Special Health Report

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Improving Memory

How to boost brain health and mental sharpness

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IMPROVING MEMORY
SPECIAL HEALTH REPORT

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ISBN 978-1-61401-322-8

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Harvard Health Publishing
Trusted advice for a healthier life

Dear Reader,

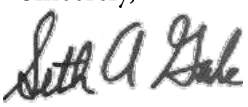
If you've picked up this Special Health Report, it's likely that you're worried about your memory. You may perceive that your memory isn't quite what it used to be. You may struggle to find occasional names or words that once came effortlessly. You may fear that these lapses—a perfectly normal sign of aging—are an early warning of dementia, and that thought may terrify you. After all, your memories define you. They make up your internal biography, the stories you tell yourself about the important events in your life, the people who've mattered to you, and the experiences you've had—in short, who you are. What would you be without your memories?

There's no getting around the fact that the ability to remember does change with age. However, as you will learn in this report, there also are ways to minimize the losses. Since the Decade of the Brain in the 1990s, we have come a long way in advancing our understanding of this vital organ. We have a deeper knowledge of how the brain functions and have unlocked many of the mysteries underlying memory. We know more about the causes and risk factors for cognitive decline. Conversely, we also have evidence for the kinds of behaviors that can help promote successful cognitive aging.

Whatever stage of life you are at, the time is now to commit to enhancing your brain and protecting it as much as possible from decline. Staying mentally active and learning new skills are good ways to do this. Although it may seem less obvious, brain health is also linked with your overall health, so it's important to keep the rest of your body in good condition, in particular the cardiovascular system. Exercise is among the best ways to maintain not only a healthy body, but also a healthy brain and a resilient memory.

In short, there are important measures you can take to protect your brain as you age. This report will show you 17 concrete steps for enhancing and preserving your memory, as well as numerous practical strategies for improving everyday recall. It will also answer common questions about memory and will provide you with important ways to help distinguish between normal memory changes and those due to disease. Finally, it will help you understand why memory, at any age, is imperfect—and that's often a good thing.

Sincerely,



Seth A. Gale, M.D.
Medical Editor

Dr. Gale would like to acknowledge the work of Dr. Kirk Daffner, the J. David and Virginia Wimberly Professor of Neurology at Harvard Medical School, who created the original version of this report.

Understanding memory

Do you worry about your memory? Many people do, especially as they age. But if you stop to think about it, all your life, you've probably experienced times when your memory failed you—perhaps on a high school history test or an examination for a driver's license. (Exactly how many feet away from a fire hydrant do you have to park, anyway?) Even as a teenager, did you remember all the verses of a popular song, or only the chorus?

Memory is not perfect, no matter how old you are. True, some people have amazing powers of recall. They remember details of events that have long since escaped you. But nature did not design the human brain—even theirs—for perfect recollection of every detail in daily life. Just as you delete old emails on your computer to create space for new ones, the brain routinely prunes out unneeded information, making way for newer, more relevant memories.

Moreover, memories are not like snapshots that are taken and then stored in their entirety in one place in the brain. Rather, memories are encoded in a fragmented manner and distributed throughout different parts of the brain; these different pieces must be reassembled when you remember something, creating the possibility that you may reconstruct the memory imperfectly. Adding to all this uncertainty, memories of an event—even one you witnessed—can be heavily influenced by what other people tell you happened or by your own biases. That's why eyewitness testimony can be unreliable.

In short, it's normal to forget things. It's also normal to become somewhat more forgetful as you grow older. However, there are numerous steps you can take to improve your memory and promote a healthy brain, plus tricks that can help you with simple challenges like remembering where you left your keys. This report will serve as your road map.

But what if your memory problems go beyond what is normal? How can you tell whether your memory lapses are caused by normal aging or something more serious, like dementia? There are some key differences, which you'll read about later in this report (see "Memory problems: Normal aging or brain disease?" on page 41). While there is still no cure for these disorders, the healthy lifestyle changes in this report can help you reduce your risk for dementia, or at least delay its onset.

Memories are not like snapshots that contain all their visual information together, complete and fully assembled. Rather, memories are fragmented, with components stored in different parts of the brain.

But first, it's important to understand the different types of memory—for example, short-term versus long-term, or procedural versus episodic. Certain types of memories are naturally more durable than others.

What is memory?

Memory refers to all that you remember, as well as your capacity for remembering. But not all memories are created equal. Some memories are meant to be retained for a short period and then discarded. For example, you only need to remember the security code your bank texts you long enough to enter it. By contrast, memories that are more important—such as

the names of close friends and relatives, your home address, and salient events in your life—are kept in the brain's equivalent of long-term storage and can be retrieved at will. Researchers and neuroscientists have devised several classification systems to describe the various forms of memory. One major system is based on the length of time you recall something, whether short-term or long-term. Another is based on the type of information you remember—for example, facts that you need to consciously recall or procedures that you can carry out automatically.

Short-term memory

Short-term memory refers to information that the mind stores temporarily, encompassing what you need to remember in the next few seconds or minutes. Short-term memories include, for example, the name of the person you just met fleetingly at a cocktail party (as well as what that person said), and the phone number of the local pizzeria, which you can forget as soon as you've placed the call.

An important form of short-term memory is working memory, which enables you to manipulate information while holding it in short-term storage. For example, working memory comes into play when you remember prices at the supermarket while at the same time performing a computation with them so you can compare costs between different brands or quantities.

Short-term memories are by nature fleeting. They turn over at a high rate because new ones are continually replacing them, and there are only so many short-term memories you can keep in mind. Research shows that the average person can hold only about seven (plus or minus two) unrelated "bits" of information in mind at one time. That's why it's easier to remember a seven-digit phone number than a longer number such as the identification number on a driver's license.

The relatively transient nature of your short-term memory is actually beneficial because it allows you to discard unnecessary information. Imagine what life would be like if you kept every short-term memory—the price of each dish you ordered from a Chinese restaurant, or what color tie your friend wore every day last month. Your mind would be so overloaded with trivia that you'd have trouble focusing on the things that really are important. It would be as if you kept all your junk mail and let it bury your personal letters, bank statements, and other important documents.

Short-term memory has another limitation. It is fragile and easily disturbed by interruptions. If you're trying to remember a phone number and someone

Flashbulb memory

Memory researchers use the term "flashbulb memory" to describe a vivid memory of the circumstances in which you learned about an unexpected, emotionally charged public event, such as the assassination of President Kennedy, the space shuttle Challenger accident, or the attack on the World Trade Center. Unlike many ordinary events you see on television or hear about from others, these events become ingrained in your memory, along with numerous minute details associated with your physical and mental state when you heard the news—where you were standing, what you were doing, who was around you, and so on. It is likely that the combination of profound meaning and emotional impact surrounding these events serves to inscribe them intensively in long-term memory.

Experts used to assume that flashbulb memories remained more accurate over time than ordinary memories, but research has shown that they are vulnerable to the same biases and distortions as memories of less dramatic events.

This theory has been corroborated in studies of different groups of people in the aftermath of the Sept. 11, 2001, terrorist attack. In a study in *The Journal of Experimental Psychology*, researchers questioned more than 3,000 people from seven U.S. cities about their memories of learning about 9/11. Participants were interviewed one week after the event and again after 11 months, 35 months, and 119 months (one month before major anniversaries). They answered questions about where they were, what they were doing, and how they felt when they first heard the news, as well as specific facts about the attack, such as the number of planes involved. The researchers found that the rate of forgetting was greatest in the first year and then leveled off—a pattern similar to ordinary memories that people have about their own life (autobiographical memories).

Flashbulb memories are distinct and important enough to be inscribed in your memory, but can be distorted over time.

walks into the room and asks you a question, chances are you'll forget the number and have to look it up again. Shifting your focus of attention to answer the question overwrites the phone number, which was being held in short-term memory.

Long-term memory

Although most unimportant short-term memories quickly decay, the brain tends to store the important ones—those that are emotionally compelling or personally meaningful. These memories can surround positive events, such as the birth of your child, or negative ones, such as the death of a parent. That stored information is long-term memory. It reflects the total of what you know: a compendium of data ranging from your name, address, and phone number to more complex information, such as the sounds and images of important events that happened decades ago. It also includes the routine information you use every day, like how to make coffee, operate your computer, and carry out all of the intricate sequences involved in performing your job or running your household.

Most people can hold only about seven bits of information in short-term memory at a time—a perfect amount for recalling a phone number.

Your long-term memory and short-term memory are not distinguished merely by how long the memories last. Another difference is the amount of information each memory system and its associated brain regions can handle. Although the brain can juggle only a relatively small number of short-term memories at a time, it can store an enormous number of long-term memories. Barring disease or injury, you can always learn and retain something new. Furthermore, long-term memories are less fragile than short-term memories, which means they're not lost when something interrupts your train of thought. Some types of previously learned long-term memories even tend to remain intact in the early stages of dementia, when people have trouble learning new information. This applies especially to procedural memory, the type of long-term memory that allows you to perform various tasks, such as walking or riding a bike, without consciously thinking about it.

Maintaining a long-term memory often requires that you periodically "revisit" it. Some memories that go unused for a long time fade or become distorted. Have you ever read a book that you loved, but years later found yourself unable to recall much more than the title? That's probably because you hadn't thought of the plot and characters in a long time. On the other hand, certain long-term memories are amazingly persistent, no matter how infrequently you use them. For example, many adults are surprised by their ability to remember minute details of their youth—an unjustified punishment they received, a fifth-grade science project, their first date. These events probably made a deep emotional impression at the time.

Interestingly, research demonstrates that although long-term memory is more durable than short-term memory, it is also changeable. For example, the way you remember your first romance can evolve over time in response to experiences and information you acquire years later.

Long-term memory can be divided into two categories—declarative memory and implicit memory (see Table 1, below).

Table 1: Types of long-term memory

DECLARATIVE (explicit) Requires conscious effort to recall	**Semantic:** General or factual information *Examples:* The year a particular president took office, names of colors, state capitals, the contents of this report **Episodic:** Personal memories *Examples:* How you met your best friend, what happened on your vacation
IMPLICIT Does not require conscious effort to recall	**Procedural:** Skills and procedures *Examples:* How to type, play golf, ride a bicycle, drive a car, brush your teeth

Quick quiz: Match the memories

Memories fall into different categories. Match the memories below to the correct type of memory in the column on the right.

1. Remembering to put your foot on the gas pedal to make the car run: ____
2. Remembering the phone number of the pizza place long enough to dial the number: ____
3. Recalling the vacation to Hawaii you took last year: ____
4. Knowing that the breed of your dog is Labrador retriever: ____

Type of memory

A. Short-term memory

B. Long-term/semantic memory

C. Long-term/episodic memory

D. Long-term/procedural memory

Answers: 1. D; 2. A; 3. C; 4. B

Memory of facts, information, and events (declarative, or explicit, memory)

Declarative memory, also known as explicit memory, is information that requires a conscious effort to recall. It is further divided into two subtypes—semantic memory and episodic memory.

Semantic memory is factual knowledge, such as the names of the continents, the color of your spouse's eyes, or what winter is. Much of the basic information you acquired during your school days falls into this category.

Episodic memory contains the images and details of experiences you have had. Episodic memories are personal memories tied to specific times and places. The party you attended last weekend and your children's birthday celebrations are episodic memories.

People say you never forget how to ride a bike. That's because procedural memory is remarkably durable. Once you've learned the steps, you don't have to think about them consciously.

Memory of skills and procedures (implicit memory)

In contrast to declarative memory, implicit memory relies on information that is stored at the subconscious level. Although there are a couple of types of implicit memory, the one that is most relevant to this discussion is procedural memory.

Procedural memory allows you to hone skills and do routine things, such as getting dressed, without consciously recalling previous experiences with the same tasks. How to ride a bicycle, tie your shoes, drive a car—each of these skills required effort and practice at one time, but once you mastered it, you were able to perform it without remembering how you learned it or the separate steps involved. When you take out your bike for a ride, for example, you don't think, "Okay, first I straddle the seat, then I put my left foot on the left pedal, and then I push off the ground with my right foot…" You just get on and go. It's as if your body does the remembering for you.

How memory works

You just saw a new movie, and you stored the memory of it in your brain, along with other information and events that you encountered today. But where, exactly, did it go? Is your brain's system for storing memories a "memory bank"—a single repository of all the sights, sounds, and facts that have made a strong enough impression for you to remember them?

The short answer is no. The memory of an event is not a single entity, like a book on a shelf. Instead, it is the aggregation of multiple streams of information from the various senses (sight, hearing, smell), filtered through your perceptions. Moreover, multiple regions of the brain are involved in the process of recording and preserving a memory (see Figure 1, below right).

The hippocampus. Deep within the brain, a structure known as the hippocampus plays a key role in acquiring and consolidating new memories. The information that will constitute a memory is sent first to the hippocampus and surrounding structures. One of these structures creates what is called a hippocampal index, which catalogs the components of a memory, so you can later "re-collect" and reconstruct the memory.

The amygdala. Situated close to the hippocampus, the amygdala is the part of the brain that reacts to emotionally powerful information. The amygdala helps to "tag" this information as important, so you are more likely to recall it later.

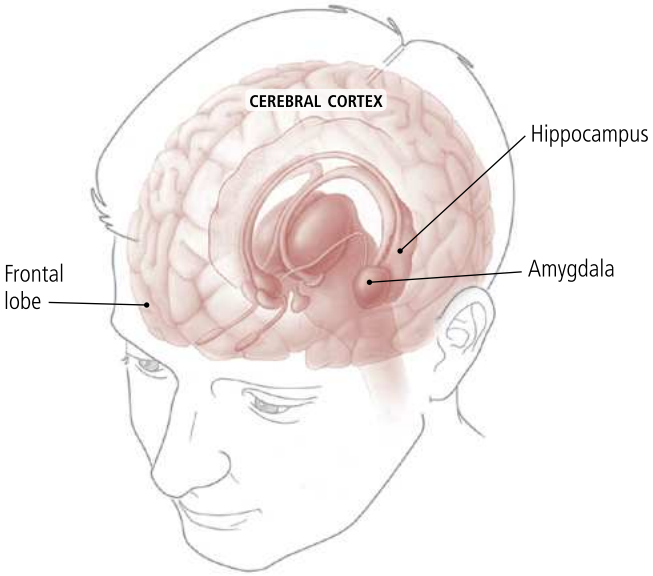
The cerebral cortex. Once a memory is established, it is not stored in a single part of the brain but instead is distributed among pertinent areas of the cerebral cortex—the large, domed outer layer of the brain that covers the brain's two hemispheres.

The frontal lobes. These are essential for focusing attention (and ignoring distractions). Focused attention is important for acquiring new information, activating and retrieving stored memories, recollecting the source of information, and keeping track of the timing and order of specific events.

How are memories processed?

For years, people believed that memories were kept in a single place in the brain. But over many decades of research, scientists realized that this assumption was incorrect. In the 1980s, the development of functional brain-imaging technology gave scientists the tools to scan people's brains as they performed a variety of tasks, including remembering things. Rather than seeing activity in a single area of the brain during memory tasks, the researchers saw that multiple areas were activated. This enabled scientists to confirm that a long-term memory's components are widely distributed in networks throughout the brain, primarily in the cerebral cortex.

Figure 1: Anatomy of memory processing



Memories are not encoded like a photograph, but rather in fragmented, distributed pieces, which need to be reassembled to remember. The hippocampus, a seahorse-shaped structure deep in the brain, and its surrounding structures play crucial roles in memory storage. The amygdala reacts to emotionally powerful information. The frontal lobes enable you to focus attention long enough to encode new information. Long-term memory storage occurs in the cerebral cortex.

It might sound odd at first that memory storage is widely distributed, but this actually makes sense. The cortex is the most highly developed part of the human nervous system, containing about 20 billion neurons (nerve cells) that collectively function to integrate sensory information, control voluntary movements, and mediate thought processes. Different areas of the cerebral cortex process different kinds of information. For example, auditory information, including speech and other sounds, is processed initially in the temporal lobes, while the registration of visual images occurs first in the occipital lobe at the back of the brain (see Figure 2, at right). What these findings suggest is that a particular aspect of a memory will most likely be stored in a region of the cortex that specializes in processing similar information.

Recalling a memory therefore requires you to activate a network that reaches across the brain, linking various bits of information. For example, to sing "The Star-Spangled Banner," you would stimulate both the language regions of the left temporal lobe (for the words) and the brain's auditory cortex (for the melody). At the same time, related memories may also be brought up through other networks. For instance, if you associate "The Star-Spangled Banner" with the American flag, that image might be called up from your occipital lobe, which processes visual information, along with images of where you were when you heard "The Star-Spangled Banner." Your memories are thus intricately broken down and cross-referenced, making your brain less like the shelves of a library and more like the Internet. Calling up memories is like searching the Web, with one or two words activating many hyperlinks.

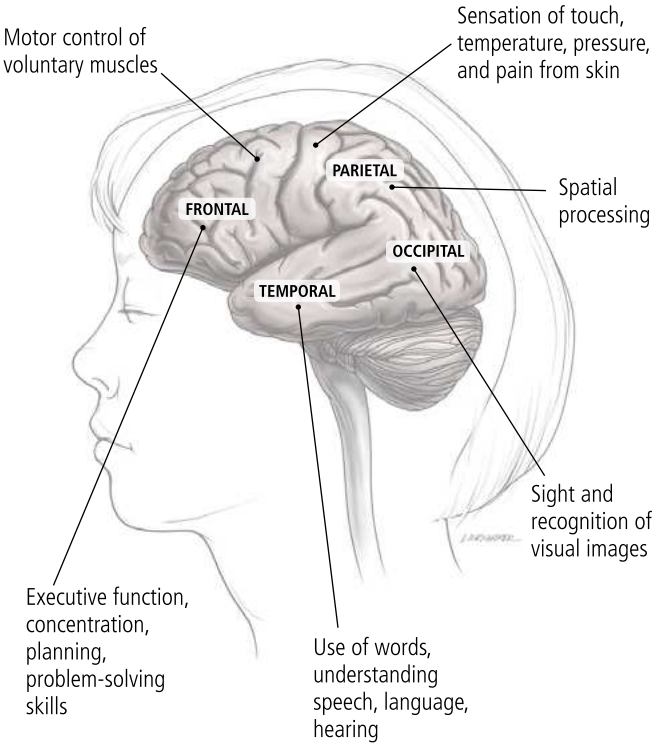
But just how does the information that you encounter on a daily basis get filed away? Memory researchers have used a three-stage model to describe how the brain learns and remembers each bit of information.

- Stage 1: acquisition (encoding)
- Stage 2: consolidation (storage)
- Stage 3: retrieval.

Impairment in any one of these three stages can result in a failure of memory. When you can't remember something (retrieval), it may be that you didn't pay enough attention when the information was coming in (acquisition) or didn't store it deeply on multiple levels in the brain (consolidation).

How smoothly the process goes—which is to say, how well you remember—depends on many things. Genetics plays a major role. Studies of human intelligence suggest that approximately 50% of mental ability is genetically determined. It may be that some people are simply better at remembering than others because of a genetic predisposition for an excellent memory. But factors within your control are also important. Overall physical health, emotional well-being, stress level, and sleep quality exert a huge influence on how well you learn and remember. (For more detail, see "17 ways to promote a healthy brain," page 23.)

Figure 2: Mapping brain functions



Different parts of the cerebral cortex of the brain specialize in different functions. Memories are stored in many parts of the brain, but some areas are more important than others. To retrieve a memory, these areas of the brain must work in coordination with others. For example, the frontal lobes (important for planning and organization) work together with several brain regions in acquiring and retrieving visual, auditory, spatial, and other information.

