Praise for *Successful Aging*

"As always, Dan shows his great facility for pulling together different parts of our field and explaining them in a way that makes them accessible to all." **—Brenda Milner, at age 101, professor of neurology at McGill University and the Montreal Neurological Institute, founder of the field of neuropsychology**

"Predictions are perilous, but here's one I can make with certainty: Tomorrow you and I will be older than we are today. That's why you, I, and everyone we know need this remarkable book. With a scientist's rigor and a storyteller's flair, Daniel Levitin offers a fresh approach to growing older. He debunks the idea that aging inevitably brings infirmity and unhappiness and instead offers a trove of practical, evidence-based guidance for living longer and better. *Successful Aging* is an essential book for the rest of your life." **—Daniel H. Pink, author of *When and Drive***

"A wise, insightful, and beautifully written book on how we can navigate the waters of time. Helpful for readers at any age." **—Daniel Gilbert, professor of psychology at Harvard University and author of *Stumbling on Happiness***

"Dan Levitin's latest is an inspiring, hopeful, and useful message—expounding on the best lessons science and art can teach us about how to expand your potential as you age."**—Ben Folds, recording artist and *New York Times* bestselling author of *A Dream About Lightning Bugs***

"In my line of work, good maps are the difference between life and death. Dan's book is an extraordinary 'map' to a place each of us eventually journeys to. In it, he explains and demystifies the aging process in layman's terms. Don't grow old without it." **—General Stanley McChrystal, U.S. Army (Ret.)**

"Growing old may be the only event in life that is both desired and feared. Daniel Levitin alleviates the fear with sound advice that can tilt the balance so that we have more healthy years and fewer sick ones. The brilliance of this book is that Levitin not only tells us what to do and what not to do—he gracefully and eloquently shares the science behind how we can change our minds and brains, and how even small changes can reap large benefits. Share this book—especially with anyone you hope to grow old with."**—Diane Halpern, former president of the American Psychological Association and professor at Claremont McKenna College**

"We are living longer than past humans, and with this comes undeniable challenges to our physical and mental well-being. Building on the psychology of personality types and developmental neuroscience, Daniel Levitin will enthrall you with this fascinating story of how the human brain ages, as he reveals just how rewarding our later years can be."**—Joseph LeDoux, professor of neural science at New York University, director of the Emotional Brain Institute at the Nathan S. Kline Institute for Psychiatric Research, and author of *Anxious* and *The Deep History of Ourselves***

DUTTON
An imprint of Penguin Random House LLC
penguinrandomhouse.com

LIBRARY OF CONGRESS CATALOGING-IN-PUBLICATION DATA
Names: Levitin, Daniel J., author.
Title: Successful aging : a neuroscientist explores the power and potential of our lives / Daniel J. Levitin.
Description: First. | New York : Dutton, [2020] | Includes bibliographical references and index.
Identifiers: LCCN 2019026873 (print) | LCCN 2019026874 (ebook) | ISBN 9781524744182 (hardcover) | ISBN 9781524744199 (ebook) | ISBN 9781524746414 (international edition)
Subjects: LCSH: Brain—Aging. | Brain—Aging—Health aspects.
Classification: LCC QP376 .L43 2020 (print) | LCC QP376 (ebook) | DDC 612.8/2—dc23
LC record available at https://lccn.loc.gov/2019026873
LC ebook record available at https://lccn.loc.gov/2019026874

Cover photographs: tree ring elements courtesy of Getty Images

btb_ppg_c0_r4

CONTENTS

PART THREE
The New Longevity

INTRODUCTION

The poet Dylan Thomas wrote that one should not go gently into that good night, that old age should burn and rage at close of day. As a younger man reading that poem, I saw futility in those words. I saw aging only as a failing: a failing of the body, of the mind, and even of the spirit. I saw my grandfather suffer aches and pains. Once agile and proudly self-sufficient, by his sixties he struggled to swing a hammer and was unable to read the label on a box of Triscuit crackers without his glasses. I listened as my grandmother forgot words, and I cried when eventually she forgot what year it was.

At work, I watched as people neared retirement age, the spark gone from their eyes, the hope from their smiles, counting the days until they could walk away from it all, yet with only the vaguest plans about what they would do once they had so much free time, all day, every day.

