It's Magical! It's Malleable! It's . . . Memory

So complex and evanescent is memory, our best metaphors fall short, bogged down in materialism. Yet through the creative blending and reblending of experience and emotion, memory builds that about us which often seems most solid—our sense of self. We remember, therefore we are.

Jill Neimark

We never know exactly why certain subjects—like certain people—claim us, and do not let us go. Elizabeth Loftus is a research psychologist who has devoted her life to the study of memory, its mystery and malleability. Of late, she has gained ingenious experiments, which have shown repeatedly that about 25 percent of individuals can be easily induced to remember events that never happened to them—false memories that feel absolutely real.

So it was something of a shock when, at a family gathering, an uncle informed the then 44-year-old Loftus that 30 years earlier, when her mother had drowned, she had been the one to discover the body in the pool. Loftus believed she had never seen her mother's dead body; in fact, she remembered little about the death itself.

Almost immediately after her uncle's revelation, "the memories began to drift back," she recalls in her recent book, *The Myth of Repressed Memory* (St. Martin), "like the crisp, piney smoke from evening camp fires. My mother, dressed in her nightgown, was floating face down. . . . I started screaming. I remembered the police cars, their lights flashing. For three days my memory expanded and swelled.

"Then, early one morning, my brother called to tell me that my uncle had made a mistake. Now he remembered (and other relatives confirmed) that Aunt Pearl found my mother's body." Suddenly Loftus understood firsthand what she had been studying for decades. "My own experiment had inadvertently been performed on me! I was left with a sense of wonder at the inherent credulity of even my skeptical mind."

Memory has become a lightning rod of late. This has been a time of fascinating, grisly stories—of recovered memories of satanic cults, butchered babies, and incest that have spawned church scandals, lawsuits, suicides, splintered families, murders, and endless fodder for talk shows. Three major books on the fallibility of memory were reviewed on the front page of the *New York Times Book Review* last spring, and three more were published this fall. The essential nature of memory, which ought by rights to be a scientific debate, has so galvanized the culture that laws have actually been revoked and repealed over it; in Illinois, for example, a law that bars people over 30 from filing lawsuits based on remembered abuse was repealed in 1992, and is now being reinstated.

Memory's ambiguities and paradoxes seem to have suddenly claimed us as they have claimed researchers for decades. This fascination cannot be explained away by the human need to memorialize the past—a need that expresses itself beautifully and indelibly in monuments like the Vietnam memorial or the AIDS quilt, and in projects like Steven Spielberg's ongoing documentary of holocaust survivors.

Memory is the likelihood that, among a vast tangle of neurons, the pathway of connections an experience forges in the brain can be reactivated again. It is the ability to repeat a performance—albeit with mistakes.

It's as if we've awakened, at the turn of the millennium, and realized that memory is the bedrock of the self—and that it may be perpetually shifting and terrifically malleable. That image of memory, whose river runs into tabloids and traumas, seems both terrifying and baptismal. If we can repress life-shaping events (such as sexual or physical abuse), or actually invent memories of events that never happened (from UFO abductions to rapes and murders), memory carries a power that promises to utterly reshape the self.

And so it's exciting news that in the past few years, scientists have begun to piece together a picture of memory that is stunning in its specifics:

- Sophisticated PET (positron emission tomography) scans can record the actual firing of the neurons that hold the pictures of our lives, and observe memory move like a current across the brain while it sleeps or wakes.
- How and where the brain lays down and consolidates memory—that is, makes it permanent—is yielding to understanding. As one researcher states, we are seeing "an explosion of knowledge about what parts of the brain are doing what."
- Hormones that help engrave the narrative of our lives into our cells have now been identified.
- Certain drugs block or enhance memory, and they may hold the key to preventing disorders as wide-ranging as Alzheimer's disease and posttraumatic stress disorder (PTSD).
- The well-known "fight-or-flight" response to stress can sear "indelible" memories into the brain.
- Memory is not a single entity residing in a single place. It is the likelihood that the pathway of neurons and connections an experience forges in the brain can be reactivated again. It involves multiple systems in the brain. The emotion associated with a memory, for example, is stored in a different place than the content of the memory itself.
- Some memories occur in a primitive part of the brain, unknown to conscious perception. That part functions "below" the senses, as it were. That is why individuals with brain damage can sometimes learn and remember—without knowing they do so.
- There is a growing understanding that an infant's early experience of emotional attachment can direct the nature and durability of childhood memories and the way they are stored in the brain.