Stage 1: Acquisition

It's common sense: for you to remember anything, your brain must first obtain the information. However, this new knowledge is initially stored in short-term memory, and most of it will quickly fade away. Getting it into long-term storage usually requires effort. The memories that endure involve information that you paid the closest attention to when you learned it. So, stop and focus on information you know you want to remember later, like where you just parked your car. Memories that involve multiple senses as well as emotions also are more likely to be retained.

Stage 2: Consolidation

Let's say that you were paying close attention to the information you just heard and that it was effectively encoded (or initially copied) in your brain. How does it become stored as a memory that you can recall in the future? For the information to become a long-term memory, its initial neuronal pathways must be strengthened. The strengthening process, typically referred to as consolidation, occurs over a period of time.

Consolidation of facts and personal memories

Several factors influence whether the hippocampus responds to the newly acquired information and gives the signal to store it as long-term memory. For example, you're more likely to retain new information if it relates to long-term memories you already have because the richer associations help you to store the information more deeply. You are much more likely to remember the names of the players on your local football team if you know something about football than if you don't follow the game at all.

Your brain also has systems for detecting things or events that are new or unusual and remembering them for future reference. Similarly, you are much more likely to consolidate memories of objects or events that affected you emotionally (see Figure 3, at right). You can probably remember the images of the World Trade Center on 9/11 far more vividly than you can recall, say, a photo of a hotel where someone in the news happened to stay.

Consolidation of skills and procedures

Consolidation of memories for skills and procedures uses a different brain system that does not depend on the hippocampus. Rather, procedural memory is stored throughout the brain in regions that are important for coordinating movement or sequential processing, such as the frontal lobes, the cerebellum, and the basal ganglia.

Even people with amnesia, who have damage to the hippocampus, can form new procedural memories—that is to say, they can learn new skills through practice. These procedural memories, such as how to cook an egg or drive a car, also tend to remain intact with aging, and even for a while in people with dementia. However, acquiring new procedural memories becomes more difficult with age because we process information more slowly.

Stage 3: Retrieval

Retrieval is the act of recalling a memory. What we think of as a memory is really a unique pattern of connections among many nerve cells. When you're

Figure 3: Remember grandma's cookies?

An experience that stimulates many parts of the brain is more likely to be remembered, particularly if it has an emotional component.

Emotion: Feelings of pleasure are processed by the brain's reward system, which includes the amygdala.

Sight: The eyes relay the image of the cookie to the primary visual cortex in the occipital lobe.

Smell: Sensors in the nose pick up the sweet scent and convey it to the olfactory region of the cortex.

Taste: Sensory receptors on the tongue deliver the flavor of the cookie to the brain's gustatory area.

not thinking about the memory, the neuronal pattern is inactive. To retrieve the information, your brain must reactivate the pattern among all these cells simultaneously.

Retrieving familiar information generally takes less than a second. But sometimes there are glitches. Similar memories have partially overlapping patterns of neuronal activation. Sometimes when you try to retrieve one bit of information, a similar memory comes to mind and blocks out the information you want (see "Blocking," page 10). For example, you may be trying to recall the name of the grocery store near the house where you used to live, but instead you keep bringing to mind the name of other grocery stores that were near to that one, or that may look or feel similar to it.

In the process, you may feel that the answer is "on the tip of your tongue." If the neuronal pathway in your brain leading to the answer is still intact, you'll eventually retrieve it. Frustratingly, you may recall the first letters of the name or just the first and last syllables before you remember the whole name. While this may be irritating, it is very common. Research shows that it happens to younger people as often as once a week and to older people with normal memories two to four times a week.

Even if your memory is perfect, it can take several seconds or more to recall complicated information. How long the process takes depends on how familiar you are with the specific information you're looking for and how much you know about the subject in general. The more knowledge you have about the topic, the more neural networks you have that can provide potential ways to access the precise information in question.

Seven flaws of normal memory

Regardless of age, you're unlikely to have a flawless memory. People who can remember very long lists of numbers or recall the minutiae of their daily lives—right down to what they ate for lunch every day last year—are exceedingly rare. And frankly, such a memory can be a burden rather than a blessing. Memory, it seems, is inherently flawed—and in more ways than you might think.

It is common with age to remember the first letters of a name or just the first and last syllables before you remember the full name. This happens to younger people, too, as often as once a week.

Daniel Schacter, a professor of psychology at Harvard University, described the most common ways that normal memory fails us in his book *The Seven Sins of Memory*. Some of these memory flaws become more pronounced with age, but unless they are extreme and persistent, they are not considered indicators of Alzheimer's disease or other memory-impairing illnesses. They are simply the way that our brains work. The following is a brief summary of Schacter's seven memory "sins."

1 Transience

This is the tendency to forget facts or events over time. You are most likely to forget information soon after you learn it. However, memory has a use-it-or-lose-it quality: memories that are called up and used frequently are less likely to be forgotten. Although transience might seem like a sign of memory weakness, brain scientists regard it as beneficial because it clears the brain of unused memories, making way for newer, more useful ones. In this sense, transience is akin to cleaning the junk out of your closets or clearing the temporary files from your computer's hard drive.

2 Absentmindedness

This type of forgetting occurs when you don't pay close enough attention to the information you want to remember. You forget where you just put your pen because you weren't focusing on where you placed

it. You were thinking of something else (or, perhaps, nothing in particular), so your brain didn't encode the information securely. Absentmindedness also involves forgetting to do something at a prescribed time, like taking your medicine or keeping an appointment. One way to avoid this problem is to identify things that can serve as cues to remind you to do something. For example, if you take medicine at bedtime, use another regular bedtime activity, such as brushing your teeth before bed, as a cue to take your medicine.

3 Blocking

Someone asks you a question and you know that you know the answer, but you can't quite think of it. This tip-of-the-tongue experience is perhaps the most familiar example of blocking—the temporary inability to retrieve a memory. Blocking doesn't occur because you weren't paying attention or because the memory you're looking for has faded from your brain. On the contrary, blocking occurs when a memory is properly stored in your brain, but something is keeping you from finding it.

In many cases, the memory block is a memory similar to the one you're looking for, and you retrieve the wrong one. This competing memory is so intrusive that you can't think of the memory you want. Scientists call blocking memories "ugly sisters" because they're domineering, like the stepsisters in *Cinderella*. Scientists think that memory blocks become more common with age and that they account for the trouble older people have remembering other people's names. But it remains unclear whether tip-of-the-tongue experiences are more common than other age-related memory problems. The good news is that most people are able to retrieve about half of blocked memories within just a minute.

4 Misattribution

Consider the following scenario: you're asked who Jackie Chan is, and you remember quite clearly not only who he is, but also what he's done lately that's been in the news. Then you're asked where you learned these details. You think for a moment and reply that it was on the evening TV news. However, there was no report about Jackie Chan on TV. Instead, you got your information from the friend you had lunch with yesterday.

Right memory, wrong source—that's one example of misattribution. Another kind of misattribution occurs when you believe a thought you had was totally original when, in fact, it came from something you had previously read or heard but had forgotten about. This sort of misattribution explains cases of unintentional plagiarism, in which a writer passes off some information as original when he or she actually read it somewhere before. Misattribution can also involve remembering something accurately in part, but mistaking some detail, like the time, place, or person involved.

Misattribution happens to everyone. Usually it's harmless, but it can have profound consequences, particularly in the criminal justice system. In some cases, misattribution on the part of eyewitnesses is responsible for the arrest and conviction of individuals for crimes they didn't commit.

As with several other kinds of memory lapses, misattribution becomes more common with age. Age matters in at least two ways. First, as you age, you absorb fewer details when acquiring information because you have somewhat more trouble concentrating and processing information rapidly. Second, as you grow older, your memories grow older as well. And old memories are especially prone to misattribution.

5 Suggestibility

Imagine that you saw someone fleeing from a car as its antitheft alarm was blaring. You didn't get a good look at the thief, but another person on the street

It's increasingly common with age to recall information, but not remember where you learned it—perhaps from a magazine or newspaper, from a website, or from a friend.

insisted that it was a man wearing a green plaid jacket. Later, when the police show you photos of possible suspects, you're confused until you see a man dressed in green plaid. Then you point to him.

Suggestibility is the vulnerability of your memory to the power of suggestion—information that you learn about an occurrence after the fact. Although little is known about exactly how suggestibility works in the brain, the suggestion fools your mind into thinking it's a real memory. Suggestibility can be the culprit in recollections that adults have of incidents from their childhood that never really happened.

6 Bias

One of the enduring myths about memory is that it works like a camera, recording what you perceive and experience with complete, objective accuracy. But even the sharpest memory isn't a flawless snapshot of reality. In your memory, your perceptions are filtered by your personal biases—experiences, beliefs, prior knowledge, and even your mood at the moment. Your biases affect your perceptions and experiences when they're being encoded in your brain. And when you retrieve a memory, your mood and other biases at that moment can influence what information you actually recall.

Bias can affect all sorts of memories, but among the most interesting examples are people's recollections of their romantic relationships. In one study, couples who were dating were asked to evaluate themselves, their partners, and their relationships—initially and then two months later. During the second session, participants were asked to recall what they had said initially. The people whose feelings for their partners and their relationships had become more negative over time recalled their initial evaluations as more negative than they really were. On the other hand, people whose feelings for their partners and their relationships had become more loving recalled their initial evaluations as more positive than they really were.

Although everyone's attitudes and preconceived notions color their memories, bias plays an especially bitter role in people prone to depression. These people tend to have what's called negative memory bias: they remember negative information better than positive information. Negative memory bias is an important risk factor for depression, which makes sense—constantly remembering sad things that happened to you more than happy things is likely to sustain a depressed mood.

One area of research that needs to be probed further is whether memory bias of any kind becomes more common with age.

7 Persistence

Most people worry about forgetting things. But in some cases people are tormented by memories they wish they could forget, but can't. The persistent memories of traumatic events, negative feelings, and ongoing fears is another form of memory problem. Some of these memories accurately reflect horrifying events, while others may be negative distortions of reality.

Two groups of people are particularly prone to having persistent, disturbing memories. One group is individuals with depression. Research has shown that depressed people are given to ruminating over unpleasant events in their lives or mistakes they believe they have made. Dwelling on such negatives also fuels a vicious cycle of increasing depression. The other group with persistent, unwanted memories includes people with post-traumatic stress disorder (PTSD). PTSD can result from many different forms of traumatic exposure—for example, sexual abuse, a terrible car accident, or wartime experiences. Flashbacks, which are persistent, intrusive memories of the traumatic event, are one hallmark of PTSD.

How memory changes with age

Around the age of 50, many people begin to notice changes in their powers of recall. Some of these changes are relatively predictable and differ from the memory impairment caused by dementia or other conditions that damage the brain. There are ways to tell the difference, as you will learn later in this report (see "Memory problems: Normal aging or brain disease?" on page 41).

But just because your memory seems to be getting worse with age, that doesn't necessarily mean that age is directly responsible or that there's nothing you can do about it. Your memory can falter as a result of stress, fatigue, or being overloaded. Some memory difficulties may also be caused by medications, poor vision or hearing, sleep disturbances, or depression—in other words, things you can take steps to correct.

This chapter covers normal age-related changes.

Brain changes that affect memory

As you get older, certain characteristic changes take place. You are likely to experience delays in your ability to recall things, which explains why you have to rack your brain to remember a name or word that is familiar to you. It also becomes more difficult to divide your attention among more than one activity or source of information. You may find it difficult to focus your attention and may notice a tendency to be more easily distracted than when you were younger.

Over time, changes take place in the brain that may account for these difficulties. Brain regions involved with memory processing, such as the hippocampus and especially the frontal lobes, undergo age-related structural and neurochemical changes. For example, the hippocampus shrinks in size. Some receptors (the lock-and-key structures on the surface of neurons needed for them to communicate with other neurons) may cease to function normally. The integrity of white matter (the wiring between neurons) often declines, which slows processing speed. The result is that as you age, it takes longer to absorb new information and to form new memories. The loss of receptors and of neurons may also make it harder to concentrate.

These changes can undermine the acquisition, consolidation, and retrieval of new information. Different kinds of memory can decline with age, including episodic memory (for example, which family member gave you a watch for the holidays a couple of years ago), semantic memory (facts, such as the year the Iraq War started), and spatial memory (such as the directions to a new location).

It's not just that you learn this sort of information more slowly; you may have more trouble recalling it because you didn't fully learn it in the first place. If you and your child or grandchild learn a new computer game together, chances are that the next day the child will remember more of the details of how to play the game than you do.

In addition, the ability to perform tasks involving attention and executive function declines with

When people of all ages encounter new information, they may all take in the big picture, but those who are older may not absorb as much detail.

age. Executive function is a group of cognitive activities that involve the overall regulation of thinking and behavior—the higher-order processes that enable us to plan, sequence, initiate, and sustain our behavior toward some goal, incorporating feedback and making adjustments along the way.

When people of all ages encounter new information, they may all take in the big picture, but those who are older may not absorb as much detail. For instance, after listening to a presentation, a 25-year-old and a 75-year-old may both remember the overall subject and basic ideas, but the 25-year-old may be able to recall more of the specifics.

Reasons for encouragement

These changes may sound disturbing, but they are relatively minor and may simply represent slower processing speed (see "Still sharp after all these years?" above right). In other words, age-related changes in the brain may slow down your learning and your recall, but they don't impair your ability to function effectively. Your ability to make sense of what you know and to form reasonable arguments and judgments is well-preserved. Moreover, the wisdom that you've gained from experience over the years remains unscathed.

In addition, you can compensate for the slowdown in information processing and diminished ability to concentrate by working harder to pay attention to any new information you are trying to learn. This doesn't have to be difficult. For example, try repeating the information several times in your mind or discussing it with friends (see "Behavioral strategies," page 17). Willpower and effort can overcome a fair amount of age-related difficulty. In many instances, if you make the effort to learn something well, you'll be able to recall it as proficiently as a younger person can. And consider this: while processing speed may become slower with age, the general amount of knowledge a person has continues to increase.

Not all memories slip

The term "age-related memory loss" might seem to suggest that all forms of memory are equally affected as you grow older, but this is not the case. In fact, while some information may become harder to recall—and new memories may be harder to lay down in the brain—other memories will remain as accessible as ever. There is truth in the old saying that "you never forget how to ride a bicycle." Procedural memory—by which you remember processes and skills such as how to ride a bicycle, use a screwdriver, or accomplish other routine tasks—does not tend to fade with age.

Brain plasticity

While certain brain regions may take a hit from the aging process, the brain is also quite adaptable. The complex network of interconnected neurons through which it processes information is fairly dynamic, changing constantly throughout life in response to everyday experiences—a phenomenon called plasticity.

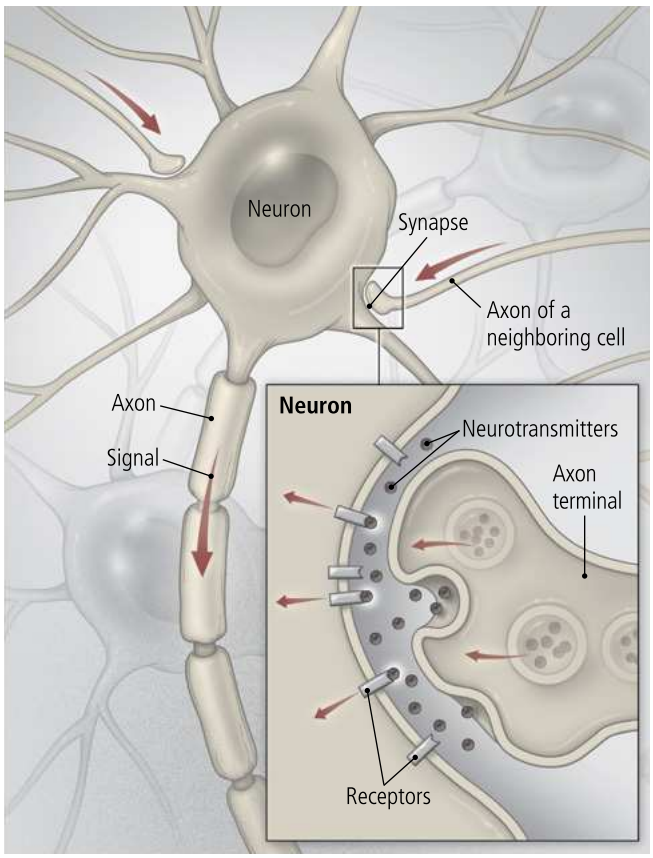
For years, the scientific view of an adult's brain was anything but encouraging. Experts believed that, unlike other cells in the body, neurons did not regenerate. They thought that the brain produced new brain cells only early in life and that once you reached adulthood, the growth of new neurons ceased and existing neurons began to die off. You may have heard the oft-repeated "fact" that you lose 10,000 brain cells a day. The idea was that your brain was shrinking, and

Still sharp after all these years?

Sometimes, what appears to be a memory problem simply reflects a slower processing speed. Comparisons of younger and older people's scores on memory, learning, and intelligence tests suggest that mental sharpness declines slightly with age. But whether such comparisons are valid is questionable because timed tests favor the younger person. For example, in one study, elderly people took 20 to 40 milliseconds longer than younger people to detect gaps in circles. Thus, the lower scores of older individuals might simply be a sign of somewhat slower responses.

In practical terms, slightly slower thinking is not necessarily a disadvantage. It may actually reflect more thorough reasoning and may result in fewer mistakes. And while older people may require more time and effort to learn new information, once they've learned it, they retain it as well as younger people.

Figure 4: A wide web of memories



In order to recall a memory, you must activate a vast network of interconnecting brain cells called neurons. Each neuron has a long, slender extension called an axon, through which it transmits signals to neighboring brain cells. At the end of each axon (the axon terminal), the neuron releases chemical messengers called neurotransmitters. These travel across a narrow space between two brain cells (the synapse) and activate receptors on the neighboring cell. Axons are covered with a substance called myelin, which appears white—hence, bundles of nerve fibers are called "white matter."

The neural pathways involved in memory are primarily in the cerebral cortex, the large, domed outer layer of the brain. Revisiting a memory strengthens the connections between brain cells that are responsible for maintaining that memory.

that could mean only one thing: as you lost neurons, you also lost some of your capacity to learn, think, and remember. Researchers now know that this neuron degradation is less pronounced than previously thought.

Not only do brain cells not die as rapidly as scientists once believed, but it may even be possible to grow a modest number of new neurons—a process known as neurogenesis. Nearly two decades ago, compelling evidence showed that human adults do sprout new neurons in the hippocampus. The significance of this is not entirely clear, and neurogenesis may be less important for memory than developing and maintaining connections among neurons—the neural pathways that are formed among brain cells as you learn new information or have experiences (see Figure 4, at left). Revisiting the information strengthens the pathways. In fact, any activities you engage in frequently—whether related to your job, your hobbies, or running a household—become more sturdily encoded.

The brain also has some capability to reorganize itself, shifting functions from one network to another, if a particular process starts to weaken. For example, some studies have found that the brains of older and younger adults may engage different brain regions to accomplish the same mental task. Scientists believe that this may be a mechanism of older brains to compensate for diminished function in the area normally used for that task.

The bottom line is this: New connections between neurons form as we learn information, hear sounds, touch things, or take in visual images in our environment. The more we use the information, the stronger the memory. Even if some brain regions weaken, the brain may be able to compensate. For these reasons, stretching your mind with mentally challenging activities can improve your memory.