But as I've grown older myself, and have spent more time with people who are in the last quarter of their lives, I've seen a different side of aging. My parents are now in their mideighties and are as engaged with life as they have ever been, immersed in social interactions, spiritual pursuits, hiking, and nature, and even starting new professional projects. They look old, but they feel like the same people they were fifty years ago, and this amazes them. Where certain faculties have slowed, they find that extraordinary compensatory mechanisms have kicked in—positive changes in mood and outlook, punctuated by the exceptional benefits of experience. Yes, older minds might process information more slowly than younger ones, but they can intuitively synthesize a lifetime of information and make smarter decisions based on decades of learning from their mistakes. Among the many advantages of being old, they are less fearful of calamities because they've been dealt a few in the past and managed to work through them. Resilience—both their own and each other's—is something they know they can count on. At the same time, they are comfortable with the idea that they may die soon. That's not the same as saying they want to die, but they no longer fear it. They've lived full lives and treat each new day as an opportunity for new experiences.

Brain researchers speculate that old age brings chemical changes in the brain that make it easier to accept death—to feel at ease with it rather than be frightened by it. As a neuroscientist, I've wondered why some people seem to age better than others. Is it genetics, personality, socioeconomic status, or just plain dumb luck? What is going on in the brain that drives these changes? What can we do to stem the cognitive and physical slowdown that accompanies aging? Many people thrive well into their eighties and nineties, while others seem to retreat from life, prisoners of their own infirmities, socially isolated and unhappy. How much control do we have over our outcomes, and how much is predetermined?

Marrying recent research in developmental neuroscience with the psychology of individual differences, *Successful Aging* sets out a new approach to how we think about our final decades. Drawing from diverse disciplines, this book demonstrates that aging is not simply a period of decay, but a unique developmental stage that—like infancy or adolescence—brings with it its own demands and its own advantages.

The book will show that how well we age depends on two parallel streams:

1. the confluence of a number of factors reaching back into our childhoods; and
2. our responses to stimuli in our environments, and shifts in our individual habits.

This provocative argument can revolutionize the way we plan for old age as individuals, family members, and citizens in industrial societies where the average life expectancy continues to rise. It offers choices we can make that will keep us mentally agile well into our eighties, nineties, and perhaps beyond. We need not stumble, stooped and passive, into that good night; we can live it up.

Two of the teachers I had in college are now in their eighties and another is in his nineties. All are still active and whip-smart. One of them, Lewis R. Goldberg, now eighty-seven, is considered the father of modern-day scientific conceptions of personality—the unique compendium of traits and features that set us apart from one another and that can profoundly influence the course of our lives. He has found that personalities can change: You can improve yourself at any stage of life, becoming more conscientious, agreeable, humble—any number of things. This is surprising, and it upends decades of casual speculation. We tend to think of personality traits as being durable, persisting forever. (Think of the curmudgeon Larry David in TV's *Curb Your Enthusiasm*.) But personality traits are also malleable. And the degree to which habitual traits drive our behavior is influenced by the situations we find ourselves in and by our own striving to improve ourselves, to become better people.

The darker side of this, unfortunately, is that some encounters and environments can cause our personalities to change for the worse. Learning how to avoid certain environments, habits, and stimuli that influence our personalities in negative ways is a crucial part of aging well. This potential malleability of personality as we age is essential to understand. Dark shifts in personality are, regrettably, all too common in our world. We all know of people who have grown bitter, isolated, or depressed as they got older.

Much of this is culturally driven. In the 1960s, when I grew up, many young people couldn't wait to push old people out of the way. For all the tolerance, peace, and love that our Woodstock generation espoused, we were quick to try to sideline our parents' generation. We chanted, "Don't trust anyone over thirty," and we might as well have chanted, "Don't even *pay attention* to anyone over seventy." Roger Daltrey of the Who summed up a pervasive sense of derision toward the elderly when he sang, "I hope I die before I get old." My friends who were born in the 1930s and 1940s have shared with me stories of indignities, prejudices, and disrespect shown toward them by people of my generation.

Aging, as it has been depicted in the media and our collective consciousness for centuries, implies both physical and emotional pain and, in many cases, social isolation. As the body became more frail, intellectual faculties weakened, and diminished vision and hearing prevented the elderly from engaging with their communities as they once did. Retirement spelled the end of life's purpose and, sadly, seemed to accelerate the end of one's life.