Memory, it turns out, is both far more complex and more primitive than we knew. Ancient parts of the brain can record memory before it even reaches our senses—our sight and hearing, for instance. At the same time, "there are between 200 and 400 billion neurons in the brain and each neuron has about 10,000 connections," notes psychiatrist Daniel Siegel, M.D. "The parallel processing involved in memory is so complex we can't even begin to think how it works."

The one thing that we can say for certain is this: If memory is the bedrock of the self, then even though that self may seem coherent and unchanging, it is built on shifting sands.

13 WAYS OF LOOKING AT THE BRAIN

Moments after being removed from the skull, the brain begins to collapse into a jellylike mass. And yet this wet aspic of tissue contains a fantastic archeology of glands, organs, and lobes, all of which have their own specialized jobs. Much of this archeology is devoted to the complex tasks of memory.

But just what is memory? According to Nobel Prize-winning neuroscientist Gerald Edelman, Ph.D., author of *Bright Air, Brilliant Fire* (Basic Books), memory is the ability to repeat a performance—with mistakes. Without memory, life itself would never have evolved. The genetic code must be able to repeat itself in DNA and RNA; an immune cell must be able to remember an antigen and repeat a highly specific defense next time they meet; a neuron in the brain must be able to send the same signal each time you encounter (for example) a lion escaped from the local zoo. Every living system must be able to remember; but what is most dangerous and wonderful about memory is that it must occasionally make errors. It must be wrong. Mere repetition might explain the way a crystal grows but not the way a brain works. Memory classifies and adapts to our environment. That adaptation requires flexibility. The very ability to make mistakes is precious.

Now you can bravely step into the hall of mirrors that is memory. And though our words to describe this evanescent process are still crude and oversimplistic, here are a few tools to travel with:

Memory can be implicit or explicit. Implicit memory is involved in learning habits—such as riding a bicycle or driving a car. It does not require "conscious" awareness, which is why you can sometimes be lost in thought as you drive and find you've driven home without realizing it. Explicit memory is conscious, and is sometimes called declarative. One form of declarative memory is autobiographical memory—our ability to tell the story of our life in the context of time.

We often talk of memory storage and retrieval, as if memory were filed in a honeycomb of compartments, but these words are really only metaphors. If memory is the reactivation of a weblike network of neurons that were first activated when an event occurred, each time that network is stimulated the memory is strengthened, or consolidated. Storage, retrieval, consolidation—how comforting and solid they sound; but in fact they consist of electrical charges leaping among a vast tangle of neurons.

In truth, even the simplest memory stimulates complex neural networks at several different sites in the brain. The content (what happened) and meaning (how it felt) of an event are laid down in separate parts of the brain. In fact, research at Yale University by Patricia Goldman-Rakic, Ph.D., has shown that neurons themselves are specialized for different types of memories—features, patterns, location, direction. "The coding is so specific that it can be mapped to different areas . . . in the prefrontal region."

What is activating these myriad connections? We still don't know. Gerald Edelman calls this mystery "the homunculus crisis." Who is thinking? Is memory remembering us? "The intricacy and numerosity of brain connections are extraordinary," writes Edelman. "The layers and loops between them are dynamic, they continually change."

Yet the center holds. The master regulator of memory, the hub at the center of the wheel, is a little seahorse-shaped organ called the hippocampus. Like the rest of the brain, it is *lateralized;* it exists in both the right and left hemispheres. Without it, we learn and remember nothing—in fact, we are lost to ourselves.

THE SEAHORSE AND THE SELF

"He's 33 years old, and he never remembers that his father is dead. Every time he rediscovers this fact he goes through the whole grieving process again," Mark Gluck, Ph.D., a professor at the Center for Molecular and Behavioral Neuroscience at Rutgers University, says of M.P., a young man who lost his memory after a stroke six years ago. Gluck has been studying M.P. for several years. After his stroke, M.P. forgot that on that very morning he had proposed marriage to his girlfriend. "He can store no new information in his long-term memory. If you tell him a phone number and ask him to repeat it, he will; but if you change the subject and then ask him the number, he can't remember. M.P. is going to be living in the present for the rest of his life. He has lost the essential ability of the self to evolve."