Memory tips and tricks

There are plenty of techniques that boost your ability to retain new information and skills. Doctors and other clinicians who work with people on improving their cognitive performance and memory have found these strategies to be effective. They aren't difficult to master. Indeed, many are simple things that you probably do already, but can benefit from doing more systematically. By investing some time to learn these skills, you can reap the rewards of a sharper, quicker mind.

Information that is organized is much easier to learn and remember. Organizational tools include calendars and notebooks. Phone apps can remind you when to do something.

These techniques fall into three general categories: organizational tools, behavioral strategies, and memory-enhancing techniques that make new information meaningful and relevant to you, thus making it easier to remember.

Organizational tools

Most people need to organize a multitude of facts each day—dates and locations of appointments, people's names and phone numbers, even where they left the car keys. Information that is well organized is much easier to learn and remember. There are many organizational tools, including time-honored ones such as address books, calendars, and notebooks. You can also get apps for smartphones and other electronic devices that remind you when it's time to do something. It doesn't matter which tool you choose; what matters is that you use it consistently.

Here's a brief list of the types of information that people often forget and some organizational strategies to help you remember. Table 2, page 16, also contains a quick troubleshooting guide for ways to deal with common memory problems.

Belongings. Have a designated spot for your most important personal belongings (keys, glasses, handbag) and always put them there when you're not using them. Or try a high-tech solution by attaching a tracking device (such as the Tile, available at www.thetileapp.com, or Apple AirTag, at www.apple.com/airtag) to items you tend to misplace.

Meetings and appointments. Maintain a calendar (on paper or on an electronic device like a smartphone or tablet) in which you write appointments and important dates, and keep it with you at all times. If you don't use electronic devices, a "memory notebook" with a weekly calendar and paper for writing down important information will suffice. Develop the habit of checking your calendar several times each day.

Daily tasks. In addition to listing your appointments, keep a list of the miscellaneous things that you have to do each day or week—

Table 2: Common memory lapses and strategies to overcome them

There are multiple behavioral and organizational strategies for overcoming memory problems, depending on what it is that you're trying to remember.

WHAT YOU FORGET	HOW TO REMEMBER BETTER
Names	• When you meet someone for the first time, stop and take the time to register the person's name. Many times you may forget a name simply because you didn't notice it being said to you in the first place. • Use a new acquaintance's name in conversation. • Think about whether you like the name. • Think of people you know well who have the same name. • Associate the name with an image, if one comes to mind. For example, link the name Sandy with the image of a beach, and imagine Sandy on the beach. Use as much detail as possible—picture her walking along the water's edge, on a beach that's familiar to you. • Put the person's name in your memory notebook (a notebook specially dedicated to things you want to remember), personal organizer, address book, or smartphone.
Where you put things	• Always put things you use regularly, such as keys and eyeglasses, in the same place. • For other objects, repeat aloud where you put them. • As you put an object down, make a point of looking at the place where you put it. • If you still don't think you'll remember, write the location down, or take a picture of it on your smartphone.
What someone tells you	• Ask the person to repeat the information. • Ask the person to speak slowly; that way, you'll be able to concentrate better. • Repeat to yourself what the person said, and think about its meaning. • If the information is lengthy or complicated (such as advice from your doctor), record it on your smartphone or a small voice recorder, or take notes.
Appointments	• Write them down in an appointment book, in a calendar that you look at daily, on your smartphone, or in another personal organizer.
Things you must do	• Write them down in your personal organizer or calendar. • Write yourself a note and leave it in a place where you'll see it (for instance, on the kitchen table or by the front door). • Ask a friend or relative to remind you. • Put an object associated with the task you must do in a prominent place at home. For example, if you want to order tickets to a play, leave a newspaper ad for the play near your telephone. • If you must do something at a particular time (such as take medicine), set an alarm.

Adapted with permission from Winifred Sachs, Center for Cognitive Remediation and Treatment, Beth Israel Deaconess Medical Center.

people to call, items you need to buy, routine maintenance on your car or home, and so on. Keep those to-do lists in your electronic organizer or memory notebook.

Contact information. Keep your address book or electronic organizer up to date with the names and phone numbers of friends, relatives, and professionals or companies with whom you interact (your bank, medical providers, health insurance company, homeowner's insurance, credit card companies, plumber, mechanic, etc.).

Vital information. Keep important documents like insurance papers and medical records in a file cabinet or other designated location. Record other vital information in your electronic organizer or a memory notebook that you keep with you. You may want to list the medications you are taking and when to take them, along with your medical history.

Locations. If you use GPS to navigate when you drive places, don't become so reliant on it that you fail to pay attention to where you're going. You'll have much better recall of an area or a route if you can put it in a broader mental context than that single blue line on your screen.

Checklists. For procedures that you may have difficulty remembering from one time to the next (like resetting the clock on your car dashboard twice a year), write the steps down. Store the instructions in a place you have easy access to

and won't lose. That may be your smartphone, a computer, or a notebook that you keep with you.

Behavioral strategies

Certain behavioral strategies can help improve your ability to learn new information effectively and retain it over time.

Focus. Your ability to focus your attention and absorb information quickly declines with age and contributes to age-related memory loss. The slowdown in processing causes a bottleneck of information entering your short-term memory, reducing the amount of information that can be acquired and encoded into long-term memory. You can enhance your focus and attention by doing the following:

- When someone is talking to you, look at the person and listen closely. If you missed something that was said, ask the person to repeat it or to speak more slowly.
- Paraphrase what is said to make sure that you understand it and to reinforce the information. For example, if someone says, "We can see the movie either at Loews Theater at 7:30 or at the Paramount at 7:50," you might respond, "Which would you prefer, 7:30 at Loews or 7:50 at the Paramount?" Then you'll be more likely to show up at the right place at the right time.
- If you find that you tend to become distracted during conversations, try getting together with people in quiet environments, such as homes instead of noisy restaurants. When you do meet people at a restaurant, sit at a table near a wall. If your companions sit against the wall and you sit facing them, you'll be able to focus on them without having your attention wander to other diners.

Focus is key to memory. When someone is talking to you, look at the person and listen closely. If you miss something, ask the person to repeat it.

You can improve your ability to focus on a task and screen out distractions if you do one thing at a time. Try to avoid interruptions. If someone asks you something while you're in the middle of reading or working, ask if the person can wait until you're finished. Don't answer the phone until you've finished what you're doing—let voicemail take the call.

Repeat. You will remember new factual information more effectively if you repeat it to yourself or say it out loud. If someone gives you directions, for example, repeat them to the person to make sure that you got them right. Discussing newly learned material with a friend or colleague is another way to help reinforce it in your mind.

Ensure comprehension. The more thoroughly you understand new information, the greater the odds that you will remember not only the general concept but also the details. You can improve your comprehension by rereading material, asking questions about it, and discussing it.

Make a note. How many times have you had a brilliant idea while getting ready for bed or standing in line and then forgotten it? Many people assume that if a thought is important enough, they will remember it. But that is unrealistic. When something significant occurs to you, write it down as soon as you can. The act of writing things down actually helps reinforce them in your mind, so you may not even need to refer to your

notes to help jog your memory.

Before going to a medical provider's office, make a list of questions you want to ask or things you want to mention. Jot down other thoughts as they come to mind: ideas related to your job, possibilities for birthday and holiday presents, the names of restaurants you'd like to try or books you'd like to read, or movies that you didn't see when they were first released. These are the sorts of ideas that often fade with time, but that you know you'll want to remember.

Practice spaced rehearsal. Research on learning has shown that "spaced rehearsal" is more effective for long-term recall than "cramming." In other words, you will remember something more effectively if you rehearse it once a day for several days rather than all at once.

If you have trouble retaining complicated information—for instance, when you read an article, take a course, or start a new project at work—try using spaced rehearsal. Write down the main points of what you have just learned and then review your notes once or twice. Read them again the following day and then again the day after. Spacing out these study sessions gives your brain a chance to consolidate the information that you have learned and form a more durable memory of it.

Do small tasks first. It's only natural to turn your attention to the large, important tasks at hand and let the mundane tasks slide. The problem with this approach is that small tasks, like answering email messages, tend to pile up and then get forgotten. If you act on them quickly, you don't have to worry about remembering to do them later.

One of the main reasons memory declines with age is that the brain processes information more slowly. Give yourself the time you need to absorb new information.

Be patient. One of the main reasons memory declines with age is that the brain processes information more slowly. Give yourself the time you need to absorb new information. Don't consider it a sign of personal failure that you need to slow down in order to learn something new.

Memory-enhancing techniques

You might have heard the term mnemonics, which refers to techniques for remembering information. (The name comes from Mnemosyne, the Greek goddess of memory.) Mnemonic techniques make use of cues and imagery, which might include acronyms, rhymes, and memorable phrases, to reinforce memories. For example, the sentence "Every Good Boy Does Fine" will help you recall that E, G, B, D, and F are the notes that fall on the lines of the treble-clef musical staff. Another common mnemonic device is the short poem that begins "Thirty days hath September …" to remind you of the number of days in each month.

Associations

When you learn something new, immediately relate it to something you already know. Making connections is essential for building long-term memories. What you're really doing is making the information meaningful, thus aiding your memory systems in the process of consolidation. Making connections between new and old information also takes advantage of the older pattern of synaptic activation, piggybacking the new material onto an existing network.

Remember names by making associations with the first letters. For example, it's fairly easy to remember the National Aeronautics and Space Administration because it is familiar as the acronym NASA. You might try this technique with people's names, too. Let's say you meet someone named Louise Anderson. Her initials are L.A., an

association that's easy to remember because it's already familiar as the abbreviation for Los Angeles.

Make associations to remember numbers such as access codes or passwords that you need to use regularly but, for security reasons, don't want to write down and keep in your pocket. For example, if you need to remember the number 221033 to get your voice mail: 22 could remind you of "catch-22," and 10 might be your house number, while 33 was your age when your daughter was born. Or try to remember the pattern it makes as you punch the numbers into the keypad.

"Chunking" information

Another technique for remembering a long series of items is to regroup them—for example, so that a list of 15 things is organized into three groups of five. For example, when you do grocery shopping, think of the items you need by categories, such as dairy, produce, desserts, frozen foods, and so on.

Chunking is also useful for remembering numbers. Phone numbers are naturally chunked into the area code, local exchange, and remaining four digits. Let's say your checking account number is 379852654. Instead of memorizing it as a string of nine single digits, try grouping the digits into three triple-digit numbers: 379, 852, and 654. You can have a different way of remembering each chunk. For example, the first one is composed solely of odd numbers. The second one represents three digits that are in a line on the telephone keypad. The third consists of three consecutive numbers in reverse order.

The method of loci

A technique called the method of loci, also known as the memory palace, originated in ancient Greece and is still one of the best ways to memorize complex or lengthy material, like speeches. The idea is to link the main points of the material to specific locations so that thinking of those locations triggers your recall.

Here's how it works: First, think of a familiar route, such as your commute to work, and imagine traveling that route, noting the stores and other landmarks along the way. Next, pick out the main points in your speech or other information and relate each point in sequence to a landmark on your route. When giving your speech (or recalling the information), think about commuting to work and seeing the landmarks. The image of the landmarks will help you remember the points of your speech. It helps if you vividly picture the images of your route, and also vividly picture something from your speech in that place. For example, if one of the points in your speech deals with a publication your company just put out, picture that publication—the title page just as it looks in real life—on the doorstep of the coffee shop you pass every day.

The loci that you use can also be rooms in your home, which you can imagine walking through sequentially, maybe starting at the front door and walking whatever path you normally take through the house. As you picture your path, mentally drop images from your speech along this route.

The method of loci (locations) dates back to antiquity. The goal is to link the ideas you want to remember for a speech or meeting to landmarks on a well-traveled route. Each piece of information should be associated with a different place.

The story method

This method is helpful when you need to remember many items, such as a list of things to do. In this case, you assign each item a visual image to represent it in the story, and then you make up a story with those images in it. Say you have to buy a present for your spouse after work, then get your dog groomed, then pick up your daughter from dance class, and then call your mother in Florida. You might picture a present buckled into the front seat of your car. Then, as you're driving the familiar

route to the store, you picture your wet and soapy dog running out in front of the car. Chasing after it is your daughter, dressed in a tutu. Next, a pile of Florida oranges rains down on your car. When you go to remember what to do, you tell yourself the story you created, remembering each errand one by one.

Look, snap, connect

This technique, which was developed by Dr. Gary Small, is all about paying attention (since you can't remember what you don't notice in the first place) and then using visualization to solidify the memory. "Look" refers to slowing down and noticing what you want to remember, such as the fact that you parked your car in section 3B of the parking garage. "Snap" means taking a mental snapshot of the item. That could be a literal image of the parking garage sign, though you'll probably be more likely to remember a more elaborate image, such as that of three bumblebees (representing the 3B section you parked in). "Connect" involves connecting the image and the thing you want to remember—in this case, the three bees and the section of the garage where you parked. Imagine the bees in your car, as you would with the story method (above). Then when you pause to remember where you parked after coming back to the garage, the image of the three bees buzzing in your car will help jog your memory.

PHYLLIS'S STORY:

The benefits of memory coaching

"I used to have a sharp memory," says Phyllis, 58. But then she started having trouble remembering all sorts of things. She'd forget where she left her glasses and her keys. She'd forget the details of conversations. Formerly an avid reader, she had trouble retaining information that she'd read.

Her doctor recommended that she see a therapist who specializes in helping people devise strategies and systems to improve everyday memory function. At her first session, the therapist asked Phyllis to tell her specifically what she'd been forgetting, then proposed a strategy for each type of memory lapse. Once a month, Phyllis met with the therapist to discuss how well the strategies were working and to fine-tune them as needed.

For example, the therapist suggested that Phyllis put her glasses and keys in the same places whenever she came home. On the occasions when she had to leave them somewhere else, the therapist told her to say out loud where she was putting them. For example, if the phone rang as she was coming in the door and she rushed into the kitchen to answer it, she would say, "I'm putting my keys on the kitchen table."

To remember information from conversations, the therapist helped Phyllis learn how to paraphrase during the course of the conversation. Restating the information in her own words would reinforce it in her mind.

To improve concentration while reading, the therapist recommended creating a place in her home just for reading that was free of distractions. Phyllis also learned how to make a brief written note summarizing the key aspect of each section of the material she was reading.

Phyllis feels that most of the strategies have proved to be extremely helpful. She still struggles to concentrate on what she's reading, although she's doing better than before she started seeing the therapist. Now that her last memory-coaching session is over, the most encouraging improvements are that she can almost always find her keys and glasses and follow the details of conversations. "I feel my memory is nearly back to normal," she says.

The SQ3R method

SQ3R stands for Survey, Question, Read, Recite, and Review. This five-step method is particularly effective for mastering a large volume of technical information from a textbook or professional document.

Survey the material by reading through it quickly. Concentrate most on the chapter headings and subheadings, as well as the first sentence of each paragraph, to get an overview.

Question yourself about the main points of the text. The more provocative and interesting your questions, the better able you will be to mentally organize the material when you read it.

Read the text carefully for comprehension, keeping in mind your questions from the second step. Don't take notes or underline yet—doing so at this stage can actually interfere with your comprehension by interrupting the flow of information.

Recite what you have just read, either to yourself or to someone else. Speaking out loud helps deepen your understanding of the material. Now is also the time to take notes.

Review the text, as well as your notes, a day or two later. Now, think critically about the information: does it support or contradict other information you know about the subject? Go back to your questions from step two. Can you answer them? Do any questions remain? Review the text quickly several more times over the next several days or weeks to help your brain consolidate and store it.

Professional memory training

You can go it alone and teach yourself techniques for strengthening your memory. Or you can get professional memory training. Some medical centers offer memory training programs in which people meet every week or so to learn memory enhancement techniques, then practice them as homework. Another alternative is to attend a series of individual sessions with a clinician who specializes in memory and other cognitive

Can computer brain-training games save your brain?

You probably know teenagers who spend large amounts of time riveted to various electronic devices playing games. There also are plenty of electronic games aimed at middle-aged and older adults worried about their memory. An Internet search will yield countless brain games for seniors. Do they work?

The quick answer is this: be wary of outsized claims about computerized brain-fitness programs. The jury is still out on whether these programs can live up to marketing promises. There is good evidence that these programs can improve your ability to perform the specific tasks in the program—for example, remembering a list of unrelated items. But whether this consistently translates to helping overall cognition and daily functioning remains to be determined. So, you'll get good at playing the computer game, but this may not help you remember the name of an acquaintance or find your car keys. That said, some programs, such as BrainHQ, Lumosity, and Cogmed, are used by medical professionals for cognitive rehabilitation. These and similar training tools have been and continue to be studied, and a handful of studies have found that a few may extend specific improvement to other domains of memory and thinking:

- In a study published in *Nature*, the program NeuroRacer yielded improvements in multitasking, something that becomes more difficult with age. The 46 older adults (ages 60 to 85) who played the game also had a boost in cognitive skills that weren't directly related to the game. Working memory (temporarily holding information in mind and manipulating it) and the ability to sustain attention also improved. The gains in memory remained six months after the end of the study.
- In a study published in the *Journal of Alzheimer's Disease*, use of a computer training program (Cogmed) improved both working memory and speed of processing. The study included 82 cognitively normal adults (ages 65 to 89) from an urban setting (in the United States) and a rural setting (in Sweden). In each setting, participants were divided into two groups. In one (the adaptive group), the difficulty of the computerized tasks increased over time based on an individual's performance. In the other (the non-adaptive group), the difficulty of the program remained the same. The adaptive group exhibited improvement on the trained tasks and on an untrained task (called the Digit Symbol Substitution Test) that depends on working memory and processing speed. The benefit of the training program was similar in both the urban and rural settings.

Studies of computer-based brain training have some limitations, however. For example, they usually don't compare one program to another or to other types of mental challenges, such as learning a new language or taking up a musical instrument. More research is needed. In the meantime, feel free to try a computer program, if you like—it certainly won't hurt. But keep in mind that some of these programs are expensive. And realize that no single computer program can replace the benefits of staying physically, mentally, and socially active throughout life.

problems, such as a psychologist, occupational therapist, or speech pathologist. Such a specialist can recommend specific strategies for the types of memory problems that affect you (see "Phyllis's story," page 20).

If you are considering a memory enhancement program, choose one that is run by a health professional with specialized training in cognitive rehabilitation. Some people benefit from individual treatment, where their particular needs can be identified and addressed.

Do memory training programs work? Studies on the effectiveness of memory enhancement programs have found some benefit.

One study demonstrated the potentially enduring value of an organized training program for cognitive enhancement. For this study—called Advanced Cognitive Training for Independent and Vital Elderly, or ACTIVE—2,832 adults over age 65 were divided into four groups. One group received 10 sessions of classroom instruction in memory. The second had 10 classroom sessions in reasoning ability. The third group received 10 hours of computer-based speed-of-processing training. The fourth group received no training and served as the control group. Some members of each training group received four additional "booster" sessions 11 months after the initial training and four more after 35 months.

Each of the training groups improved in the cognitive area that was trained. For example, the memory group showed enhancement on tests of memory. There was no improvement in mental functions not specifically trained. Follow-up studies demonstrated that the improvements lasted many years. Ten years after the study began, the effects held up for reasoning and speed of processing, but were no longer maintained for memory. Even so, after 10 years, the participants in each of the three training groups reported less decline in their ability to engage in daily activities (for example, handling finances, shopping, preparing meals, housework, driving) compared with those in the control group.