My grandfather, a first-generation college student who worked his way through medical school to become one of the first radiologists in California, was pushed out of the very department he founded at his hospital, just because he turned sixty-five. From what we

know today about diagnostic radiology, he was probably better at his job at sixty-five than when he was younger, because so much of it depends on pattern-matching circuits in the brain that improve with experience. The sense of marginalization and uselessness my grandfather experienced in the workplace was opposite what he had with us at home in the family—we loved and venerated him, and we were devastated when he died at sixty-seven. In a letter he wrote to the family before the surgery that ultimately cost him his life, he expressed deep sadness about the "loss of respect" for him at the hospital. I always suspected that this loss of respect had an impact on his stamina, resilience, and mood to such a degree that a minor surgical complication cost him his life.

I want to draw out explicitly what happens in the brain when we feel rejected or underappreciated. Our bodies react to insults, both psychological and physical, by releasing cortisol, the stress hormone. Cortisol is very useful if you need to invoke the fight-or-flight response—say, when you're confronted by an attacking tiger—but it is not so useful when you're dealing with longer-term psychological challenges such as loss of respect. The cortisol-induced stress reaction reduces immune-system function, libido, and digestion. This is why, when you're stressed, you might have an upset stomach. It makes sense for the fight-or-flight response to do this: It needs to direct all your resources to the temporary state of physically dealing with an imminent threat. But the psychological stresses that can come from interpersonal conflicts, left unresolved, can leave us in a physiologically stressed state for months or years. In contrast, when we're actively engaged and excited about life, our levels of mood-enhancing hormones such as serotonin and dopamine increase, and the production of NK (natural killer) and T cells (lymphocytes) also increases, strengthening our immune systems and cellular repair mechanisms. My grandmother, my family, and I might have enjoyed my grandfather's company a lot longer if social stressors hadn't come into play.

Fast-forward twenty-five years. My own father, a businessman, was strongly encouraged to retire when he was sixty-two, to make way for someone younger. Like his father before him, he felt pushed out and began to question his self-worth. His social world shrank, he began to suffer physical ailments, and he became depressed. But by then, in 1995, the tide was already turning. Society and employers were awakening to the Eastern idea that the elderly may be not only of some value, but of superior value. My father put out feelers and was offered a job teaching a course at the USC Marshall School of Business. Soon he was teaching a full load of four courses per semester. That was twenty-five years ago. My father just signed a four-year renewal to teach until he's eighty-nine. The students love him because he is able to pass on his real-world experience to them in a way that younger professors can't. And by the way, that depression and those physical ailments were dramatically reduced once he found meaningful work.

Of course, finding ways to stay active and engaged is not always easy in old age, and it doesn't completely compensate for biological decline. But new medical advances and positive lifestyle changes can help us to find enhanced fulfillment in life where previous generations may not have been able to do so.

When I was in college, one of my favorite professors was John R. Pierce, a former director of the Jet Propulsion Laboratory, the inventor of satellite telecommunication, a prolific sci-fi writer, and the person who named the transistor when a team under his supervision invented it. I met him when he was eighty, in the second iteration of his "retirement," giving classes on sound and vibration. He invited me to dinner at his house once; we became

friends and went out to dinner regularly. Around the time John turned eighty-seven, he grew depressed. One of the pastimes he enjoyed most was reading, but now his eyesight was failing. I bought him some large-type books and that perked him up for a few weeks, but much of what he wanted to read—technical books, science fiction—was not available in large type. I'd go over and read to him when I could, and I arranged for some Stanford students to do the same. But he still kept slipping. Then he was diagnosed with Parkinson's. His shaking bothered him. His memory was failing. He no longer found pleasure in things that he used to enjoy. And he was growing increasingly disoriented.

I suggested that he ask his doctor about taking Prozac, which was new at the time, and just being prescribed for the kinds of age-related problems he was facing. (Prozac helps to boost levels of serotonin in the brain—one of those mood-enhancing hormones I mentioned previously.) It was transformative. Although it didn't help the Parkinson's specifically, his attitude changed. He felt younger. He started holding dinner parties again, and lecturing to students, something he had given up doing just a year earlier. A simple chemical change in his brain gave him a second wind. John lived to ninety-two, and much of those last five years were filled with joy and satisfaction for him. And for me, too—it felt like getting a second chance with my grandfather who had died too soon.

I saw John two weeks before he passed at age ninety-two, and he was excitedly planning some new experiments he wanted to do. That's the way to go out.