M.P. is uncannily similar to one of the most remarkable and intensively studied patients of all time, a man called H.M., who lost his memory after undergoing brain surgery to treat epilepsy. This type of memory loss, called anterograde amnesia, stops time. It usually results from damage to the hippocampus, which normally processes, discards, or dispatches information by sending signals to other parts of the brain.

"The hippocampus is critical for learning," says Gluck, "and it's also one of the most volatile, unstable parts of the brain—one of the first parts damaged if oxygen is cut off. Think of it as a highly maneuverable kayak; it has to immediately capture a whole range of information about an event and needs the ability to go rapidly through many changes. We think the hippocampus serves as a filter, learning new associations and deciding what is important and what to ignore or compress. That's why it's critical for learning." The hippocampus is, in a sense, a collating machine, sorting and then sending various packets of information to other parts of the brain.

One of the most exciting advances in neuroscience may lie ahead as researchers begin to actually model the living brain on the computer—creating a new era of artificial intelligence called neural networks. Gluck and researchers at New York University have begun to model the hippocampus, creating "lesions" and watching what happens—in the hope that they can develop specialized tests that will identify Alzheimer's in its early stages, as well as develop machinery that can learn the way a brain does. Thus far their predictions about its role have been borne out—in fact, Gluck is developing applications for the military so that hippocampal-like computers can learn the early signals of engine malfunctions and sound the alarm long before a breakdown.

The hippocampus does not store memories permanently. It is a way station, though a supremely important one. Like a football player in the heat of the game, it passes the ball to other parts of the brain. This takes minutes, or maybe even hours, according to James McGaugh, Ph.D., of the University of California at Irvine. At that point, memories can still be lost. They need to be consolidated; the network of neurons responsible for a memory needs to be strengthened through repeated stimuli, until the memory exists independent of the hippocampus, a process known as long-term potentiation (LTP).

Once again, a word picture of this process is extremely crude. In actuality, Edelman points out, "the circuits of the brain look like no others we have seen before. The neurons have treelike arbors that overlap in myriad ways. Their signaling is like the vast aggregate of interactive events in a jungle."

No one is certain how long it takes to fully consolidate a memory. Days? Weeks? Perhaps it takes even years until the linkages of networks are so deeply engraved that the memory becomes almost crystallized—easy to recall, detailed and clear. Individuals like M.P. seem to lose several years of memory just prior to hippocampal damage; so do Alzheimer's patients, who usually suffer hippocampal damage as their brains begin to malfunction, and who recall their childhood days with fine-etched clarity but find the present blurred.

A MAGIC RHYTHM OF MEMORY?

Just how and when do memories become permanent? Scientists now have direct evidence of what they have long suspected—that consolidation of memories, or LTP, takes place during sleep or during deeply relaxed states. It is then that brain waves slow to a rhythm known as "theta," and perhaps, according to McGaugh, the brain releases chemicals that enhance storage.

In an ingenious experiment reported in the journal *Science* last July, researchers planted electrodes in different cells in rats' hippocampi, and watched each cell fire as the animals explored different parts of a box. After returning to their cages, the rats slept. And during sleep the very same cells fired.

There seems to be a specific brain rhythm dedicated to LTP. "It's the magic rhythm of theta! The theta rhythm is the natural, indigenous rhythm of the hippocampus," exclaims neuroscientist Gary Lynch, Ph.D., of the University of California at Irvine. Lynch is known for his inspiring, if slightly mad, brilliance. His laboratory found that LTP is strongest when stimulation is delivered to the hippocampus in a frequency that corresponds to the slow rhythms of theta, of deep relaxation. Research by James McGaugh seems to confirm this: the more theta waves that appear in an animal's EEG (electroencephalogram), the more it remembers.