The researchers also found that participants who completed the computer-based speed-of-processing training reduced their risk of dementia after 10 years by 29% compared with the control group that received no training. These results provide the strongest evidence to date in support of computerized brain training. Bear in mind, however, that the results must be replicated to be considered valid, and more research is needed before making a definitive recommendation (see "Can computer brain-training games save your brain?" on page 21).

Over all, the results of a study like ACTIVE show that keeping your mind active can have long-term benefits. You don't need a computer to do that. Studies show that all kinds of mentally stimulating activities are good for cognitive health (see "17 ways to promote a healthy brain," page 23).

17 ways to promote a healthy brain

As you get older, certain aspects of memory normally decline, but that doesn't mean you're powerless to protect your brain as you age. In fact, there is a lot you can do to boost your powers of recall and improve overall cognition.

Mounting evidence shows that certain lifestyle measures can help, and these are endorsed by several medical associations, including the Alzheimer's Association and the American Heart Association / American Stroke Association. Lifestyle measures that promote brain health include exercising regularly, eating a healthy diet, reducing stress, getting a good night's sleep, and staying mentally active. In addition, to the extent possible, it's important to protect your brain from injury and other assaults that can damage your memory and increase your risk for dementia.

One thing you won't find on our list is supplements. Although many people believe they help, there's little evidence from clinical trials to back this (see "Can supplements boost memory?" below). By contrast, there is considerable evidence for the lifestyle recommendations in this chapter. As you will see, each one is accompanied by a paragraph or more, labeled "What you can do," which will give you specific ideas on how to accomplish the goal.

Physical and mental fitness go hand in hand. People who engage in regular aerobic exercise tend to have better mental function than those who do not, and their memory declines less over time.

Can supplements boost memory?

Numerous supplements are promoted for brain-enhancing qualities. Some of them—including ginkgo biloba, ginseng, choline, selenium, and apoaequorin (Prevagen)—have undergone testing for possible effects on cognition. While some studies have found small benefits with some of these supplements, other studies cast doubt on their effectiveness. Based on the paucity of evidence from scientific studies, it's not possible to recommend use of any of these pills for brain health. However, it's also not possible to conclude that they don't help *anyone*. In most cases, more research is needed.

If you are inclined to try a supplement, you should discuss it with your doctor and agree on a short trial period, perhaps weeks to a couple of months, to see if you notice any difference. If there are multiple supplements you want to try, try just one during the test period, so you will know which one (if any) is affecting you.

1 Exercise

Physical fitness and mental fitness go together. People who engage in regular aerobic exercise (meaning any exercise that speeds up your heart rate and breathing) tend to have better mental function than those who do not exercise, and they experience less of a decline in memory over time. Some evidence shows that strength training can also be beneficial.

Exercise appears to help memory in numerous ways, enhancing the ability of the brain to adapt and compensate for age-related decline. For example, physical fitness seems to slow the normal age-related shrinkage of the brain. Studies have found that physically active older adults have greater brain volume over all and a lower incidence of age-related brain changes than those who are less fit. This seems to translate to maintaining higher levels of mental func-

tion longer. Of particular significance, exercise may boost the size of the hippocampus, which typically shrinks as you age.

In part, these beneficial effects may be the result of increased levels of a compound called brain-derived neurotrophic factor (BDNF). BDNF promotes the growth of neurons in the brain and strengthens the connections between brain cells. Exercise also encourages the formation of new blood vessels in the brain. And it can reduce your stress levels and improve your sleep—two measures that help memory in additional ways (see "Manage your stress," page 30, and "Get a good night's sleep," page 25).

Exercise also promotes brain health by helping other parts of the body. For example, it helps maintain a robust cardiovascular system, which ensures a good supply of oxygen-rich blood to the brain. It also helps reduce the risks for type 2 diabetes, high cholesterol, and high blood pressure—problems that can lead to brain-damaging cardiovascular problems, including strokes, and increase the odds of developing dementia.

A study of 191 women, published in the journal *Neurology,* demonstrated the brain-protective effect of exercise—specifically, protection against dementia. The participants were given an exercise test when the study began in 1968 and were then tested for dementia six times over the next 44 years. A total of 40 women met the criteria for high fitness, while 92 of them had medium fitness, and 59 had low fitness. Compared with women who had medium fitness in midlife, those with high fitness were 88% less likely to develop dementia—and among high-fitness women who did develop dementia, the age of onset was an average of 11 years later than in those with medium fitness.

What you can do. Researchers don't know precisely how much exercise is needed for good brain health, but one thing is clear—you only reap benefits if you exercise on a regular basis. You can't exercise for a week or two and consider it done. The available research suggests that the exercise needn't be extreme, but should be moderately vigorous—and that the more time you spend exercising, the better. (See "Move more, sit less: Exercise recommendations for older adults," below, for the official guidelines.)

A formal exercise program is best. If you're just starting, you can find helpful guidance on building a well-rounded program in another Harvard Special Health Report titled *Starting to Exercise* (see "Resources," page 51). But any physical activity is better than none, so try to build more activity into your daily routine. Here are some examples:

- When possible, walk instead of driving.
- Use the stairs instead of the elevator.

Move more, sit less: Exercise recommendations for older adults

If you're generally fit and have no limiting health conditions, you can follow the guidelines listed below, which will deliver benefits for your body as well as your brain. If you have a health condition that limits your activity, do as much as you are able to do comfortably and safely. Always check with your doctor before starting an exercise program.

The Physical Activity Guidelines for Americans from the U.S. Department of Health and Human Services recommend this combination:

- Two hours and 30 minutes (150 minutes) to five hours (300 minutes) of moderate-intensity aerobic activity (e.g., brisk walking) every week. If you're very fit, you can cut the time in half by substituting vigorous-intensity aerobic activity (e.g., jogging or running). Or, try an equivalent mix of the two. In general, two minutes of moderate activity equal one minute of vigorous aerobic activity.
- Muscle-strengthening activities on two or more days a week that work all major muscle groups (legs, hips, back, abdomen, chest, shoulders, and arms). Allow 48 hours between sessions.
- Balance exercises for older adults who need them.

Bear in mind that any exercise is better than none. A growing body of evidence suggests that simply getting up and walking around can help. Long hours of sitting reduce blood flow to the brain, worsen the health of blood vessels, and reduce blood sugar control. That's why the current version of the guidelines urges everyone to "move more and sit less."

- Park at the far end of the parking lot.
- Schedule time each day for exercise.
- March in place while waiting for the microwave to heat your food.
- Plant and tend a garden.
- Take an exercise class or join a health club.
- Swim regularly, if you have access to a pool.
- Learn a sport that requires modest physical exertion, such as tennis.
- Schedule exercise on your calendar.

2 Keep learning

There's growing evidence that continuing to challenge your mind throughout life can help maintain your cognitive function and create a buffer against mental decline. Studies have shown that people who have more years of education preserve their overall mental function longer and have a lower risk of developing dementia than those with fewer years of education. Scientists believe that intellectual enrichment and learning stimulate the brain to make more connections. As a result, the "educated brain" may possess a greater reserve of cognitive ability—a deeper well, so to speak—and be able to sustain a greater loss of neurons. But if you failed to get an advanced degree when you were in your 20s, that doesn't mean it's too late for you.

A lifelong habit of learning and engaging in mentally challenging activities seems to keep the brain in shape. A study published in *JAMA Neurology* found that people maintained better memory and thinking abilities in later life if they had higher levels of formal education, had held mentally stimulating jobs earlier in their lives, or engaged in higher levels of non-work-related mental stimulation in mid- to late life.

A meta-analysis that reviewed results from 19 studies found that people who regularly engage in mentally stimulating activities—such as reading, writing, playing board games, doing crossword puzzles, playing musical instruments, and gardening—have a lower risk of developing dementia later.

What you can do. Exercising your brain with challenging activities is believed to stimulate connections between brain cells. Some ways of stimulating your mind are obvious—for example, doing crossword puzzles, reading, participating in a book discussion group, playing chess, or taking classes. However, the most beneficial activities may be ones that challenge your brain in entirely new ways—for example, learning a new language, taking up a new musical instrument, or engaging in social activities with people you're meeting for the first time.

You don't have to go to great lengths or spend a lot of money to find mental stimulation. Mental challenges also come from the unexpected occurrences that take you out of your daily routines and make you think. If you're still working, chances are that you get some of these curveballs thrown at you from time to time. But if you aren't working and your time is largely unscheduled, you may need to actively seek out novel experiences and learning opportunities. Planning day trips or longer vacations, meeting regularly with friends, going to the theater or to museums, or just making a point of varying your routine can help keep your mind active and engaged. You can also try cooking new recipes, joining a club, or learning a new art or craft.

3 Get a good night's sleep

People who don't sleep well at night tend to be more forgetful than people who sleep soundly, and they have more difficulty focusing their attention on tasks. A good night's sleep is essential for consolidating memories and transferring them to long-term storage (see "Sleep, perchance to remember," page 26). Much research has now suggested that the brain clears out toxins during sleep, including a toxic protein called beta-amyloid that is associated with Alzheimer's disease. Sleep deprivation may have implications for your risk of developing dementia.

Although people differ in their need for sleep, older adults should try to get at least seven hours of sleep nightly to ensure adequate daytime alertness and memory function. Getting consistently good-quality sleep can reverse sleep-related impairments of thinking and memory. But some people have difficulty getting enough sleep. With age, people become more prone to sleep disorders. These make it harder to get adequate sleep, and they can contribute to a general decline in mental function.

The most common sleep disorder is insomnia. Unfortunately, many medicines used in the treatment of insomnia can also impair memory and general cognitive function, so it's best to avoid long-term use of sleep-inducing medications. Instead, try the sleep tips described below or see a therapist who offers cognitive behavioral therapy for treating insomnia (CBT-i).

Another sleep disorder is obstructive sleep apnea (OSA), which can lead to memory impairment if not treated. People with OSA have short pauses in breathing that disrupt sleep with "mini-awakenings"—in severe cases, hundreds of times a night. An estimated 25% of American adults have sleep apnea, with more men than women affected. It is more common with age. OSA is often associated with loud snoring. If you have OSA, treating the problem appears to improve some aspects of cognitive function.

What you can do. The following practices can help reduce insomnia:

- Establish and maintain a consistent sleep schedule and routine. Go to bed at the same time each night, and wake up at the same time each morning. A set sleep routine will "train" you to fall asleep and wake up more easily.
- Use the bed only for sleep and sex.
- Plan to do your most vigorous exercise early in the day. Exercising in the hours immediately before bedtime causes physiological changes that may interfere with sleep. Exercising in the morning, on the other hand, enhances your alertness when you need it most—at the beginning of the day.
- Avoid coffee and other sources of caffeine (e.g., chocolate, many soft drinks, some brands of pain relievers, many types of tea) after 2 pm.
- Avoid excessive napping during the daytime. Prolonged napping can disrupt your natural sleep cycle and prevent you from feeling tired enough to fall asleep at night.
- Don't take sleeping pills unless nothing else works. If you do take a prescription sleep medicine, it's best to use it only on a short-term basis, as some sleep medications are habit-forming. In addition, like sleep deprivation itself, sleeping pills can cause memory loss.
- If you use a smartphone, tablet, or computer, try one of the apps for relaxation, mindfulness, or meditation techniques geared toward helping you fall asleep. Some free options include Meditainment and Insight Timer. Remember to point the screen away from your eyes: research shows that the blue light emitted from computers, tablets, and smartphones can interfere with sleep.
- Don't try to sleep if you're not tired; otherwise, you'll set yourself up for tossing and turning. If you're still awake after about 20 minutes in bed, get up and read awhile to help yourself relax.

If you experience persistent sleep problems, consult your physician so that you can identify the specific issues and get the necessary treatment.

Sleep, perchance to remember

Why does sleep matter to memory? One theory suggests that changes in brain activity during two phases of sleep—slow-wave sleep (deep sleep) and rapid-eye-movement (REM) sleep—are important for memory consolidation. Research with rodents showed that during slow-wave sleep, the pattern of activity in the hippocampus was very similar to the pattern that appeared earlier when the animals were engaged in learning something. This finding suggests that during slow-wave sleep, the hippocampus "replays" the recently acquired information to strengthen the neuronal patterns that were activated during the acquisition phase. This replaying of the learning scenario is the key component of the consolidation process. Researchers are investigating whether they can enhance this natural process using a noninvasive brain stimulation technique delivered during sleep. Results of at least one study were promising, but it's not yet ready for general use.

Research has also revealed that during REM sleep—the phase of sleep when dreaming occurs—there is increased activity in the cortex. Some scientists now think that dreaming is one of the ways in which the brain strengthens the neuronal pathways that encode memories.

4 Eat a healthy, plant-based diet

The evidence is mounting that certain healthy eating patterns may lessen the risk of developing mem-

ory problems. These are the Mediterranean diet, the Dietary Approaches to Stop Hypertension (DASH) diet, and a hybrid of these called the MIND diet. (MIND stands for Mediterranean-DASH Diet Intervention for Neurodegenerative Delay.) The three diets are quite similar, but while the DASH diet was formulated to control high blood pressure—and the Mediterranean diet is good for heart health over all—only the MIND diet was specifically formulated to optimize brain health. The diet includes 10 brain-healthy food groups:

- green leafy vegetables (six or more servings per week)
- other vegetables (at least one serving a day)
- nuts (five or more servings a week)
- berries (at least twice a week)
- beans (four or more times a week)
- whole grains (three servings a day)
- fish (one or more times a week)
- poultry (two or more times a week)
- olive oil (use as primary oil)
- wine (no more than one glass a day).

The MIND diet also urges people to limit consumption of foods from five less-healthy groups—red meat, butter and margarine (less than 1 tablespoon a day), cheese (less than one serving a week), pastries and sweets, and fried or fast food.

Studies indicate that all three diets may be beneficial for cognitive health. A study published in *Advances in Nutrition* reviewed evidence on the three diets from 56 studies and found that closely following any of the three was associated with less cognitive decline and possibly a lower risk for dementia. The strongest association was for the MIND diet. Including olive oil in the diet was shown to be particularly beneficial.

One component of these diets—fish (which contains omega-3 fatty acids)—may also be good for the brain. Evidence that supports the connection between brain health and omega-3s includes data from the Framingham Heart Study. This study revealed that people with initially higher blood levels of the omega-3 fatty acid docosahexaenoic acid (DHA) had lower rates of dementia over a period of nine years.

Eating a lot of fruits and vegetables can be especially helpful because many are good sources of vitamins and other nutrients that may protect against diseases and age-related deterioration throughout the body. A study published in the *Journal of Nutritional Science* in 2021 of adults ages 65 to 84 found that having high blood levels of the nutrients alpha carotene, lutein, and zeaxanthin correlated with better cognitive function. The presence of these nutrients reflects high intake of fruits and green leafy vegetables and low consumption of fried foods. Fruits and vegetables also promote a healthy heart, and as neurologists say, "What's good for the heart is good for the brain."

What's good for the heart is good for the brain. The MIND diet encourages greater consumption of fruits and vegetables, including berries at least twice a week and beans four or more times a week.

What you can do. If you want to try a Mediterranean, DASH, or MIND diet, here are the common principles behind them:

- Increase your consumption of fresh fruits and vegetables. Half your plate should contain produce.
- Limit red meat, and avoid processed meat entirely. Fish, poultry, and beans are better protein sources.
- Choose whole grains—such as whole-grain bread and brown rice—over highly processed grains.
- Use olive oil in cooking.
- Snack on nuts (such as walnuts or almonds) and dried fruit (in moderation), instead of potato chips, crackers, or ice cream.

It may be tempting to fill in nutritional gaps with vitamins and fish oil capsules. But with a few possible exceptions, that will not have the desired effect (see "What about vitamins?" below).

5 If you drink alcohol, do so moderately

Drinking too much alcohol on a regular basis increases the risk for memory loss and cognitive decline. It has been well established for a century or more that people with alcoholism can develop cognitive impairment and severe dementia. Studies have demonstrated that significant alcohol use is associated with difficulty performing short-term memory tasks, such as memorizing lists. Another type of memory loss associated with heavy alcohol use is alcohol amnestic disorder (or Korsakoff syndrome), a form of dementia in which severe amnesia comes on suddenly and dramatically because of long-term vitamin B_1 (thiamine) depletion. The memory loss with this disorder can be permanent in some cases. Other alcohol-related memory problems may be reversible if a person sharply cuts down on drinking and eats a healthy diet.

When it comes to light or moderate drinking, the role of alcohol in memory performance is less clear-cut. Traditionally, moderate consumption has been defined as no more than two drinks a day for men and one a day for women, and light drinking less than that. Over the long term, some studies have linked moderate consumption with a reduced risk of dementia. Some studies have suggested that alcohol in small doses may be "memory-protective" because of its antioxidant properties and the fact that it decreases the risk of non-hemorrhagic stroke.

However, a large study published in *The Lancet* analyzed levels of alcohol use and its health effects in 195 countries over two decades and suggested that perhaps no amount of alcohol is really safe. We also know that moderate drinking can interfere with memory in the short term. Certainly, your ability to remember and think clearly are impaired while you're under the influence of alcohol. In addition, alcohol consumption can disrupt sleep (which is important for consolidating memories) and may contribute to depression.

What you can do. Many questions remain about the relationship between alcohol and memory. If you do not currently drink alcohol, don't start. If you do

What about vitamins?

Consuming adequate amounts of vitamins and minerals is essential for overall health, including brain health. But there is no convincing evidence that taking vitamin supplements at doses higher than the Recommended Dietary Allowance (RDA) improves memory in the short term or protects against dementia in the long term. That said, a few vitamins are worthy of special consideration.

B vitamins. In the realm of memory and cognition, you want to be sure you are getting the RDA of the B vitamins—especially B_6, B_{12}, and folic acid. A vitamin B_{12} deficiency, in particular, can cause disorientation and confusion (see "Potentially reversible causes of dementia," page 42). Vitamin B_{12} is found in meat, poultry, seafood, dairy products, and eggs. Vegans and some vegetarians, who do not get enough B_{12} in their diets, can prevent or treat a vitamin B_{12} deficiency by taking supplements. In addition, about 6% of people ages 60 and older are deficient in vitamin B_{12}, and nearly 20% are borderline deficient. Older adults produce less stomach acid than younger people, which makes it harder for them to extract this vitamin from food sources. People who complain of memory or thinking difficulties should have a blood test to rule out a vitamin B_{12} deficiency, since it is often treatable.

Vitamin D. Some studies have found that low levels of vitamin D can impair mental function. Other studies have found a possible connection between low vitamin D levels and increased risk for dementia.

In theory, you can meet most, if not all, of your vitamin D requirement with exposure to the sun on the arms and legs for about 10 to 15 minutes a day. Sunlight penetrates the skin and converts a naturally occurring substance into the form of vitamin D that can be used by the body as a nutrient. However, in the northern latitudes, it can be difficult to get enough sun exposure, especially in the winter. Moreover, few foods naturally contain vitamin D, the main exception being fatty fish (salmon, mackerel, and tuna). Milk and some juices are fortified with vitamin D. If getting enough sun-generated vitamin D is not feasible and you don't consume much in your diet, then consider a daily multivitamin or separate supplement to meet the recommended dietary intake of 600 to 800 IU per day.

enjoy a cocktail or glass of wine, keep it moderate. Clearly, it's better to forgo alcohol altogether than to over-imbibe.

6 Maintain a healthy weight

Maintaining a healthy weight, particularly during middle age, can help reduce your risk of dementia. However, roughly one-third of Americans are obese, meaning that they have a body mass index (BMI) of 30 or higher. (To calculate your BMI, go to www.health.harvard.edu/BMI.) Obesity leaves you more prone to a host of medical problems, including dementia. Particularly risky is having so-called central obesity—the classic "spare tire"—in middle age. In addition, people with obesity face a higher risk of heart disease and diabetes—two conditions that have also been linked to memory impairment and a higher risk of dementia.