At the time I knew John, I was young and not thinking about my own inevitable aging. But in the decades since then, in experiencing my own gradual mood shifts and in talking to a great many research colleagues and doctors, I've come to see a future in which we can plan ahead to fend off some of the adverse effects of aging; a future in which we can harness what we know about neuroplasticity to write our own next chapters the way we want them to come out; a future in which healthy lifestyle choices and a broader use of antidepressants and other medications can temper or reverse the effects of depression and other changes in mood that we have for too long assumed were an irreversible part of the aging process. In addition, new innovations in medical science and treatment protocols are sure to become available.

For example, recent discoveries about changes in sleep chemistry and neuronal waveforms suggest a different approach to this most basic of human activities. Sleep deprivation at any age is bad for you. It has been tied to diabetes in pregnancy, postpartum depression in new fathers, and bipolar disorder at all ages. You may have read that "old people" don't need as much sleep as young people and can get by on four or five hours a night. This myth has recently been exposed by Matthew Walker at UC Berkeley. It's not that we need less sleep as we get older—it's that changes in the aging brain make it difficult for older adults to get the sleep they need. And the consequences are serious. Sleep deprivation in the aged is directly responsible for cognitive decline, not to mention increased risk of cancer and heart disease. Grandma didn't forget where she put her glasses because she's senile—it's because she's sleep-deprived. Walker has found evidence that sleep deprivation increases the risk of Alzheimer's.

Alzheimer's disease (AD) is now the third leading cause of death in the United States. This doesn't mean we should jump to the conclusion that there is an epidemic in the making, or that environmental toxins are causing it. They might be, but AD is primarily an old person's disease; medical advances have made it so that we are living longer, and that means we are living long enough to *get* Alzheimer's. Now, for reasons we don't yet understand, AD is selective with regard to sex. Sixty-five percent of patients are women, and a woman's chances of getting AD now exceed her chances of getting breast cancer.

Approximately two-thirds of the overall risk that you'll get Alzheimer's comes from your genes, with the remaining one-third associated with environmental factors such as whether or not you have a history of depression or head injuries. In this way, events of childhood can have an effect many, many decades later. Recent science demonstrates that environmental stimuli, behavior, and luck all play a role, as I will show throughout the book. On the biological side, a brain with Alzheimer's is easily recognized by the shrinkage of the hippocampus—the seat of memory—and of the outer layers of the cerebral cortex (the part of the brain associated with complex thought and movements). You may have heard of amyloids, aggregates of proteins that have been found in the brains of Alzheimer's patients. One particular protein, beta-amyloid, begins destroying synapses (connections between the brain's neurons) before it clumps into plaques that cause the death of neurons themselves.

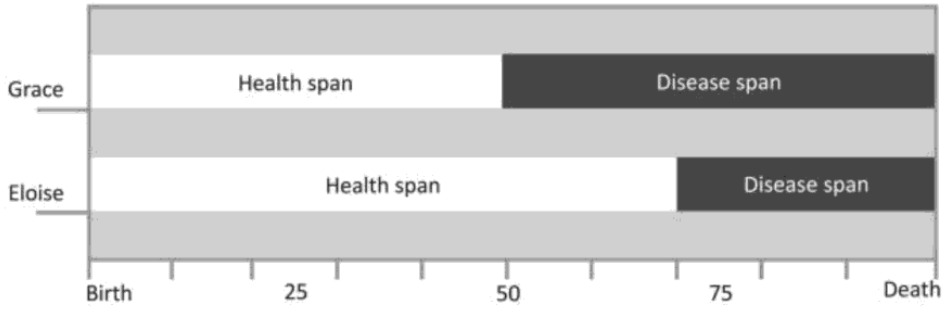
Dale Bredesen, a neurologist who studied under my colleague Stan Prusiner at UCSF, has studied these interacting factors for thirty years. His Bredesen Protocol is the topic of a *New York Times* bestseller. Fending off Alzheimer's, he says, involves five key components: a diet rich in vegetables and good fats, oxygenating the blood through moderate exercise, brain training exercises, good sleep hygiene, and a regimen of supplements individually tailored to each person's own needs, based on blood and genetic testing. The Bredesen Protocol is still in its early stages of validation—the primary proof of concept was based on only ten patients. The patients have to be in very early stages of Alzheimer's. And since the protocol is new, they haven't had anyone on it for more than five years. The protocol may or may not help, but at least the first four parts won't cause any harm—we don't know enough about the supplements—and to many it makes sense to start following these healthy lifestyle practices on the chance that they will end up being scientifically validated.