No wonder, then, that recent experiments show sleep improves memory in humans—and specifically, the sleep associated with dreaming, REM (rapid eye movement) sleep. In Canada, students who slept after cramming for an exam retained more information than those who pulled an all-nighter. In Israel, researchers Avi Karni and Dov Sagi at the Weizmann Institute found that interrupting REM sleep 60 times in a night completely blocked learning; interrupting non-REM sleep just as often did not. These findings give scientific punch to "superlearning" methods like that of Bulgarian psychiatrist Georgi Lozanov, which utilizes deep relaxation through diaphragmatic breathing and music, combined with rhythmic bursts of information.

THE HAUNTED BRAIN

What happens when memory goes awry? It seems that some memories are so deeply engraved in the brain that they haunt an individual as if he were a character in an Edgar Allen Poe story. How, asks Roger Pittman, M.D., coordinator of research and development at the Manchester (New Hampshire) Veterans Administration Medical Center and associate professor at Harvard Medical School, does the traumatic event "carve its canyons and basins of memory into the living brain?"

'We believe that the brain takes advantage of hormones and chemicals, released during stress and powerful emotions, to regulate the strength of memory.' We owe our very lives to this; a dangerous event needs to be recalled.

In any kind of emotionally arousing experience, the brain takes advantage of the fight-or-flight reaction, which floods cells with two powerful stress hormones, adrenaline and noradenaline. "We believe that the brain takes advantage of the chemicals released during stress and powerful emotions," says James McGaugh, "to regulate the strength of storage of the memory." These stress hormones stimulate the heart to pump faster and the muscles to tense; they also act on neurons in the brain. A memory associated with emotionally charged information gets seared into the brain. We owe our very lives to this: a dangerous, threatening, or exciting event needs to be recalled well so that we may take precautions when meeting similar danger again.

Scientists are now beginning to understand just how emotional memory works and why it is so powerful. According to Joseph Ledoux, Ph.D., of the Center for Neural Science at New York University, the hormones associated with strong emotion stimulate the amygdala, an almond-shaped organ in the brain's cortex.

It's long been known that when rats are subjected to the sound of a tone and a shock, they soon learn to respond fearfully to the tone alone. The shocker is that when the auditory cortex—the part of the brain that receives sound—is completely destroyed, the rats are still able to learn the exact same fear response. How can a rat learn to be afraid of a sound it cannot hear?

The tone, it appears, is carried directly back to the amygdala, as well as to the auditory cortex. Destroy the amygdala, and even a rat with perfect hearing will never learn to be afraid of the sound. As neurologist Richard Restak, M.D., notes, this "implies that much of our brain's emotional processing occurs unconsciously. The amygdala may process many of our unconscious fear responses." This explains in part why phobias are so difficult to treat by psychotherapy. The brain's memory for emotional experiences is an enduring one.

But the ability of the brain to utilize stress hormones can go badly awry—and a memory can become not simply permanent but intrusive and relentless. "Suppose somebody shoots you and years later you're still waking up in a cold sweat with nightmares," says McGaugh. "The hormonal regulation of memory, when pushed to an extreme in a traumatic situation, may make memories virtually indelible."

Such memories seem so powerful that even an innocuous stimulus can arouse them. Roger Pittman compares the inescapable memories of PTSD, where flashbacks to a nightmarish trauma intrude relentlessly on daily life, to a black hole, "a place in space-time that has such high gravity that even light cannot pass by without being drawn into it."

So with ordinary associations and memories in PTSD: "As all roads lead to Rome, all the patient's thoughts lead to the trauma. A war veteran can't look at his wife's nude body without recalling with revulsion the naked bodies he saw in a burial pit in Vietnam, can't stand the sight of children's dolls because their eyes remind him of the staring eyes of the war dead."

The tragic twist is that, Pittman believes, each time a memory floods in again, the same stress hormones are released, running the same neural paths of that particular memory and binding the victim ever tighter in the noose of the past. Yet in response to the stress of recalling trauma, the body releases a flood of calming opiates. These neurochemicals, which help us meet the immediate demands of stress and trauma, might create a kind of unfortunate biochemical reward for the traumatic memory. "This whole question of an appetitive component to trauma is really fascinating and as yet unexplored," notes Pittman. "It may explain the intrusive, repeating nature of these memories. Maybe, however horrible the trauma, there's something rewarding in the brain chemicals released."