Maintaining a healthy weight over time is clearly beneficial. Researchers are investigating whether you can derive the same benefits if you're overweight or obese and then lose weight. Results from several studies suggest that weight loss has the potential to improve cognition and slow the rate of decline in people who already have some memory impairment. This is a topic of continuing research.

What you can do. You've heard it over and over—consume fewer calories. That generally means eating less processed food. Replacing calorie-dense foods, like cookies, crackers, and donuts, with low-calorie foods like fruits and vegetables both fills you up and reduces your caloric intake. The number of calories you need each day depends on your sex, age, and level of activity (see Table 3, above).

There are simple ways to trim your daily calories. Simplest of all is to cut out high-calorie beverages, like sodas, lattes, sports drinks, and energy drinks. Sugar-packed beverages can add hundreds of calories per day, but without satisfying your sense of hunger, so you end up eating just as many solid calories. Instead, let unsweetened coffee, tea, seltzer, herbal teas, and naturally flavored waters satisfy your desire for flavor in a beverage.

Then try to dial back on the snacks you indulge in while engaging in other activities, like working on the computer. Without even realizing it, you can down a whole stack of crackers if you're not paying attention. When you actually focus on what you're eating, you consume much less.

If eating at night is your problem, try closing the kitchen after dinner. If you've eaten three full meals during the day, so that you don't feel deprived, you can reasonably tell yourself you don't need late-night snacks. Once this becomes a habit, it will be much easier to do.

Many more strategies are available in the Harvard Special Health Report *Lose Weight and Keep It Off* (see "Resources," page 51). If you still find it difficult

Table 3: How many calories do you need each day?

This table shows roughly how many calories a person of average weight needs to consume each day to maintain his or her current weight. If you want to lose weight, you will need to take in fewer calories. If you are overweight, these give you targets to slowly work toward.

	AGE	RELATIVELY SEDENTARY	MODERATELY ACTIVE	ACTIVE
Women	31 to 50	1,800	2,000	2,200
	51 and over	1,600	1,800	2,000–2,200
Men	31 to 50	2,200–2,400	2,400–2,600	2,800–3,000
	51 and over	2,000–2,200	2,200–2,400	2,400–2,800

Source: Dietary Guidelines for Americans, 2020–2025.

Many people find that their tendency to snack at night defeats their efforts at weight control. If this is your problem, try closing the kitchen at night and telling yourself you've already had three meals.

Social relationships serve as a buffer against stress, provide intellectual stimulation, and expose you to new information—all good for the brain. If a friend is also a workout buddy, so much the better.

to change your diet, consider consulting a dietitian or nutritionist. Either one can guide you to an overall healthier way of eating and suggest foods and methods of preparation you haven't thought of. You may find that foods you used to dislike are actually not bad if prepared in a different way.

7 Stay socially active

Some research suggests that older adults who are socially engaged have better memory and other cognitive abilities, and may even be at a lower risk for dementia, compared with those more socially isolated. A study of 3,610 people (ages 24 to 96) looked at the relationship between participants' mental function and their level of social contact based on how often they talked on the phone to friends, neighbors, and relatives. The researchers found that the higher the individual's level of social interaction, the better his or her mental function; this result was found across all age groups.

There are several ways in which social engagement may benefit your memory. Social interaction often goes hand in hand with intellectual stimulation. Carrying on conversations not only exposes you to new information, but also forces you to frame your thoughts in different ways. Social relationships can also provide support during stressful times, reducing the damaging effects that stress can have on the brain.

What you can do. Reach out to others. Social support can come from relationships with friends, relatives, or caregivers, as well as from community volunteer organizations, recreational sports teams, religious communities, or other organized groups. You can even tackle two brain-boosting options at once by finding an exercise buddy or joining a walking group. If physical limitations keep you from regularly engaging in these activities, stay connected via telephone, video chat (with options such as FaceTime, Zoom, Skype, WhatsApp, and others), or social media.

8 Manage your stress

Stress can be defined as the body's response to actual or perceived physical, mental, or emotional pressure. Stress can impair memory in more ways than one. For starters, the stresses of everyday life—like deadline pressure, monthly bills, or arguments with friends or family members—can cause you to expend mental energy just to manage the anxiety and distress. By contrast, reducing these stressors gives your mind the freedom to handle other cognitive tasks.

In addition, stress can trigger the body's natural "fight or flight" reaction, which occurs in response to a perceived threat. To protect itself, the body releases stress hormones, including cortisol and epinephrine (also known as adrenaline). These hormones prime your body to respond to a physical danger by either running or standing your ground. Energy-boosting glucose is released into your bloodstream to fuel your muscles. Your heart pounds and breathing quickens to deliver oxygen and nutrients to those muscles. Sharpened senses, such as vision and hearing, make you more alert. Platelets become stickier, so clots can form more easily to minimize bleeding from potential injuries. Immune system activity picks up to fight germs from wounds.

This physical reaction can help you sprint out of the path of an oncoming bus or fight an assailant—and in the short run, it gives you increased energy and focus. But when your cortisol level remains high for too long, it can harm brain structures vital to memory, including the hippocampus. In today's world, sources of stress have also multiplied (for example, environmental disasters, a country divided by political views, and public health crises like COVID-19), making our

personal and collective management of stresses in a healthy and sustainable way imperative.

What you can do. There's no one-size-fits-all strategy for coping with stress. You have to find solutions that work for you—whether taking a brisk walk, listening to music, talking to a friend, or engaging in relaxing activities, such as gardening or knitting. Developing a practice of mindfulness can also help and has specifically been linked to benefits for memory. In one study of 34 adults ages 65 and older with high anxiety-related stress, eight sessions of a mindfulness-based stress reduction program not only lessened the severity of their anxiety but also improved their performance on a memory test that involved recalling the details of a paragraph when asked about it later. The study was published in the *International Journal of Geriatric Psychiatry*.

Mind-body exercises like yoga or tai chi may also prove helpful. A handful of small studies have investigated the effects of yoga on memory. For example, one study found that participants who completed eight weeks of Hatha yoga improved on tests of working memory when compared with a group that engaged in an eight-week program of stretching and strengthening exercises.

The Harvard Special Health Report *Stress Management* includes dozens of strategies for coping with stress (see "Resources," page 51). If you can't reduce stress on your own, you might benefit from counseling. Some research indicates that it may not be the actual stressors in your life that cause problems so much as your *perceived* level of stress.

9 Try meditation

Meditation is a practice that can improve your mental clarity and help you attain a more balanced emotional state by sitting quietly and focusing on a particular object, sound, or your own breath. Everyone can benefit from meditation. It is not a specialized activity that must be done or taught by experts of any kind. And meditation can boost your memory in multiple ways.

Meditation improves your ability to concentrate, even when things around you are chaotic—thus improving attention, which is crucial for memory acquisition. It helps reduce stress, counteracting the harm of chronic high levels of stress hormones on your brain, including the hippocampus, which can shrink under a steady onslaught of cortisol. And it can improve your ability to get a restful night's sleep—another memory booster.

There are many types of meditation. One that has been studied for improved cognition is mindfulness meditation. In this practice, you pay attention to what you're experiencing from moment to moment, without focusing on thoughts about the past or concerns about the future, and without analyzing or making judgments about what is going on around you. You allow whatever thoughts, emotions, or sensations that you experience to arise in consciousness, making an effort to observe them without becoming "attached" to them.

Emerging research suggests that mindfulness meditation programs may improve cognitive abilities, such as attention and some aspects of memory, in people with mild cognitive impairment. Meditation has also been shown to reduce stress and improve mood, well-being, and sleep—all of which may have a positive effect on memory—in older adults with perceived memory loss.

Studies have demonstrated the effectiveness of mindfulness meditation for reducing stress, boosting mood, and improving sleep in older adults with perceived memory loss.

What you can do. Numerous books, online videos, smartphone apps, and workshops can help you learn the techniques of meditation. It may be worth looking at the writings and programs developed by Jon Kabat-Zinn, a longtime scholar on the science and practical applications of mindfulness meditation for health conditions and overall wellness (see "Resources," page 51). Apps, such as Head-

space (www.headspace.com), Waking Up (www.wakingup.com), and Calm (www.calm.com), may be helpful as well.

10 Manage your medical conditions

Conditions that have been connected with heart disease—including high blood pressure, high cholesterol, and type 2 diabetes—have also been linked to memory problems. Moreover, they can increase your risk of suffering brain-damaging strokes and dementia or cause memory problems to appear at an earlier age (see "A lesson from the Nun Study," below). To help keep your memory sharp as you age, it's important to manage medical conditions such as high blood pressure and diabetes (see "Life's Simple 7: Ways to help your heart and your brain," page 33).

High blood pressure. Adults with high blood pressure (hypertension) are more prone to memory impairment than people with normal blood pressure. Moreover, people with hypertension experience memory loss that is more severe than that suffered by individuals who don't have hypertension. These differences hold true regardless of age.

High blood pressure also increases the risk for dementia, especially when it is present in midlife. It likely does so by accelerating atherosclerosis, the buildup of plaque in the arteries that impairs circulation. A reduction in circulation can slow blood flow to the brain, which can harm neurons. Even worse, if blood flow to multiple small vessels of the brain is blocked, brain tissue in that area can die. Each episode of damage—which is actually a tiny stroke—affects a small area of the brain, and symptoms may not be apparent until a significant amount of tissue has been destroyed. This is a form of vascular dementia, which is a well-recognized cause of memory loss in older people.

High blood pressure is generally easy to treat with a healthy lifestyle and, if necessary, medication. Lowering blood pressure reduces your risk for heart attacks and other forms of cardiovascular disease. Recent research shows that it also may reduce your chances of developing mild cognitive impairment (MCI, a problem that often precedes dementia) and full-blown dementia. In a 2019 study published in *JAMA*, 9,361 people (average age 68) who had high blood pressure but not dementia were assigned either to a standard treatment group (which aimed to keep participants' systolic blood pressure under 140 mm Hg) or an intensive treatment group (with a target of under 120 mm Hg). Lower blood pressure turned out to be better. There was a 19% lower rate of new cases of MCI among those receiving intensive treatment compared with standard treatment. What's more, MRI scans of 454 participants demonstrated that those in the intensive-treatment group had significantly fewer small, silent strokes (also known as microvascular disease or white matter lesions), which are very common in people ages 60 and older. However, the *JAMA* study did not show a significant reduction in the risk for full-blown dementia, likely because it did not continue for long enough.

High cholesterol. Like high blood pressure, high cholesterol levels appear to increase the risk for memory impairment and dementia years down the road. There's more than one form of cholesterol. Low-density lipoprotein (LDL) cholesterol is considered "bad"

A lesson from the Nun Study

Thanks to a community of nuns who were willing to participate in an extensive long-term study, researchers have gained valuable insight into cognition and dementia.

For the study, the 678 sisters, who were ages 75 and older when the study began, underwent yearly medical exams and evaluations of mental function, and they agreed to donate their brains for autopsy after they died. Researchers also had access to extensive data about the sisters' families, medical histories, and education. When the sisters died, autopsies of their brains revealed that those who had the fewest signs of having had strokes (and who therefore had healthier cardiovascular systems) had been the least likely to demonstrate symptoms of Alzheimer's disease during their lifetimes—even if the autopsy also showed that they had brain changes that are characteristic of Alzheimer's disease (amyloid plaques and neurofibrillary tangles).

From this finding, the researchers concluded that a healthier cardiovascular system can help the brain maintain normal function longer.

because it can build up in the walls of arteries and lead eventually to heart attacks and strokes. High-density lipoprotein (HDL) cholesterol helps to clear excess cholesterol from arteries and is therefore considered "good." Having high LDL cholesterol levels in midlife has been shown to raise risk for later developing mild cognitive impairment or dementia.

Diabetes. Several large studies have documented links between diabetes and decline in memory and thinking. People with diabetes are at greater risk for mild cognitive impairment, vascular dementia, and Alzheimer's disease. Scientists think that many factors link diabetes and dementia. People with diabetes have chronically high blood sugar, especially if the disease is not well controlled. This may damage small blood vessels in the brain. In addition, high blood sugar depresses the function of the hippocampus, which, as noted earlier, plays a key role in the acquisition and consolidation of new memories. There is some evidence that better control over blood sugar levels is associated with improved cognitive functioning.

Many people with diabetes also have high cholesterol levels, high blood pressure, or both. These conditions, too, may contribute to the higher risk for dementia faced by people with diabetes.

Metabolic syndrome. People who have a combination of the medical conditions described above have what is called metabolic syndrome. You have metabolic syndrome if you have three or more of the following:

- high blood pressure
- excess belly fat, meaning a waist size of 40 inches or more for men, or 35 inches or more for women
- high triglycerides, a kind of blood fat
- low HDL cholesterol
- high fasting blood sugar.

Metabolic syndrome puts you at greater risk for a host of problems, including strokes, diabetes, and a fatal heart attack. Some research suggests that problems with memory and thinking should be added to that list. This makes sense because most of the components of metabolic syndrome increase your risk for cognitive impairment.

What you can do. Ideally, you want to keep your blood pressure, cholesterol levels, blood sugar levels, and weight within the normal range throughout life. That means blood pressure below 120/80 mm Hg, total cholesterol below 180 mg/dL, blood sugar levels below 100 mg/dL before eating and below 140 mg/dL two hours after eating, and BMI between 18.5 and 24.9. Several lifestyle practices, including a number of measures already discussed, can help you.

- Exercise regularly. This helps to reduce blood pressure, lower LDL cholesterol, and nudge up HDL cholesterol. It can also help keep blood sugar levels under control.
- Eat a healthy diet that's rich in vegetables and fruits to help control both your blood pressure and cholesterol levels. One option is the Mediterranean diet. Another is the MIND diet (see "Eat a healthy, plant-based diet," page 26).
- Limit salt intake to help control your blood pressure. Your body needs a small amount of sodium to function normally. But most of us consume too much, mostly in the form of salt. Most people ages 2 to 50 should consume less than 2,300 mg of

Life's Simple 7: Ways to help your heart and your brain

The American Heart Association (AHA) recommends seven lifestyle strategies to lower risk for heart disease:

1. Manage your blood pressure.
2. Control your cholesterol levels.
3. Reduce blood sugar.
4. Get active.
5. Eat better.
6. Lose weight.
7. Stop smoking.

Not surprisingly, these measures can protect the brain as well. A study of over 6,600 people ages 65 and older, published in *JAMA*, found that adherence to the AHA's Simple 7 was linked to lower rates of dementia and cognitive decline over an average of eight-and-a-half years. Even following just a few of the recommendations reduced risk. For each additional strategy optimally managed, the risk declined by 10%. People who had all seven under good control showed just half the rate of decline on tests of memory and cognitive function as those who were not managing any of the strategies at optimal levels.

sodium a day. But if you are over age 51, are Black, or have high blood pressure, diabetes, or chronic kidney disease, the target is less than 1,500 mg. If you're eating packaged foods, read food labels for sodium content and choose foods with lower amounts. If you're cooking from scratch, you can control the amount of sodium you add. Try reducing the amount, and soon your palate will adjust. You can also compensate for reduced salt by using salt substitutes or adding herbs and spices.

- Reduce stress to help keep your blood pressure under control. Blood pressure fluctuates throughout the day in response to a variety of factors, including stress and anxiety (see "Manage your stress," page 30).
- Don't smoke. This is important for many reasons. Among smoking's many harmful effects, it raises blood pressure and increases the risk of heart disease and stroke. (See "Don't smoke," page 38, for tips on how to kick the habit.)

If lifestyle measures don't bring your numbers down to the right range and keep them there, talk to your doctor about medications to lower blood pressure, reduce cholesterol, and control blood sugar.

11 Get your hearing and vision tested

If you have trouble hearing something, you're bound to have trouble remembering it, because you never properly acquired the information in the first place. Even the act of trying to make sense of garbled sounds may interfere with memory because you're using mental energy that could be devoted to encoding what you hear. One study found that adults with mild to moderate hearing loss remembered fewer of the items from a list of 15 spoken words than did adults with good hearing. The researchers concluded that the extra effort involved in trying to hear the words diverted brain resources from acquisition and consolidation of memory.

Equally worrisome, the struggle to hear what others are saying may lead a person to become socially disengaged (see "Stay socially active," page 30). Some studies have shown that even mild levels of hearing loss increase the long-term risk of cognitive decline and dementia.

Similarly, problems with vision can undermine cognitive functioning. Poor eyesight may reduce your physical activity, dampen your mood, and limit your social interactions, all of which can have a negative impact on memory. A 2021 study followed 394 women in their 40s and 50s for over 15 years and found that vision impairment that was moderate or worse was associated with lower scores of cognitive function as these women transitioned from midlife to older adulthood. Strikingly, a study published in the journal *PLOS One* found that cataract surgery (which markedly improves vision) reduced the rate of cognitive decline among older adults.

What you can do. Periodic hearing and vision tests should be part of routine medical care. Both hearing loss and vision loss are treatable. A study published in the *Journal of the American Geriatrics Society* found that use of hearing aids may slow cognitive decline in older adults and should be considered much earlier in the course of hearing impairment. Hearing aid technology has improved greatly in recent years; if you tried a hearing aid in the past and didn't find it helpful, consider trying again. Successful use of a hearing aid may require several follow-up visits to the hearing aid specialist, who will fine-tune and adjust the device for your needs.

As for poor vision, the answer may be as simple as checking the prescription on your glasses. Periodic eye exams can also help catch other problems (such

Regular eye exams can help catch debilitating eye diseases before they steal your sight. Poor eyesight may reduce your physical activity, dampen your mood, and limit your social interactions.

Do estrogen and testosterone affect memory?

In addition to thyroid hormones (see "Have your thyroid hormones checked," below), other naturally occurring hormones can affect memory and overall cognitive function. In particular, research has focused on the sex hormones estrogen and testosterone.

Estrogen. Many women experience trouble with memory during menopause, when their levels of estrogen fall sharply. Fluctuating and declining estrogen levels can cause hot flashes and sleep disturbances, which may also be to blame for memory problems. Some studies suggest that estrogen protects neurons, which might explain a connection with memory. If that's true, you would think that hormone supplements should protect against age-related memory difficulties, but that's not necessarily the case. One study of medical records of female members of the Kaiser Permanente health maintenance organization found that women who took hormone therapy at midlife (around age 48) had a 26% lower risk of developing dementia later, whereas those who took the hormone supplements only later in life (about age 76) had a 48% *higher* risk. More research is needed before doctors can make definitive recommendations regarding hormone therapy and the risks of dementia or memory problems in general. Alzheimer's disease and other dementias occur more frequently in women than men, and research is under way to determine what role changes in estrogen levels in women over the life span may play in the risk of later-life cognitive decline. Men do not have age-related reductions in estrogen, and levels are not significantly associated with risk of cognitive impairment or dementia risk.

Testosterone. Men with high levels of testosterone have better visual and verbal memories than men with low levels. However, the value of testosterone supplementation in older men is controversial. Testosterone supplements have drawbacks—they can increase the risk of some kinds of cancer and may also raise the risks for stroke and vascular dementia. In addition, the type of testosterone and the amount (if any) that should be given as a treatment for memory problems still needs to be established.

as glaucoma or macular degeneration) early and allow you take action to preserve your eyesight. Cataracts are one of the most common causes of vision loss and can easily be treated with surgery.