Prusiner won the Nobel Prize for discovering prions, proteins that can accumulate and cause neurogenerative diseases like Creutzfeldt-Jakob disease, a fatal condition that is characterized by memory loss and behavioral changes. Sound familiar? These are the markers of Alzheimer's, of course, and Prusiner now believes that prions, because they can assemble into amyloid fibrils, are responsible for Alzheimer's and Parkinson's disease. At the cutting edge of this research is the idea of neuroinflammation as a precursor to Alzheimer's, appearing long before clinical signs and symptoms. This is because the visible symptoms appear only during the actual destruction of brain regions—the cognitive effects we notice, such as memory loss and mood change, reflect relatively late stages of the underlying disease process. Depressive-like symptoms, such as loss of interest and energy, often appear long before other, more serious manifestations.

Several teams of scientists have found that a chronic inflammatory process precedes the onset of Alzheimer's, and this strongly suggests a potential health-care strategy involving anti-inflammatory drugs, one that we might see in widespread use in the next few years. Current research is focused on whether anti-inflammatories (such as ibuprofen) can ease symptoms once they've arrived, or whether the drugs must be given before the onset of symptoms and thus act as a preventative (which is appearing to be the case). Another cutting-edge treatment being investigated involves immunization with antibodies that can prevent the formation of amyloid fibrils in the first place.

We talk about life span as the length of time that one is alive. Except for cases of death by accident, most of us will die of some kind of disease, or our parts will just wear out. You can think of the time line of your life span as being divided into two parts: the period of time that you're generally healthy (the health span) and the period of time that you're sick (the disease span). Obviously, it is important to minimize the disease span.

Consider two friends who die at one hundred, both with identical life spans but very different disease spans. Grace begins a gradual health decline at fifty and by eighty requires twenty-four-hour care. Eloise begins to decline at seventy but the real health problems don't kick in until ninety-five. All of us would prefer to have that extra twenty years of smooth sailing, followed by an extra fifteen years of happy life before disease limits our activities. I wrote this book on the premise that it is never too late to tilt the balance in our favor, to increase our health span by making important changes to how we approach aging.



The environmental factors I've described here can have either a positive or negative impact on the way we experience old age—our engagement with the world, our habits, our will to live, and medicine. A second strand of the narrative for *Successful Aging* is the developmental side, a story that begins, ironically, in childhood.

I mentioned earlier that social stress can lead to a compromised immune system. That happens at any age. Michael Meaney at McGill University showed that the kind of care a mother gives to her offspring alters the chemistry of the DNA in certain genes involved in physiological stress responses. Rat pups who are licked more in the first six days of life grow into adult rats who are far more secure and less likely to be afflicted with stress. In particular, those baby rats that received a great deal of licking and grooming produced fewer stress hormones when dealing with a challenging or stressful situation than the rats who received less care, and here's the kicker: The effects held well into adulthood.

Meaney has gone on to show comparable effects in humans, and the opposite set of outcomes for children who are neglected or abused as infants. In the stress story, early experience interacts with genetics and brain structure. "Women's health is critical," Meaney says. "The single most important factor determining the quality of mother-offspring interactions is the mental and physical health of the mother. This is equally true for rats, monkeys and humans." Parents living in poverty, suffering from mental illness, or facing great stress are much more likely to be fatigued, irritable, and anxious. "These states clearly compromise the interactions between parents and their children," he says. And, subsequently, they compromise their children's brain chemistry and resilience in the face of setbacks—even future ones.

Meaney emphasizes that "human brain development occurs within a socioeconomic context, and childhood socioeconomic status (SES) influences neural development—particularly of the systems that subserve language and executive function" (deciding what to do next and then doing it). Research has shown the importance of prenatal factors, parent-child interactions, and cognitive stimulation in the home environment in promoting healthy, lifelong neural development. These findings should direct us toward improving the programs and policies that are designed to alleviate SES-related disparities in mental health and academic achievement.

Nurture (or lack thereof) early in life affects the development of a number of brain systems selectively, such as glucocorticoid (GLUE-co CORT-ick-oid) receptors in the hippocampus, which are a primary component of the stress response, part of the feedback mechanism in the immune system that reduces inflammation. Meaney also showed that parenting affects the function of the pituitary and adrenal glands, which regulate growth, sexual function, and the production of cortisol and adrenaline. Early traumas can last a lifetime. They can be overcome with the right behavioral and pharmacological interventions, but it takes some work. More cuddles and hugs go a long way, particularly in the vulnerable first year of life. As parents (and grandparents and teachers), our choices about how we raise our children in their first years will have a far greater impact on what their last years look like than we might previously have recognized.