A solution, then, to treating the kind of PTSD we see in war veterans and victims of rape and child abuse, might lie in blocking the action of some of these stress hormones. And perhaps a key to enhancing ordinary learning is to create a judicious amount of stress—excitement, surprise, even a healthy dose of fear (like the kind one may feel before cramming for a demanding final exam).

A landmark study recently reported by James McGaugh and Larry Cahill, in *Nature,* indicates that any emotion, even ordinary emotion, is linked to learning. They gave two groups of college students a drug that blocks the effects of adrenaline and noradrenaline, then showed the students a series of 12 slides that depicted scenes such as a boy crossing the street with his mother or visiting a man at a hospital. A control group was told an ordinary story (son and mother visit the boy's surgeon father) that corresponded to some of the slides. The experimental group heard a story of disaster (boy is hit by car; a surgeon attempts to reattach his severed feet).

Two weeks later, the volunteers were given a surprise memory test. Students who heard the ordinary story recalled all 12 slides poorly. The second group, however, recalled significantly better the slides associated with the story of disaster.

Then, in an ingenious twist, McGaugh and Cahill repeated the experiment with new volunteers. Just before the slide show, the experimental group was given a beta blocker—a drug that acts on nerve cells to block the effect of stress hormones. Two weeks later they could not be distinguished from the control group. They similarly remembered all 12 slides poorly.

The implications of this elegant experiment are far reaching. "Let's suppose," postulates McGaugh, "that a plane crashes near Pittsburgh and you're hired to pick out the body parts. If we give you a beta blocker, we impair your 'emotional' memory, the memory for the trauma, without impairing your normal memory."

Pittman looks forward in the next decade to drugs that not only block PTSD but help ameliorate it. "There seems to be a window of opportunity, up to six hours or so in rats in any case, before memories are consolidated." During that time effective drugs, such as beta blockers, might be administered.

MEMORY LOST AND REGAINED

The stories are legendary. Elizabeth Loftus has found ordinary memory to be so malleable that she can prompt volunteers to "remember nonexistent broken glass and tape recorders; to think of a clean-shaven man as having a mustache, of straight hair as curly, of hammers as screwdrivers, to place a barn in a bucolic scene that contained no buildings at all, to believe in characters who never existed and events that never happened."

Sometimes the memories become so seemingly fantastical that they lead to court cases and ruined lives. "I testified in a case recently in a small town in the state of Washington," Loftus recalls, "where the memories went from, 'Daddy made me play with his penis in the shower' to 'Daddy made me stick my fist up the anus of a horse,' and they were bringing in a veterinarian to talk about just what a horse would do in that circumstance. The father is ill and will be spending close to $100,000 to defend himself."

Nobody is quite sure how memories might be lost to us and then later retrieved—so-called repression. Whatever it is, it is a different process than traumatic amnesia, a well-known phenomenon where a particular horrendous event is forgotten because it was never consolidated in long-term memory in the first place. Such is the amnesia of an accident victim who loses consciousness after injury. Repressed memory, on the other hand, is alleged to involve repeated traumas.

According to UCLA's Daniel Siegel, both amnesia and repression may be due to a malfunction of the hippocampus. In order to recall an explicit memory, and to be able to depict it in words and pictures, the hippocampus must process it first. Perhaps, postulates Siegel, the work of the hippocampus is disrupted during trauma—while other components of memory carry on. We know, for example, that primitive responses like fear or excitement stimulate the amygdala directly; learning can occur without our "knowing" it.

If explicit memory is impaired—you forget what happened to you—but implicit memory is intact, you may still be profoundly influenced by an experience. Siegel thinks that some individuals remove conscious attention during repeated trauma, say from an unbearable event like repeated rapes. In the parlance of the mind trade, they "dissociate."

While his theory may explain repressed memory plausibly, it doesn't suggest how the memory emerges decades later, explicit and intrusive. And it doesn't answer the contention of many researchers that such repression is probably rare, and that the wave of repressed memories we are hearing about today may be due to invention.