12 Have your thyroid hormones checked

The thyroid gland secretes hormones that control metabolism, the rate at which the body burns energy. When the thyroid doesn't function properly, it can release too much or too little of these hormones, making the metabolism run too fast or too slow. Either problem can interfere with learning and memory, but in a different way.

- Hyperthyroidism, which causes an abnormally fast metabolism, can make people feel confused.
- Hypothyroidism, which causes an abnormally slow metabolism, can make people feel sluggish, sleepy, and depressed.

Research on animals shows that changes in thyroid hormone levels cause physiological changes in the hippocampus. Research also shows that when thyroid disorders are treated, people's memory problems diminish.

What you can do. If you think you might have a thyroid problem, ask your doctor for a simple blood test to check your levels of thyroid hormones and thyroid-stimulating hormone. Treatment can be as straightforward as taking pills containing synthetic thyroid hormone. Note that the usefulness of other hormone supplements is very much in question (see "Do estrogen and testosterone affect memory?" above).

13 Review your medications

Many over-the-counter and prescription drugs have side effects that can scramble thinking and dim your memory. Older people tend to be more sensitive to these effects. Moreover, older people often take multiple medications. Although one drug alone may not cause problems, the cumulative effect of several drugs may impair memory and thinking.

Popular over-the-counter drugs with these side effects—often listed on the label as dry mouth, blurred vision, and confused thinking—include the antihistamines brompheniramine (found in Dimetapp, among others), chlorpheniramine (found in Chlor-Trimeton, Triaminic, and many others), and diphenhydramine (best known as Benadryl). Doctors sometimes recommend that people take diphenhydramine to help them fall asleep. (In fact, it is the main sedating ingredient

in many over-the-counter sleep aids, such as Sominex, Unisom, Tylenol PM, Advil PM, Motrin PM, and Aleve PM.) But if it causes you mental confusion, try nondrug approaches to improving sleep instead (see the tips under "Get a good night's sleep," page 25).

Among prescription drugs, the prime culprits include certain ones used to treat depression, such as amitriptyline (Elavil) and nortriptyline (Pamelor); overactive bladder, such as oxybutynin (Ditropan, Oxytrol); and heartburn, such as cimetidine (Tagamet). Some fast-acting anxiety medications, like the benzodiazepines—lorazepam (Ativan), alprazolam (Xanax), and diazepam (Valium)—can also affect cognition and should be discussed with any prescriber.

Many of these medications share a common mechanism: blocking the neurotransmitter acetylcholine, which is why they're called anticholinergic medications. Several studies have found that the use of these drugs is linked to a more rapid decline in cognitive performance and a higher risk of dementia. Note that certain medications used to *treat* Alzheimer's disease, such as donepezil (Aricept), have the opposite effect—they boost levels of acetylcholine in the brain.

What you can do. If you've noticed any kind of confusion or thinking problems since starting a new medication or supplement, ask your doctor about a possible substitute, which is often (though not always) possible. For some people, especially older adults, medications (both prescribed and over-the-counter) can cause clouded thinking and memory, even if you've taken them for a long time without any problem. If you notice a marked deterioration in your memory, review your medications, including nonprescription drugs, with your medical providers to identify a possible culprit, even if you've taken these medications for a long time. For some potential alternatives to drugs with anticholinergic actions, see Table 4, below.

14 Treat depression

The relationship between depression and memory loss is complex. Depression can be a cause as well as an effect of memory dysfunction. Severe, ongoing, and untreated depression can make people forgetful by interfering with their ability to concentrate and process information. This is particularly true in older adults. Once the depression is treated, the person's memory can often return to the level of function that existed before he or she was depressed.

Depression has another possible effect on mental function: it seems to put people at risk for later dementia, particularly Alzheimer's disease and vascular dementia. The reason for this is not entirely understood.

Depression that occurs for the first time in an older adult may also be an early symptom of dementia. Thus, older people who develop late-life depression need to be closely watched. There are key differences in the memory loss experienced by people suffering from depression alone and people experiencing depression in conjunction with Alzheimer's disease. In

Table 4: Medications that may affect memory—and possible substitutes for them

IF YOU TAKE…	… ASK ABOUT SWITCHING TO ONE OF THESE DRUGS
amitriptyline or doxepin (Silenor)	a wide range of alternatives, depending on your reason for taking a tricyclic antidepressant (neuropathic pain, depression, etc.)
captopril	a different ACE inhibitor
cold or allergy medication containing brompheniramine, chlorpheniramine, or diphenhydramine	loratadine (Claritin), fexofenadine (Allegra), or another non-sedating antihistamine
oxybutynin (Ditropan) or tolterodine (Detrol)	darifenacin (Enablex), solifenacin (Vesicare), or trospium (Sanctura), which are anticholinergic but more selective for the bladder
paroxetine (Paxil)	another SSRI, such as escitalopram (Lexapro), citalopram (Celexa), or sertraline (Zoloft), or a drug from the SNRI class, such as duloxetine (Cymbalta) or venlafaxine (Effexor)

people with depression alone, mental function usually fluctuates with mood. When mood improves—generally in response to treatment with medication, psychotherapy, or both—mental function tends to improve as well. By contrast, someone with Alzheimer's will continue to have impaired cognitive functioning even when the depression lifts.

What you can do. Depression goes beyond occasionally feeling sad or blue for a couple of days, which is normal. If the feelings last and are intense enough to interfere with daily life, you probably have depression. There are several signs and symptoms of depression. According to the National Institute of Mental Health, they include

- persistent sad, anxious, or "empty" feelings
- feelings of hopelessness or pessimism
- feelings of guilt, worthlessness, or helplessness
- irritability, restlessness
- loss of interest in activities or hobbies once pleasurable, including sex
- fatigue and decreased energy
- difficulty concentrating, remembering details, and making decisions
- insomnia, early-morning wakefulness, or excessive sleeping
- overeating or appetite loss
- thoughts of suicide or suicide attempts
- aches or pains, headaches, cramps, or digestive problems that do not ease even with treatment.

If you have any of these symptoms, seek help from a mental health professional, such as a psychiatrist, psychiatric nurse practitioner, psychologist, or social worker. These professionals can provide counseling and possibly medication. Your primary care doctor can also refer you to a mental health professional.

15 Know the risks and potential benefits of cannabis before you use it

The plant *Cannabis sativa* contains more than 400 different compounds, including a number that are biologically active in humans. Of these, two are of particular interest—the potentially therapeutic compound cannabidiol (CBD) and the psychoactive chemical tetrahydrocannabinol (THC).

CBD appears to be beneficial for various medical conditions, including epilepsy and neuropsychiatric symptoms (agitation, anxiety) in Alzheimer's disease and related dementias. Preliminary research indicates that CBD may have an additional benefit for mental performance—notably, improved sleep. But most CBD products lack FDA approval. The exception is the CBD-containing drug Epidiolex, which was approved in 2018 to treat two rare and severe forms of epilepsy. As for the plethora of unregulated CBD products on the market, many have CBD levels that are too low to get into the bloodstream, so any benefits may result at least in part from the placebo effect. And questions remain. What is an effective dose? How can you be sure you're getting that dose from an unregulated product? And is it safe to use long-term?

There are also many questions surrounding THC, which is found in medical and recreational marijuana (the dried flowers, leaves, stems, and seeds of the cannabis plant). In the medical sphere, marijuana is used to control pain, relieve nausea, and treat certain cases of anorexia. At low doses, it can also relieve anxiety and post-traumatic stress disorder. But at high doses, it has the opposite effect, increasing anxiety and paranoia.

When it comes to memory and other cognitive functions, THC may be problematic. There's no question that while people are under the influence of marijuana, they can have short-term problems with

Cognitive impairment and bypass surgery

High blood pressure, high cholesterol, and smoking all make clogged arteries more likely. If the problem becomes serious, a surgical procedure called coronary artery bypass may be needed. Some people who undergo this type of surgery experience memory loss and problems concentrating for a while after the operation. Why this happens is not clear.

Newer surgical techniques have made cognitive impairment after heart surgery less common. However, if you are preparing for a bypass operation, talk with your surgeon ahead of time about what strategies are available to minimize the chances of post-surgery memory and thinking problems. After the operation, tell your doctor about any problems with attention or concentration that develop.

thinking, working memory, executive function, and psychomotor function (physical actions that require conscious thought, such as driving a car or playing a musical instrument). This is because THC attaches to receptors in brain regions that are vital for memory formation, including the hippocampus, amygdala, and cerebral cortex. The extent to which *long-term* use of marijuana (either for medical or recreational purposes) produces persistent cognitive problems is not known. However, studies in peer-reviewed journals show that marijuana use can increase the risk of psychosis and that daily use for many years can result in cognitive impairment.

As with CBD, there are questions surrounding the dose, timing, and safety of marijuana use. In states where marijuana is legal for either medical or recreational purposes, products must be tested to ensure potency and the absence of contaminants (pesticides, heavy metals, molds). But where it is not regulated, there are no guarantees. What's more, a product that's good for one person may not be good for another. For example, the prescription drugs Marinol and Syndros, which contain synthetic THC, have FDA approval for treating nausea and vomiting in people undergoing chemotherapy. However, pregnant women should not take these capsules or smoke marijuana to control nausea, as it crosses the placenta and can affect brain development in the fetus. Some research indicates that, once these children are born, they may have greater difficulty with attention, memory, and problem solving. Similarly, teens should not use marijuana, since their central nervous system is still developing.

Unfortunately, definitive answers to questions about cannabis are hard to come by, as research is limited. Even while states are increasingly moving to decriminalize marijuana, it remains a Schedule 1 (illegal) drug at the federal level under the Controlled Substances Act. For this reason, it has been difficult for researchers in the United States to obtain federal research funding to study marijuana, limiting the amount of high-quality evidence available.

What you can do. Talk to your doctor before beginning to use marijuana or CBD. There are increasing numbers of medical practitioners with knowledge about the potential benefits and harms of cannabis. The CDC website also includes information about many aspects of marijuana and health (see www.cdc.gov/marijuana). If you use marijuana, understand you may have problems with memory and related cognitive functions while under its influence. There also is a possibility of developing cognitive problems with long-term use.

16 Don't smoke

Smokers face an increased risk for dementia. A meta-analysis of 19 studies involving a total of more than 26,000 participants found that smokers showed a greater yearly decline in cognitive scores than nonsmokers. The more you smoke, the greater the risk. In one large and racially diverse study, researchers found that people who had smoked more than two packs of cigarettes a day at midlife had more than double the risk of developing dementia in old age when compared with nonsmokers. But here's the good news: people who had stopped smoking by midlife had a risk of dementia like that of people who had never smoked.

No one knows whether smoking directly impairs memory or is merely associated with memory loss because it increases the risk for vascular diseases, stroke, and high blood pressure—all potential causes of memory impairment and dementia.

Most studies on smoking and cognition have examined the effects of traditional tobacco-based products. The research hasn't yet caught up to the growing trend of electronic nicotine delivery systems. These include e-cigarettes, personal vaporizers, e-cigars, and other products that produce an aerosolized mixture of liquids and nicotine for inhaling. There is a perception that vaping is safer than traditional smoking, but this has not been proven. In fact, there is evidence that vaping may have an adverse effect on the immune system, blood vessels, and gene activity. Daily vaping has been associated with an increased risk of heart attacks.

What you can do. If you smoke, it pays to quit. Research shows that people who stop smoking have less mental decline than people who continue to smoke. Of course, quitting isn't easy. Cigarette smok-

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Smokers are at increased risk for dementia. The more you smoke, the greater the risk. Vaping brings risks, too. There are many strategies for quitting. If necessary, try nicotine lozenges, gums, or patches.

ing is both physically and psychologically addictive, and both of these aspects must be addressed. Success often requires a combination of counseling, social support, and some sort of nicotine replacement or other drug therapy. Here are some specific strategies:

- Set a firm date when you will quit.
- Remove all cigarettes and ashtrays from your home, car, and place of work.
- Tell family and friends and ask for their support.
- Call 800-QUIT-NOW (800-784-8669) to find the quit line in your state.
- Find counseling (individual, group, or telephone) that you are comfortable with.
- Find new approaches to handling stress. A counselor or fellow smokers who are quitting can help you come up with new coping skills that don't involve smoking.
- At least at first, minimize time spent around people who are smoking.
- If necessary, use some form of nicotine replacement. Skin patches, gums, and lozenges can be obtained without a prescription. Nicotine can also be delivered in inhalers and a nasal spray. To obtain these forms, you will need to have a prescription from your doctor.
- If you need additional help, talk to your doctor about other medications that may help you. These include bupropion and varenicline (Chantix).

If you try to quit smoking and don't succeed, don't be discouraged. Try again. Many people fail at their first attempt to quit smoking. Consider trying a different technique to find what works for you.

17 Protect your brain from injury and toxins

Head trauma is a major cause of memory impairment and appears to be a risk factor for future development of dementia (see "Head trauma," page 45).

Physical blows aren't the only sources of brain injury. Lead, mercury, and other chemicals present in homes and workplaces can cause memory loss and poor concentration. Lead poisoning can result from drinking contaminated tap water and breathing in lead dust generated by the deterioration of lead paint in homes built before 1978, when it was outlawed. Carbon monoxide fumes leak from malfunctioning household furnaces and are spewed from automobile exhaust systems. Mercury and other toxic substances are found in some paints, dyes, and inks used in artwork. Still other sources of toxic exposure are pesticides used in home gardens, darkroom chemicals, and chemicals used in metalwork and woodwork.

Growing evidence links long-term exposure to air pollution—particularly, nitrogen dioxide, carbon monoxide, and fine ambient particulate matter (PM2.5)—to increased risk of impaired cognitive function and dementia. Recent research has shown that improving air quality can improve brain health. Studies presented at the Alzheimer's Association International Conference in 2021 found that reductions in nitrogen dioxide and PM2.5 over 10 years resulted in lowered risk for dementia and slower cognitive decline.

What you can do. You can reduce the risk of head trauma by using the appropriate gear during high-speed activities and contact sports. Wear seat belts when you ride in motor vehicles. (Car accidents are by far the most common cause of brain injury.) Wear a helmet when bicycling, riding on a motorcycle, in-line skating, and skiing.

As for exposure to toxic substances, you can reduce your risk by taking sensible precautions. Before using paints, solvents, and pesticides, read the labels for safe handling. Test your home water supply and use a water filter to eliminate lead, if necessary. Avoid

sanding, scraping, and otherwise disrupting lead paint on older homes. If you do plan to remove lead paint, hire a government-approved contractor for this work. Have your car and furnace serviced regularly to minimize carbon monoxide emissions. If you have a gas range, make sure it's vented. You can check indoor air quality with an inexpensive air quality monitor.

Making changes—and making them stick

Now that you've learned 17 ways to preserve and improve your memory, the next (and hardest) step is to implement these changes in your life. Good intentions are not enough. Putting these measures into practice can be a challenge, because you have to establish new habits—and the old ones are stubborn. If you're going to succeed, you need some good strategies. And luckily there are some. The Harvard Special Health Report *Simple Changes, Big Rewards* includes step-by-step ways to accomplish a variety of goals, such as eating better, losing weight, exercising more, and improving your sleep (for more information, see "Resources," page 51). Here are some quick tips to boost your chances of success.

Make a concrete plan. Start by setting goals. That's where this report can help. Review the 17 strategies in this chapter and choose the ones that seem most helpful to you. The act of writing goals or plans down increases the likelihood you will follow through. Try to make the goals specific, measurable, and achievable. You will have a better chance of achieving them if you have concrete ways to carry them out, as opposed to just aiming generally to lose weight, for example.

Be accountable. Find ways to hold yourself accountable to your plan. One option is to share your goal or goals with friends or family members, who will periodically check on your progress. Or post your goal on a social media account (Facebook, Twitter), so you've made a public commitment to it. You might also consider putting some money on the line by making a commitment contract. This is a contract you make with yourself to commit to future healthy behavior. You set aside a sum of money each month toward meeting a particular goal (for example, stopping smoking or losing a certain amount of weight). Not achieving the goal means forfeiting the money. There are even websites to help you, such as StickK (www.stickk.com) and WayBetter (www.waybetter.com).

You are more likely to make changes that stick if you have a person or a group of people working with you. Friends or family can provide encouragement and hold you accountable.

Seek social support. You are more likely to achieve your goals if you have a person or group of people who will work with you. For example, if the goal is to exercise more, you might get a trainer, find a friend to go to the gym with, or sign up for a class. If your goal is to lose weight, ask family members to help you—for example, by not keeping a lot of tempting, calorie-dense snacks in the kitchen and not encouraging you to eat rich desserts when you go out to dinner.

Associate new behaviors with pleasure, not deprivation. We are creatures of habit, which over time become ingrained. The fact that the old habits are often pleasurable or in some way comforting doesn't help. One way to increase your odds of establishing a healthy new habit is to link a challenging new activity with something pleasurable (a healthy reward). It can be something as simple as treating yourself to a cup of coffee after an exercise session (or something else you appreciate, if you don't enjoy coffee). Or it can be something a little more complicated, like cultivating the awareness that you're not just preventing future brain trouble by working out, but that you actually feel better every time you go to the gym. Ultimately, forcing yourself to engage in brain-healthy activities is less likely to succeed than finding ways to make the activities enjoyable and meaningful.

Memory problems: Normal aging or brain disease?

It's common to become somewhat more forgetful as you age. The question is, how can you tell whether your memory lapses are within the scope of normal aging or are a symptom of something more serious?

The changes associated with normal aging may make life frustrating at times, such as when you can't remember the name of someone you just met or have difficulty concentrating. But they don't tend to interfere with your ability to go about your daily life. By contrast, people with dementia have a loss of memory and other mental function severe enough to impede their ability to operate independently at home, socially, and at work. The source of the dysfunction often is some type of injury to the brain that goes beyond normal changes. For a variety of reasons, neurons, neural networks, and brain regions are damaged to the point that they fail to work effectively.

Neuroscientists and physicians have identified some key differences between normal memory lapses and those that occur with dementia (see Table 5, below). For example, word finding can become problematic for everyone. You know the word or the name you want to recall; you just can't quickly retrieve it (it's on the "tip of your tongue"). With normal forgetfulness, the information is not lost. It may require some context, a reminder, or even time, but you should remember it.

Table 5: Normal aging or dementia?

Medical providers often use information like that summarized in this table to get an initial impression of whether someone may have normal cognitive aging or dementia. Additional evaluation is needed to draw firmer conclusions.

NORMAL AGING	DEMENTIA
The person remains independent in daily activities.	The person is significantly dependent on others for key daily living activities.
The person complains of memory loss but can provide considerable detail regarding incidents of forgetfulness.	The person complains of memory problems only if specifically asked and cannot recall instances when memory loss was noticeable.
The individual is more concerned about perceived forgetfulness than close family members are.	Close family members are much more concerned than the individual is about incidents of memory loss.
Recent memory for important events, affairs, and conversations is not impaired.	Recent memory for events and ability to converse are both noticeably impaired.
The person has occasional difficulty finding words.	The person makes frequent word-finding pauses and substitutions.
The person does not get lost in familiar territory, but may have to pause momentarily to remember the way.	The person gets lost in familiar territory while walking or driving and may take hours to return home.
The individual operates common appliances even if she or he is unwilling to learn how to operate new devices.	The person cannot operate common appliances and is unable to learn to operate even simple new appliances.
There is no decline in social skills.	The person may lose interest in social activities or exhibits socially inappropriate behaviors.
Performance on mental status examinations is normal relative to the individual's age, education, and culture.	Performance on mental status examinations is below normal in ways not accounted for by educational or cultural factors.

