of what you encounter every day is simply filtered out, and only a few stimuli pass into your conscious awareness. If you remembered every single thing that you noticed, your memory would be full before you even left the house in the morning. What scientists aren't sure about is whether stimuli are screened out during the sensory input stage or only after the brain processes its significance. What we do know is that how you pay attention to information may be the most important factor in how much of it you actually remember.

Short and Long Term Memory

Once a memory is created, it must be stored (no matter how briefly). Many experts think there are three ways we store memories: first in the sensory stage; then in short-term memory; and ultimately, for some memories, in long-term memory. Because there is no need for us to maintain everything in our [brain](#), the different stages of human memory function as a sort of filter that helps to protect us from the flood of information that we're confronted with on a daily basis.

The creation of a memory begins with its perception: The registration of information during perception occurs in the brief sensory stage that usually lasts only a fraction of a second. It's your sensory memory that allows a perception such as a visual pattern, a sound, or a [touch](#) to linger for a brief moment after the stimulation is over.

After that first flicker, the sensation is stored in short-term memory. Short-term memory has a fairly limited capacity; it can hold about seven items for no more than 20 or 30 seconds at a time. You may be able to increase this capacity somewhat by using various memory strategies. For example, a ten-digit number such as 8005840392 may be too much for your short-term memory to hold. But divided into chunks, as in a telephone number, 800-584-0392 may actually stay in your short-term memory long enough for you to dial the telephone. Likewise, by repeating the number to yourself, you can keep resetting the short-term memory clock.

Important information is gradually transferred from short-term memory into long-term memory. The more the information is repeated or used, the more likely it is to eventually end up in long-term memory, or to be "retained." (That's why studying helps people to perform better on tests.) Unlike sensory and short-term memory, which are limited and decay rapidly, long-term memory can store unlimited amounts of information indefinitely.

People tend to more easily store material on subjects that they already know something about, since the information has more meaning to them and can be mentally connected to related information that is already stored in their long-term memory. That's why someone who has an average memory may be able to remember a greater depth of information about one particular subject.

Most people think of long-term memory when they think of "memory" itself -- but most experts believe information must first pass through sensory and short-term memory before it can be stored as a long-term memory. To learn how information makes its way out of long-term memory, see the next page. We will explore how memories are recalled and what happens when a memory cannot be retrieved - a phenomenon you might call "forgetting."

Memory Retrieval

When you want to remember something, you retrieve the information on an unconscious level, bringing it into your conscious mind at will. While most people think they have either a "bad" or a "good" memory, in fact, most people are fairly good at remembering some types of things and not so good at remembering others. If you do have trouble remembering something -- assuming you don't have a physical disease -- it's usually not the fault of your entire memory system but an inefficient component of one part of your memory system.

Let's look at how you remember where you put your eyeglasses. When you go to bed at night, you must register where you place your eyeglasses: You must pay attention while you set them on your bedside table. You must be aware of where you are putting them, or you won't be able to remember their location the following morning. Next, this information is retained, ready to be retrieved at a later date. If the system is working properly, when you wake up in the morning you will remember exactly where you left your eyeglasses.

If you've forgotten where they are, one of several things could have happened:

- You may not have registered clearly where you put them down to begin with.
- You may not have retained what you registered.
- You may not be able to retrieve the memory accurately.
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Therefore, if you want to stop forgetting where you left your eyeglasses, you will have to work on making sure that all three stages of the remembering process are working properly.

If you've forgotten something, it may be because you didn't encode it very effectively, because you were distracted while encoding should have taken place, or because you're having trouble retrieving it. If you've "forgotten" where you put your eyeglasses, you may not have really forgotten at all -- instead, the location of your eyeglasses may never have gotten into your memory in the first place. For example, you probably would say that you know what a five-dollar bill looks like, but most of the times that you've seen one, you've not really encoded its appearance, so that if you tried to describe it, you probably couldn't.

Distractions that occur while you're trying to remember something can really get in the way of encoding memories. If you're trying to read a business report in the middle of a busy airport, you may think you're remembering what you read, but you may not have effectively saved it in your memory.

Finally, you may forget because you're simply having trouble retrieving the memory. If you've ever tried to remember something one time and couldn't, but then later you remember that same item, it could be that there was a mismatch between retrieval cues and the encoding of the information you were searching for. As we get older, memory problems tend to increase. In the next section, you will learn how aging can affect memory.

Effects of Aging on Memory

There you are at a business function and you see a colleague across the room. As you walk over, you suddenly realize you can't remember the person's name. Odds are you're not suddenly developing [Alzheimer's disease](#), although many people jump to that conclusion. You're simply experiencing a breakdown of the assembly process of memory -- a breakdown that many of us begin to experience in our 20s and that tends to get worse as we reach our 50s. This age-dependent loss of function appears in many animals, and it begins with the onset of sexual maturity.

We saw earlier in this chapter that as you learn and remember, your brain doesn't change its overall structure or grow whole new batches of [nerve cells](#) -- it's the connections between cells that change as you learn. Your synapses are reinforced, and cells make more and stronger connections with each other. But as you begin to age, these synapses begin to falter, which begins to affect how easily you can retrieve memories.

Researchers have several theories about what's behind this deterioration, but most suspect that aging causes major cell loss in a tiny region in the front of the brain that leads to a drop in the production of a neurotransmitter called acetylcholine. Acetylcholine is vital to learning and memory.

In addition, some parts of the brain that are essential to memory are highly vulnerable to [aging](#). One area, called the hippocampus, loses 5 percent of its nerve cells with each passing decade -- for a total loss of 20 percent by the time you reach your 80s. In addition, the brain itself shrinks and becomes less efficient as you age.

Of course, other things can happen to your brain to speed up this decline. You may have inherited some unhealthy genes, you might have been exposed to poisons, or perhaps you smoked or drank too much. All these things speed up memory decline.

So you can see that as you age, some physical changes in the brain can make it more difficult to remember efficiently. The good news is that this doesn't mean that memory loss and dementia are inevitable. While some specific abilities do decline with age, overall memory remains strong for most people throughout their 70s. In fact, research shows that the average 70-year-old performs as well on certain cognitive tests as do many 20-year-olds, and many people in their 60s and 70s score significantly better in verbal intelligence than do younger people.

Studies also have shown that many of the memory problems experienced by older people can be lessened -- or even reversed. Studies of nursing-home populations show that patients were able to make significant improvements in memory when given rewards and challenges. Physical exercise and mental stimulation also can really improve mental function.

Evidence from animal studies suggests that stimulating the brain can stop cells from shrinking and can even increase brain size in some cases. Studies show that rats living in enriched environments with lots of toys and challenges have larger outer brains with larger, healthier brain cells. And animals given lots of mental exercise have more dendrites, which allow their cells to communicate with each other. Research has shown that, in our later years, a stimulating environment encourages the growth of these dendrites, while a dull environment impedes it.

The important point to remember is that as you age, you may not learn or remember as quickly as you did when you were in school -- but you will likely learn and remember nearly as well. In many cases, an older person's brain may be less effective not because of a structural or organic problem but simply as a result of lack of use.

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