It turns out that it's relatively easy to confuse imagery with perception. The work of Stephen Kossyln, Ph.D., a psychologist at Harvard University and author of *Image and Brain* (MIT press), has shown that the exact same centers in the brain are activated by both imagination and perception. "PET studies have shown that, when subjects close their eyes and form visual images, the same areas are activated as if they were actually seeing." The strength of the imagined "signal" (or image) is about half that of a real one. Other research shows that the source of a memory—the time, place, or way the memory began—is the first part to fade. After all, the source of a memory is fragile.

If we concentrate on generating images that then get recorded in the web of neurons as if they were real, we might actually convince ourselves that confabulations are true. (This might also explain how some individuals who lie about an event eventually convince themselves, through repeated lying, that the lie is true.)

The fragility of source memory explains why, in a famous experiment by psychologist John Neisser, John Dean's testimony about Richard Nixon was shown to be both incredibly accurate and hugely inaccurate. "His initial testimony was so impressive that people called him a human tape recorder," recalls psychologist Charles Thompson, Ph.D. "Neisser then compared the actual tapes to his testimony, and found that if you really looked at the specifics, who said what and when, Dean was wrong all over the place. But if you just looked at his general sense of what was going on in the meetings he was right on target. His confusion was about the source." In general, supposes Thompson, this is how memory works. We have an accurate sense of the core truth of an event, but we can easily get the details wrong.

'It's easy to confuse memory with experience. The exact same brain centers are activated by imagination and perception.'

"Memory is more reconstructive than reproductive. As time passes, details are lost. We did a study where we asked people to keep a daily diary for up to a year and a half, and later asked them questions about recorded events. The memory of the core event and its content stayed at a high level of about 70 percent, while the peripheral details dropped quickly."

CAN MEMORY CREATE THE SELF?

From Freud on down, it was believed that memories from infancy or early childhood were repressed and somehow inaccessible—but that their clues, like the bits of bread dropped by Hansel and Gretel in the forest, could be found in dreams or in the pathology of waking life. Now we know better. It's that the brain systems that support declarative memory develop late—two or three years into life.

If we don't actually lay down any memories of our first few years, how can they shape our later life? An intriguing answer can be pieced together from findings by far-flung researchers.

Daniel Siegel plows the field of childhood memory and attachment theory. He finds that memory is profoundly affected in children whose mothers had rejected or avoided them. "We don't know why this happens, but at 10 years old, these children have a unique paucity in the content of their spontaneous autobiographical narratives." As adults, they do not recall childhood family experiences.

It may be that memory storage is impaired in the case of childhood trauma. Or it may be, Siegel suggests, that avoidant parents don't "talk to children about their experiences and memories. Those children don't have much practice in autobiographical narrative. Not only are their memories weak or nonexistent, the sense of self is not as rich. As a psychotherapist, I try to teach people to tell stories about their lives. It helps them develop a richer sense of self."

As far as the biology of the brain goes, this may be no different than training an 18-year-old boy to distinguish between whales and submarines; if the hippocampus is continually fed a stimulus, it will allocate more of the brain's capacities to recording and recognizing that stimulus. In the case of autobiographical narrative, however, what emerges is magical and necessary: the self.

That is almost like saying memory creates the self, and in a sense it does. But memory is also created and recreated by the self. The synergy between the two is like two sticks rubbed together in a forest, creating fire. "We now have a new paradigm of memory," notes Loftus, "where memories are understood as creative blendings of fact and fiction, where images are alchemized by experience and emotion into memories."

"I think it's safe to say we make meaning out of life, and the meaning-making process is shaped by who we are as self," says Siegel. Yet that self is shaped by the nature of memory. "It's this endless feedback loop which maintains itself and allows us to come alive."

When we think of our lives, we become storytellers—heroes of our own narrative, a tale that illumines that precious and mysterious "self" at the center. That "I am" cannot be quantified or conveyed precisely and yet it feels absolute. As Christopher Isherwood wrote long ago in *The Berlin Stories,* "I am a camera." Yet, as the science is showing us, there is no single camera—or if there is, it is more like the impressionist, constantly shifting camera of *Last Year at Marienbad.* Memory is malleable—and so are we.