Source: Adapted from the American Medical Association's Diagnosis, Management and Treatment of Dementia: A Practical Guide for Primary Care Physicians.

For a person with dementia, the word is usually lost for good. People with Alzheimer's disease often can't name common objects. They also forget names, and not just the names of acquaintances. They often can't remember the names of their relatives and other people they know well. Depending on the severity of the disease, a person with dementia may be unable not only to retrieve the names of people, but also to recognize who they are.

Some causes of serious memory impairment are reversible (see "Potentially reversible causes of dementia," below right). For example, certain medications can cause memory problems, and stopping the medication will restore mental function (see "Review your medications," page 35). But many causes of dementia, like Alzheimer's disease, are permanent. The following are some examples of conditions that prevent neurons from functioning normally, causing a variety of mental impairments, including memory loss.

Mild cognitive impairment

People with mild cognitive impairment (MCI) have either memory loss or a decline of other mental functions, or both. These problems are more persistent and severe than normal age-related changes but don't meet the criteria for dementia. MCI has two major subtypes: amnestic (when memory is impaired) and non-amnestic (which affects other types of cognitive functioning, such as language, attention, or spatial processing). Impairment in both categories is called multi-domain MCI.

In addition to being more severe than normal age-related memory loss, MCI is also different in terms of the kind of information a person forgets. With normal memory loss, people tend to forget things that aren't terribly important to them—the name of a casual acquaintance, for example, or an appointment for a dental cleaning. With MCI, a person may not be able to learn and retain important new information, such as the record of a favorite sports team, the outcome of important political events, or the plans of close friends or family members.

When taking memory tests, people with the amnestic type of MCI have more trouble remembering the details of pictures they've seen or paragraphs they've read just a few minutes earlier. Their memory difficulty is comparable to that of someone with very mild Alzheimer's disease. But on tests that measure other mental functions, such as their ability to keep the details of routine activities straight, people with

Potentially reversible causes of dementia

For some types of dementia, treatment can improve mental functioning. In a small percentage of people, the dementia may be completely reversible if treatment begins early.

Reactions to drugs. Certain medications can cause memory problems. Stopping the medication often can restore mental function (see "Review your medications," page 35).

Vitamin B_{12} deficiency. An untreated deficiency of vitamin B_{12} can have a variety of consequences, including a form of dementia. Dementia due to a low vitamin B_{12} level is rare because vitamin B_{12} is plentiful in eggs, dairy products, meat, fish, and poultry, and it's efficiently stored in the liver. With age, however, people become less efficient at absorbing the vitamin from food. B_{12} injections or tablets, if started early, can remedy symptoms.

Hydrocephalus. Hydrocephalus ("water on the brain") is an excess of cerebrospinal fluid within the fluid-filled cavities of the brain. A version called normal-pressure hydrocephalus (NPH) occurs in a small number of older adults as a result of head trauma, brain hemorrhage, or meningitis (inflammation of the membrane covering the brain), or for no obvious cause. The condition is treated by implanting a tube (shunt) that drains excess fluid from the brain.

Tumors. Brain tumors can interfere with cognitive functioning and cause personality changes. In rare cases, the first symptoms of slow-growing tumors resemble dementia.

Subdural hematomas. A hematoma is a localized pooling of blood outside a blood vessel. When a hematoma is located in the area between the brain surface and the thin membrane that covers it (called the subdural area), it can cause changes in memory and thinking. Subdural hematomas usually are caused by a significant blow to the head. Removing the blood by a surgical procedure within days to weeks of the injury may restore mental function.

Alcoholism. Excessive drinking can injure the brain. People who abuse alcohol are likely to have a thiamine (vitamin B_1) deficiency due to extreme malnutrition, which can cause Korsakoff's syndrome—a profound state of amnesia. Consuming excessive amounts of alcohol for a decade or more can also be directly toxic to the brain, causing impaired thinking. Abstaining from alcohol may partly restore mental functioning.

this type of MCI perform as well as healthy people and much better than people with Alzheimer's. The crucial difference between someone with MCI and someone with dementia is that in the person with MCI, the impairment in mental function does not yet substantially interfere with day-to-day functioning.

MCI becomes more common with age, affecting 15% to 20% of people ages 65 or older. About 33% to 50% of people with MCI have early, underlying brain changes due to Alzheimer's disease, and they go on to develop Alzheimer's dementia five or more years after developing MCI. The other half to two-thirds of people with MCI do not progress to full-blown Alzheimer's or another dementia. Some even go back to having normal cognitive function. If MCI remains stable or reverts to normal, it most likely resulted from a condition such as depression, a sleep disorder (like obstructive sleep apnea), medications that interfere with cognition, or a medical condition.

To diagnose MCI, a physician will ask about your medical history and will often refer you for neuropsychological or cognitive testing (see "When to see a doctor," page 47).

The symptoms of amnestic MCI include

- a subjective sense of failing memory, preferably backed up by another person such as a family member (for example, the person reports being very forgetful, or that his or her memory is much worse than in the past)
- memory impairment (for age and education) as determined by testing
- essentially normal general cognitive function
- no substantial difficulties carrying out activities of daily living
- no dementia.

Dementia

Dementia is a brain disorder involving memory impairments or other kinds of cognitive problems that are severe enough to interfere with a person's ability to function at home, socially, or at work (see "Recognizing dementia," page 44). Although memory loss is a common symptom, the condition also can involve impairments in abstract thinking, reasoning and judgment, language, and visuospatial abilities. People with dementia may also experience personality and behavior changes such as agitation and delusions.

Below, you'll find short summaries of the various causes of dementia.

Alzheimer's disease

Alzheimer's disease is the leading cause of dementia, accounting for 60% to 80% of all cases. The impairments of memory and thinking in Alzheimer's disease have been linked to two abnormal features in the brain—amyloid plaques and neurofibrillary tangles. The damage associated with plaques and tangles leads to the death of neurons in regions essential to memory and thinking and eventually spreads to other areas of the brain as well.

For most people with Alzheimer's disease, worsening problems with memory are the most prominent early symptom of the disease. (However, this is not universal. For some, behavioral symptoms or speech or language difficulties are the most noticeable signs of trouble.) Although people with Alzheimer's are frequently able to recall events from many years ago, they have profound difficulty acquiring new memories. That's partly because the hippocampus and other structures in the brain's memory network are particularly vulnerable to the damage from Alzheimer's disease. A person with dementia may ask a question, get an answer, then ask the same question a few minutes later.

Other cognitive problems that are common in Alzheimer's disease include impairments in judgment, problem solving, language, interpretation of visual images and spatial relationships, mood, and personality. Behavioral and psychological problems can also occur.

One type of memory that tends to hold up pretty well in people with Alzheimer's disease is procedural memory—the ability to perform many routine tasks (such as brushing one's teeth). This is because procedural memory is supported by different brain systems than declarative memory (which, for example, is used to remember the name of an object).

Many people who have a relative with Alzheimer's disease worry about their own chances of developing the ailment. However, the role of genetics in Alzheim-

er's disease is complex. People who have a parent or sibling with Alzheimer's have four times the risk of developing the disease compared with people who don't have a family history. But this does not mean they definitely will develop it, unless they have one of the rare early-onset forms of the disease. In the vast majority of Alzheimer's cases, some combination of genes and environmental factors likely must interact to initiate the events that lead to the disease.

Recognizing dementia

Although people in the earliest stages of dementia often sense that something is wrong, the illness eventually deprives them of the insight necessary to understand their problems. So it's usually up to a family member or friend to recognize the symptoms. The Alzheimer's Association has put together a list of 10 signs that should not be ignored.

1. Memory loss that is severe enough to disrupt daily life—for example, asking for information over and over again.
2. Challenges in planning or solving problems, such as trouble following a recipe or keeping track of monthly bills.
3. Difficulty completing familiar tasks at home, at work, or at leisure—for instance, trouble driving to a familiar location.
4. Confusion over time or place.
5. Trouble understanding visual images and spatial relationships, including difficulty judging distances and determining color.
6. New problems with words in speaking or writing, including difficulty following or joining a conversation.
7. Putting things in unusual places and being unable to find them again.
8. Decreased or poor judgment—for example, giving large amounts of money to telemarketers or paying less attention to personal hygiene.
9. Withdrawal from work or social activities.
10. Changes in mood and personality, including becoming suspicious, depressed, fearful, or anxious.

If you suspect that someone you know has dementia, arrange for a medical evaluation. Making a diagnosis of dementia requires a thorough examination by a physician. Many forms of dementia are not reversible, but early detection provides an opportunity to minimize other medical conditions that may bring out severe dementia symptoms earlier than they might otherwise show themselves. It also allows family members more time to come to terms with the illness and to plan for long-term care. While Alzheimer's medications bring only a moderate, temporary improvement in symptoms, they may be most helpful early on. And other symptoms commonly associated with dementia, such as depression, can also be addressed.

Vascular dementia

Another common type of dementia is vascular dementia. Vascular dementia has several possible causes, including strokes, injury to the white matter (microvascular disease), and bleeding in the brain.

Brain cells, like tissues elsewhere in the body, need a constant supply of oxygen to live; they get this oxygen from the blood. When blood flow is interrupted during a stroke (see Figure 5, page 45), some brain cells die. Dementia symptoms can develop afterward. Even small strokes or chronic damage to the small vessels in the brain can build up silently over years, increasing the risk for cognitive decline and dementia. Most people with vascular dementia have a gradual worsening of memory and mental functioning similar to Alzheimer's disease. Others have sudden changes in memory and thinking at the time of a stroke, followed by a leveling off.

Other types of dementia

Although Alzheimer's disease and vascular dementia are the most common forms of dementia, there are others.

Dementia with Lewy bodies. This progressive form of dementia stems from a buildup of abnormal proteins called Lewy bodies in brain cells that control cognitive functions and movement. According to the Lewy Body Dementia Association, this type of dementia affects 1.4 million Americans. The cognitive symptoms include problems with executive function, attention, processing speed, visuospatial abilities, and memory. People with this form of dementia often experience varying levels of alertness, sleep disturbances, visual hallucinations,

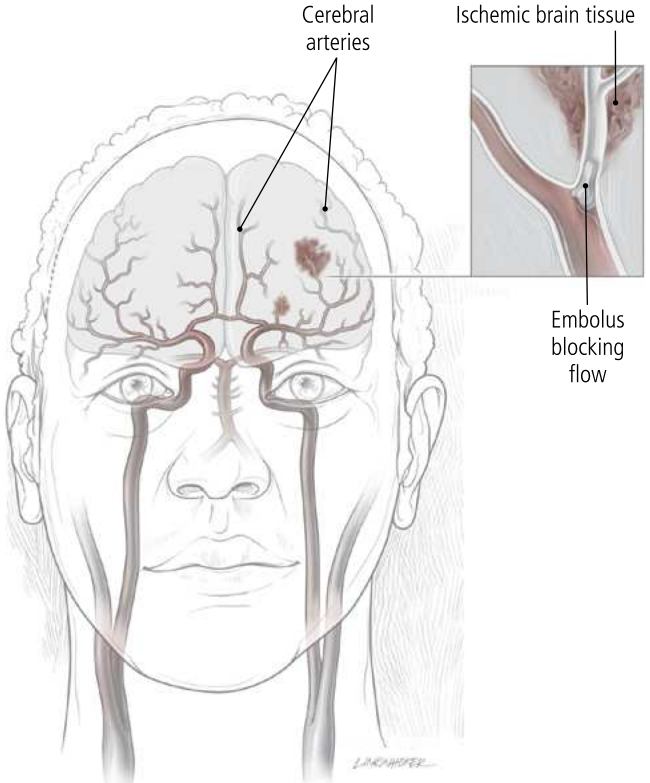
and mild motor symptoms of Parkinson's disease.

Parkinson's disease dementia (PDD). For dementia to be termed Parkinson's disease dementia, a person must have had Parkinson's disease for one year or more before the dementia came on. In PDD, as in Lewy body dementia, symptoms include impaired attention, impaired visuospatial function, problems retrieving information, and difficulties with executive function. Dementia is very common in people with Parkinson's disease, though just how common is hard to say. Studies suggest that close to one-third of people with Parkinson's disease suffer from some form of dementia.

Frontotemporal dementia (FTD). This group of diseases causes neurons in the frontal and temporal lobes of the brain to die. The symptoms depend on the part of the brain affected, but the most common signs include extreme changes in behavior and personality, such as inappropriate behavior, limited empathy, a lack of inhibition, euphoria, or—in contrast—apathy. Other forms may affect language or movement. It is sometimes misdiagnosed as a psychiatric disorder or Alzheimer's disease, but tends to occur at a younger age than is typically seen with Alzheimer's, usually from the mid-50s to the mid-60s. Of those with FTD, nearly one-fifth have a family history of dementia, suggesting the illness often has a genetic component.

Primary age-related tauopathy (PART). A form of dementia that closely mimics Alzheimer's disease, PART involves just one of the two signature features of Alzheimer's—neurofibrillary tangles. These twisted fibers form when a protein called tau, which exists inside brain cells, becomes abnormal for unknown reasons. The result is cognitive impairment, especially memory loss, but there are fewer of the behavioral changes seen in other forms of dementia. This condition has only recently been identified, and more research is under way.

Figure 5: What happens during an ischemic stroke



Ischemia refers to an insufficient supply of blood to an organ. Most strokes—about 87%—are so-called ischemic strokes, which are caused by the blockage of an artery that feeds the brain. Many of these ischemic strokes are caused by emboli, blood clots that travel to the brain after forming elsewhere, typically in the heart or aorta.

Mixed dementia

Many people have more than one type of dementia—a condition known as mixed dementia. For example, Alzheimer's disease may be accompanied by vascular dementia or dementia with Lewy bodies, or by a combination of such problems. The older people are, the more likely it is that they will have mixed dementia.

Head trauma

A blow to the head that is strong enough to cause a concussion—a brief alteration of consciousness—can also impair memory. The blow can damage brain cells, or it can stretch or tear the axons, the fine filament "tails" of the neurons (see Figure 4, page 14). Most people who suffer mild concussions recover their memories and other mental functions completely within a few hours or days. More severe head trauma, such as an injury sustained in a high-speed collision, frequently destroys brain tissue and injures nerve fibers throughout the brain. This type of damage sometimes requires many years of rehabilitation, and some injuries cause permanent impairments.

Amnesia: Memory loss caused by injury or trauma

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Amnesia is the inability to form new memories or, in some cases, to remember existing ones. Amnesia occurs when key structures of the brain—such as the hippocampus, which is essential for encoding memories—don't function properly. Some types of stroke, concussive injury, chronic alcoholism, disruption of oxygen supply, or certain kinds of infections (such as viral encephalitis) can cause amnesia. It is also a common side effect of electroconvulsive therapy used to treat major depression, although the effect is typically temporary.

People with amnesia don't forget everything, and they can retain their general level of intelligence. They have a normal attention span and can form short-term memories lasting perhaps a few minutes, if not distracted. Their procedural memory—which covers well-established skills such as driving a car or brushing their teeth—remains intact, because retention of these skills doesn't depend on the hippocampus and surrounding brain structures. The breakdown occurs with acquiring new long-term declarative memories, which often depend on the hippocampus.

People with anterograde amnesia are unable to form new long-term memories after an injury or the onset of illness. People with retrograde amnesia have difficulty retrieving previously learned information, memories that had been acquired before the onset of the condition that caused the amnesia.

The duration of amnesia depends on the cause. If the disruption of brain function is temporary (as in a blow to the head that causes a concussion), most of the lost memory will be restored, although memories formed just before and soon after the injury occurred may be lost forever.

There is also a less common condition called transient global amnesia (TGA). TGA refers to a brief period of time (usually hours) during which a person is unable to retain new information and tends to ask questions repetitively. After recovering, she or he does not remember the events that occurred during that period. TGA is not related to later development of a more serious memory disorder such as Alzheimer's disease, although the precise cause of the condition is uncertain. Emotionally or physically stressful events such as intense physical activity, sudden immersion in hot or cold water, sexual intercourse, or medical procedures can trigger an episode. TGA tends to be more frequent in people who get migraines. Certain drugs and medications can also produce TGA-like episodes.

People who sustain multiple injuries from concussion—boxers and football players, for example—appear to be prone to developing dementia and other brain disorders later in life. There's also evidence that repeated concussions raise the risk of chronic traumatic encephalopathy, a serious and progressive condition. Symptoms can include alterations in mood (depression, suicidal thoughts, anxiety, apathy), cognition (impairments in memory and executive function), behavior (impulsivity, aggression), and motor function (gait, balance, tone).

There is a growing awareness of reduced cognitive function caused by sports activities that involve impacts to the head that can result in repetitive concussions. These include football, soccer, lacrosse, and ice hockey. Many professional organizations, universities, and secondary schools in the United States have put into place concussion prevention and management guidelines. Prevention is clearly the best medicine here, but if you or someone you love does get a concussion, it's important to follow your doctor's orders when it comes to rest and rehabilitation.

Other disorders

Among the many illnesses that interfere with brain function—including memory—are multiple sclerosis, epilepsy, brain tumors, Huntington's disease, Creutzfeldt-Jakob disease, and late-stage AIDS. Some infectious agents, such as herpesviruses, Lyme disease bacteria, and coronaviruses (including SARS-CoV-2, the virus that causes COVID-19), sometimes cause persistent infections that can directly interfere with brain function.

When to see a doctor

If you're concerned about your memory, or if people close to you have noticed some worrisome trends, see your doctor for an evaluation. Because memory loss can be a symptom of many different medical problems, it's important to identify the cause and begin treatment as soon as possible. In some cases, addressing a medical disorder or treating an emotional problem can lead to improvements in memory. For instance, people with depression or sleep disorders often find that treating those conditions improves their memory function or at least prevents further decline.

If you are worried about your memory, start by seeing your primary care provider. The doctor will ask questions to narrow down possible causes of your memory issues and will perform a physical exam.

The first step

Begin by consulting your primary care provider, who is in a good position to relate your memory symptoms to medical conditions you have had or medications you are taking. But don't expect to get a definitive diagnosis. There is no single test that can pinpoint the cause of memory loss. The diagnostic process often requires a mental and physical examination, a variety of tests, and, depending on the results, monitoring over a period of several months or even longer.

Expect your medical provider to ask you a lot of questions about your memory. For example:

- How long have you been having problems?
- Did the trouble come on gradually or suddenly?
- What sorts of things have become hard to remember?
- Are your difficulties preventing you from doing everyday activities like cooking or paying the bills?
- Are you taking any prescription or over-the-counter medications?

These questions help the provider narrow down the possible causes of your memory loss. For example, if your memory loss came on relatively quickly—and occurred shortly after you started taking a drug that is known to affect memory—then the diagnostic process may focus on that drug. Depending on the medication, your doctor may ask you to stop taking it or may prescribe a different drug to see whether your memory improves.

Because certain emotional and medical conditions can affect memory, the doctor will review your medical history, ask you about new symptoms and illnesses, and perform a physical exam. Blood pressure will be measured, and blood tests may be ordered to check for diabetes. If you have one of these conditions, your doctor can make sure that it is properly controlled, either with medication or through lifestyle adjustments, such as a modified diet. Your doctor may also check your blood and urine for signs of liver, kidney, or thyroid problems; inflammation; or vitamin deficiencies. The doctor may ask whether you've been under a lot of stress lately or if you've been feeling blue, because stress and depression can cause memory impairment as well as loss of interest in previously enjoyable activities. If depression is an issue, your doctor may refer you to a psychologist or a psychiatrist for further evaluation and treatment.

To reach a clear diagnosis, the medical provider may need you to track your symptoms for several months, and so may ask you or your spouse to keep a record of your symptoms and then return to the office after that period. He or she can then determine if the symptoms are improving, staying the same, or getting worse.

If your doctor suspects you may have dementia, he or she may refer you to another health care provider who specializes in the assessment and care of people with cognitive impairment and dementia. Specialists include neuropsychologists, cognitive neurologists, geriatric psychiatrists, neuropsychiatrists, and geriatricians.

Neuropsychological testing

If your symptoms warrant a more comprehensive evaluation, your physician may refer you to a neuropsychologist, a doctor with expertise in the relationship between cognitive performance and brain function. Neuropsychologists typically use a battery of tests of mental abilities to evaluate your cognitive function. The tests assess attention, memory, executive function, language, and spatial ability. The doctor may also use questionnaires to gauge your mood.

The neuropsychologist will interpret and analyze the test results in light of your age, level of education, and other variables that influence cognitive ability and memory capacity, as well as in the context of your medical history and other diagnostic studies. That way, he or she can determine if the findings suggest a specific type of disorder or if they reflect normal age-related changes in cognitive function. The testing process might involve any of the following:

For people who might have dementia, an MRI or CT scan may help rule out other causes of memory problems. An amyloid PET scan can detect amyloid plaques, a hallmark of Alzheimer's disease.

Testing attention. Failure to pay close enough attention is one of the primary reasons people fail to learn new information—they never absorbed it completely in the first place. There are many tests that can be used to assess attention. As one example, the neuropsychologist might read you a sequence of numbers and then have you repeat back as many as you can remember.

Testing memory. Memory testing usually requires that you listen to or view some information and answer questions about it or reproduce it immediately afterward, and then again 10 to 30 minutes later. Some memory tests entail learning and remembering visual information, such as a picture that you are asked to study or a design you are asked to copy. The neuropsychologist might also test your long-term memory by asking you questions about your personal history or factual information you may have learned in the past, comparing it to information gathered from medical records or other sources.

Testing executive function. Executive function is the umbrella term for the high-level mental functions that involve the overall regulation of thought and behavior, such as control over multitasking, maintaining focus on a task, inhibiting impulses, planning, initiation, reasoning, and problem solving. You use such functions even when doing simple things like following a recipe. Executive function is also important in appreciating the subtle, implicit rules that guide social interactions—for example, exhibiting normal consideration for others and the motivation to engage with them. People who are having difficulty in this area are often unaware of the problem; family members may be the first to notice a personality change. These types of problems with executive function are usually not assessed through testing, but rather through direct observation and discussion with family members.

Testing language. Language functions include the abilities to express yourself through speaking and writing and to understand what another person is saying or what you are reading. The neuropsychologist may ask you to name common objects or pictured items. You may be asked to follow instructions as a way of determining if you understand what's being said. You may also be asked to read a brief paragraph, repeat phrases, or describe a picture in writing.

Testing spatial ability. Spatial ability includes analyzing visual information such as shapes, faces, and routes between locations on a map. Because the right side of the brain plays an important role in analyzing spatial information, people who are having difficulty with this type of function may have a condition that has damaged the right hemisphere, such as a stroke. Spatial ability tests include drawing and copying designs, solving maze puzzles, and putting blocks together to construct a specific pattern.

Brain-imaging tests

A magnetic resonance imaging (MRI) or computed tomography (CT) scan produces a structural image of your brain. These imaging methods provide the most definitive means of identifying certain causes of memory problems, such as a stroke, brain tumor, or subdural hematoma (a collection of blood under the surface of the skull). All of these conditions can injure the brain, producing neurological and cognitive symptoms. Treatment for these conditions can lead to improvement, particularly if they are detected early.

For people suspected of having dementia, an MRI or CT scan may be done to rule out other possible causes of memory and thinking problems or to look for shrinkage in certain brain areas that would indicate the possibility of Alzheimer's or other neurodegenerative diseases. A type of brain-imaging test known as an amyloid PET scan can detect amyloid plaques—one of two hallmarks of Alzheimer's disease in the brain—but by itself it is not enough to diagnose Alzheimer's. The FDA has approved the use of amyloid PET scanning, but it is not yet covered by Medicare or private health insurance.

Spinal fluid tests

In some cases when Alzheimer's is suspected, a specialist may send you to have a lumbar puncture (also known as a spinal tap). In this test, a specialist inserts a small needle between two vertebrae in the lower (lumbar) portion of the back and withdraws a small sample of cerebrospinal fluid, the clear liquid that surrounds and cushions the brain and spinal cord. People with Alzheimer's disease have abnormal levels of beta-amyloid and tau in their cerebrospinal fluid—specifically, low beta-amyloid and high tau. The cost of this spinal fluid test is covered by many insurance companies, but it is best to check with your provider's office for details.

A lumbar puncture can help confirm a diagnosis, but, like an amyloid PET scan, it is not sufficient to make a diagnosis by itself.

Treatment

The treatment for memory loss depends on the cause. Sometimes it's as straightforward as treating an underlying disorder, such as depression or thyroid dysfunction, or discontinuing a medication like diphenhydramine (Benadryl). There is no medication for treating normal age-related memory loss.

For Alzheimer's disease, there are several FDA-approved medications that have been around for 20 years, but they are not cures. They offer modest, temporary improvements in memory, other cognitive functions, and daily functioning in some people. More recently, in June 2021, the FDA approved the first monoclonal antibody, aducanumab (Aduhelm), for use in people with mild cognitive impairment or mild dementia due to Alzheimer's disease, but it has been highly controversial.

Cholinesterase inhibitors. The drugs in this class work by raising levels of acetylcholine, a neurotransmitter that's important for memory and learning, in the brain. They are donepezil (Aricept), galantamine (Razadyne), and rivastigmine (Exelon). The cholinesterase inhibitors work by blocking an enzyme that breaks up acetylcholine, which presumably makes

more acetylcholine available in the brain. Donepezil and rivastigmine have been approved for use in mild, moderate, or severe Alzheimer's disease, while galantamine is for mild to moderate disease. There is no evidence that any of the cholinesterase inhibitors are effective for preventing the development of dementia in people with MCI.

Side effects of these medications are primarily gastrointestinal symptoms, including nausea and diarrhea.

NMDA-receptor antagonist. Memantine (Namenda) is FDA-approved for treating moderate to severe Alzheimer's disease. It is an NMDA-receptor antagonist, which blocks glutamate, a neurotransmitter, from attaching to NMDA receptors in the brain. Too much glutamate stimulating these receptors can damage neurons and synapses, leading to memory loss and problems with other brain functions.

As with cholinesterase inhibitors, memantine usually provides only a modest benefit that might be apparent for six months or less. Taking memantine with a cholinesterase inhibitor may provide additional benefit.

Anti-amyloid monoclonal antibody. Aducanumab (Aduhelm) is a laboratory-created antibody that harnesses the immune system to attack amyloid, enhancing the clearance of beta-amyloid from the brain. The drug received FDA approval in 2021. However, it generated controversy because the removal of beta-amyloid from the brain was accompanied by a slowing of cognitive decline in only one of the two pivotal trials that were required for approval. Because the evidence on cognition was not strong and the drug has potentially significant side effects, the FDA granted only conditional approval, which requires further testing of the drug over the next couple of years. In the meantime, the drug can be used. However, Medicare will only cover the cost of the drug for patients enrolled in clinical trials that are approved by the NIH or FDA.

Planning ahead

Your next steps depend on your situation, whether you are experiencing dementia or normal aging. If you do receive a diagnosis of Alzheimer's disease, it is time to begin planning for the future. You may have many years when you are still able to cope, but there will eventually come a time when you can no longer manage your affairs. You will need a legal document called a durable power of attorney, usually the simplest way to grant another person the power to make decisions on your behalf. This document also permits the person to take on certain responsibilities such as managing money and paying bills for you.

Every adult should have an up-to-date will and another document called a health care power of attorney, which appoints someone to make medical decisions for you if you are unable to do so yourself.

You will also want a second document called a health care power of attorney, which appoints someone who can make decisions for you about medical care when you are no longer able to do so yourself.

Finally, you will need to make a will. Every adult should have a health care power of attorney and an up-to-date will, but these become especially important when you have a medical diagnosis.

If your problem involves normal aging rather than dementia, there are other steps to take as well, as outlined in this report. If there's one thing we hope we've made clear, it's that not all memory problems are cause for alarm, but in order to have the best chance of preserving (and even improving) your powers of recall and overall brain health, the 17 lifestyle measures are essential. These measures—many of them endorsed by the Alzheimer's Association—will foster not only cognitive health, but also general health.

Taken together, these steps can help you to live well for as long as possible.

Resources

Organizations

Alzheimer's Association
225 N. Michigan Ave., 17th Floor
Chicago, IL 60601
800-272-3900 (toll-free)
www.alz.org

This nonprofit organization supports research on treatments for Alzheimer's disease and provides information and support to families. The association has local chapters throughout the United States.

Dana Foundation
10 Rockefeller Plaza, 16th Floor
New York, NY 10020
212-223-4040
www.dana.org

The Dana Foundation is a private organization that supports brain research and educates the public about neuroscience through free publications.

National Institute of Mental Health
6001 Executive Blvd., Room 6200, MSC 9663
Bethesda, MD 20892
866-615-6464 (toll-free)
www.nimh.nih.gov

This branch of the National Institutes of Health is a source of information on depression, anxiety, and other mental illnesses that may contribute to memory loss.

National Institute of Neurological Disorders and Stroke
NIH Neurological Institute
P.O. Box 5801
Bethesda, MD 20824
800-352-9424 (toll-free)
www.ninds.nih.gov

This branch of the National Institutes of Health posts information on Alzheimer's disease, mild cognitive impairment, and other neurological disorders on its website, including the latest findings on drug treatments.

National Institute on Aging
Building 31, Room 5C27
31 Center Drive, MSC 2292
Bethesda, MD 20892
800-222-2225 (toll-free)
www.nia.nih.gov

This branch of the National Institutes of Health conducts research and publishes information on aging and health.

Books

Chicken Soup for the Soul: Boost Your Brainpower
Marie Pasinski, M.D.
(Chicken Soup for the Soul Publishing, 2012)

This book provides practical tips and medical advice for improving memory, along with motivational stories.

Harvard Medical School Guide to Achieving Optimal Memory
Aaron P. Nelson, Ph.D., M.D., and Susan Gilbert
(McGraw-Hill, 2005)

This easy-to-understand guide explains how to know if you have a memory problem, discusses factors that can impair memory, and offers tips to optimize your memory.

Keep Your Brain Young: The Complete Guide to Physical and Emotional Health and Longevity
Guy McKhann, M.D., and Marilyn Albert, Ph.D.
(Wiley, 2002)

The book offers strategies for improving memory and maintaining brain health.

The Memory Bible: An Innovative Strategy for Keeping Your Brain Young
Gary Small, M.D., and Gigi Vorgan
(Hachette Go, 2021)

This book describes memory exercises and outlines a brain fitness program designed to improve mental performance.

The MIND Diet: A Scientific Approach to Enhancing Brain Function and Helping Prevent Alzheimer's and Dementia
Maggie Moon, M.S., R.D.
(Ulysses Press, 2021)

This book provides an easy-to-follow program for keeping your mind sharp by eating the right foods and avoiding ones that can harm the brain.

Mindfulness for Beginners: Reclaiming the Present Moment—And Your Life
Jon Kabat-Zinn, Ph.D.
(Sounds True, 2016)

This book invites the reader to explore and experiment with formal meditation practices and the cultivation of mindfulness in everyday life.

Moonwalking with Einstein: The Art and Science of Remembering Everything
Joshua Foer
(Penguin Books, 2012)

This book recounts the author's yearlong quest to improve his memory, drawing on cutting-edge research and time-tested tricks of the mentalists' trade. He explores common tools for improving memory.

Seven Steps to Managing Your Memory
Andrew E. Budson, M.D., and Maureen K. O'Connor, Psy.D.
(Oxford University Press, 2017)

This book addresses key concerns about memory using real-life examples and provides information on managing age-related memory loss.

Harvard Special Health Reports

The following Special Health Reports from Harvard Medical School go into greater detail on various topics mentioned in this report. These reports can be ordered online at www.health.harvard.edu or by calling 877-649-9457 (toll-free).

Alzheimer's Disease: A guide to diagnosis, treatment, and caregiving
Gad A. Marshall, M.D., Medical Editor
(Harvard Medical School, 2021)

This Special Health Report gives in-depth information on

diagnosing and treating Alzheimer's disease. It includes help for family members and caregivers as well as individuals with Alzheimer's.

Controlling Your Blood Pressure: What to do when your doctor says you have hypertension
Randall M. Zusman, M.D., Medical Editor
(Harvard Medical School, 2021)

In 2017, the total number of Americans with high blood pressure rose sharply when medical guidelines lowered the threshold for diagnosing the problem. This report shows you how to keep your blood pressure in a healthy range by making lifestyle changes, such as losing weight, increasing activity, and eating more healthfully. A special section includes 20 strategies for cutting back on salt. The report also helps you understand the many classes of blood pressure medications.

Coping with Hearing Loss: A guide to prevention and treatment
David Murray Vernick, M.D., and Ann Gentili-Stockwell, M.A., Medical Editors
(Harvard Medical School, 2019)

Age-related hearing loss affects one in three Americans by age 65. New hearing aids—some smaller than a jelly bean—are producing greater amplification with less distortion. This Special Health Report will brief you on how hearing loss is measured. It will prepare you to work with an audiologist for an accurate diagnosis, help you determine what to look for in a hearing aid, and offer steps to take to prevent further damage.

Improving Sleep: A guide to a good night's rest
Lawrence Epstein, M.D., Medical Editor
(Harvard Medical School, 2022)

This report explains the different stages of sleep and why they are so important for health. It explores the causes of insomnia and the techniques and sleep aids that can help you improve your slumber. It includes tips for beating jet lag and spells out the latest information on the causes and treatment of sleep apnea, restless legs syndrome, and other sleep stealers.

Living Well with Diabetes: Smart strategies for controlling your blood sugar
David M. Nathan, M.D., Medical Editor
(Harvard Medical School, 2021)

This report explains how diabetes occurs and includes detailed, up-to-date information on medications. It explains how and when to monitor your blood sugar and how to cope with both short- and long-term complications of the disease. A special section deals with lifestyle strategies for managing diabetes.

Lose Weight and Keep It Off: Smart approaches to achieving and maintaining a healthy weight
Florencia Halperin, M.D., Medical Editor, and Carrie Dennett, M.S., R.D.N., Nutrition Editor
(Harvard Medical School, 2020)

This report will help you cut calories in healthful ways. Equally important, it addresses mental and emotional issues like comfort eating and overcoming cravings. It gives you strategies for preventing the munchies, making snacks healthier, and adopting lifestyle changes that help shed pounds. It also includes sections on weight-loss programs, medications, and surgery.

Managing Your Cholesterol: Lifestyle habits and medications to lower your risk of heart disease
Jorge Plutzky, M.D., Medical Editor
(Harvard Medical School, 2022)

This report covers the many factors that affect your cholesterol levels—including genes, diet, exercise, and various medical conditions—and it explains the latest medical guidelines and their implications for treatment. It includes detailed chapters on statins, PCSK9 inhibitors, and other cholesterol-lowering medications.

Simple Changes, Big Rewards: A practical, easy guide for healthy, happy living
Howard E. LeWine, M.D., Medical Editor
(Harvard Medical School, 2019)

Most of us have habits we would like to change. This report tackles some of the major ones—including eating better, exercising more, losing weight, easing stress, and getting more sleep. For each goal, there are six steps, graded easy, medium, or hard, to help you achieve your target. Includes tips for setting goals and breaking other unhealthy habits.

Starting to Exercise: 10 easy workouts to help you get fit, firm, and flexible
Lauren Elson, M.D., Medical Editor, and Michele Stanten, Fitness Consultant
(Harvard Medical School, 2018)

If you've never had a formal exercise program—or you've allowed yours to lapse over the years because of illness, time pressures, or family obligations—the idea of starting an exercise program may seem daunting. This report helps you get started with a balanced program, including aerobic exercise, strength training, balance exercises, and stretches.

Stress Management: Enhance your well-being by reducing stress and building resilience
Gregory Fricchione, M.D., Medical Editor
(Harvard Medical School, 2020)

While no life is stress-free—and some stress is actually good—unrelenting stress causes undeniable harm. This report spells out numerous ways to relieve stress and build resilience. A special section includes tips for taking the sting out of 10 common stressors, mini-relaxations to use throughout the day, and mindfulness techniques to reduce workday stress.

Thyroid Disease: Understanding hypothyroidism and hyperthyroidism
Jeffrey R. Garber, M.D., Medical Editor
(Harvard Medical School, 2022)

For a tiny gland, the thyroid can have an outsized impact on your health. This report helps you recognize the symptoms and find the treatment you need.

Glossary

acetylcholine: A chemical neurotransmitter that plays a role in attention, learning, and memory by helping brain cells communicate with each other.

acquisition: The first step in memory formation, in which the brain absorbs new information.

amnesia: A condition caused by brain injury or illness and characterized by an inability to form new long-term memories or to remember earlier ones.

amygdala: A brain structure with strong connections to the hippocampus and other structures of the limbic system that is vital to emotional arousal and the formation of long-term memories.

axon: A long filament-like projection of a neuron that conducts electrical signals away from the neuron cell body (nucleus) to other cells.

cerebral cortex: The outer layer of gray matter surrounding the cerebrum that carries out all aspects of higher brain function, including thought, memory, sensation, and voluntary movement.

cognitive function: All of the brain mechanisms involved with thinking, reasoning, learning, and remembering.

consolidation: A key phase in memory formation, in which the brain transforms newly acquired information into long-term memories.

cortisol: A hormone released by the body in response to physical or emotional stress. High levels of cortisol can damage the regions of the brain that are crucial to memory function.

declarative memory: Memory for facts (semantic memory) and for events (episodic memory); also called explicit memory.

dementia: A progressive decline across multiple cognitive domains, resulting in impairment of everyday function.

encoding: A multistage process by which sensation, perception, or thought is transformed into neural representations that can be stored in memory.

executive function: A group of cognitive activities that involves the overall regulation of thinking and behavior; the higher-order processes that enable us to plan, sequence, initiate, and sustain our behavior toward some goal, incorporating feedback and making adjustments along the way.

frontal lobes: Regions located in the front of the brain that play a major role in executive function.

hippocampus: A seahorse-shaped structure situated within the limbic system deep in the brain that has a central role in memory processing.

limbic system: A network of brain structures crucial for regulating emotions. The hippocampus, one of the structures that make up the limbic system, is instrumental in memory formation.

mild cognitive impairment (MCI): A condition characterized by the loss of cognitive function—usually memory—that is more severe than is normal for a person's age, but without obvious impairment in activities of daily living.

neuron: A type of cell found in the brain, spinal cord, or nerves that transmits information to and from other neurons.

neurotransmitter: A chemical substance that relays signals from one neuron to another.

procedural memory: The long-term memory of skills and procedures, or "how-to" knowledge.

retrieval: The act of recalling previously learned information; it involves the reactivation of particular nerve cell pathways that encoded a given piece of information.

synapse: The junction between two neurons, across which chemical neurotransmitters carry messages.

white matter: The fiber bundles that connect neurons, allowing communication between brain cells. These bundles consist of the axons of cells, plus the protective, white-colored myelin sheath covering each axon.

working memory: A type of short-term memory process that involves temporarily storing and manipulating information.

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ISBN 978-1-61401-322-8
SY71000

IM0722