A third strand of *Successful Aging,* along with environmental influences and neural development, is that I've come to see old age as a unique period of growth, a life stage with its own distinct character, rather than a period of decline or a gradual turning down of the dials and knobs one by one.

When many of us think of aging, what first comes to mind might be a panoply of age-related problems that we're all familiar with: loss of vision, loss of hearing, aches and pains. What exactly happens when the brain and body age—what physiological changes affect our experience of ourselves and others? I'll delve into these questions in this book, including brain cell atrophy, DNA sequence damage, compromised cellular repair functions, and neurochemical and hormonal changes.

I'll also explore some effects that are just as common but less talked about. For example, most of us experience metabolic changes that mean you can't just continue eating the same things you've always eaten and maintain your weight or your figure. We may become lactose intolerant. (Evolutionary forces were mainly concerned with digesting mother's milk when we're young, not eating ice cream when we're fifty.) Our digestive system experiences changes that, along with causing lactose intolerance, may make us gassier as we age. Our skin becomes drier. Our eyes become drier. Caffeine may affect us differently or stop providing its beneficial effects entirely. Processing refined sugar becomes more difficult as our pancreas ages. *Successful Aging* will tell you what to expect, or perhaps explain some of the things you're already experiencing. But this is not a book about problems. My goal is to provide some solutions, guidelines, and helpful tips from the cutting edge of scientific medicine about how to live fully and happily, in a way that pushes these infirmities and indignities to the background and allows us to fully experience the meaningful things in the third act of our lives.

Now that the Woodstock generation is entering our sixties and seventies, we have a chance to change the status quo about the role older people play in daily life. Of course, this satisfies our own self-interest, but, more important, it can help to rekindle our generation's ideal of improving society, ideals like respecting the planet and all the living beings who call it home, helping those less fortunate than ourselves, promoting tolerance and inclusiveness, and allowing people who are different from us to embrace, not be embarrassed by, those differences.

The cost of sidelining the elderly is enormous in lost economic and artistic productivity, severed family connections, and diminished opportunities. We can begin to model better behavior by embracing those who are a generation ahead of us—our parents' generation.

And we can adopt practices that will keep us, as older beings, relevant and engaged with others well into our eighties and nineties . . . and perhaps beyond. I argue here for a very different vision of old age, one that sees our final decades as a period of blossoming, a resurgence of life that does not chase after our younger years, but instead embraces the gifts that time can bring.

What would it mean for all of us to think of the elderly as resource rather than burden and of aging as culmination rather than denouement? It would mean harnessing a human resource that is being wasted or, at best, underutilized. It would promote stronger family bonds and stronger bonds of friendship among us all. It would mean that important decisions at all scales, from personal matters to international agreements, would be informed by experience and reason, along with the perspective that old age brings. And it might even mean a more compassionate world. Among the chemical changes we see in the aging brain are a tendency toward understanding, forgiveness, tolerance, and acceptance. While older adults may become more set in their ways, and there is a tendency toward conservatism, they can at the same time become more accepting of individual differences and appreciative of the struggles that others have had to face. Older adults can bring a much-needed compassion to a world being rent by impatience, intolerance, and lack of empathy.

We have a silo problem in my field of cognitive neuroscience. There's a tendency for researchers to talk to people in their own area, and not to talk across areas. In the last thirty years we've seen big, transformative advances in the understanding of many core ideas about personality, emotions, and brain development. But few people in one area talk to people in another, and so we're left with a situation where neither medical professionals nor the public are able to leverage these advances for our individual and common good.

I was extraordinarily fortunate when I started out, to have mentors who were working in diverse areas, and all of them are still active—personality psychologists (like Lew Goldberg and Sarah Hampson, now eighty-seven and sixty-eight, respectively), cognitive psychologists (Michael Posner and Roger Shepard, now eighty-three and ninety, respectively), and developmental neuroscientists (Ursula Bellugi, now eighty-eight, and Susan Carey, now seventy-seven). This led me to bridge two areas that have maintained separate intellectual traditions—developmental neuroscience and individual differences (personality) psychology. The more I study the intersection of these two, the more intrigued I am at how they can help us to understand the aging brain and the choices all of us can make to maximize our chances of living long, happy, and productive lives. The intersection of these two scientific fields, and how they apply to aging, is the core theme that runs throughout *Successful Aging,* and something that no one else has written about for a popular audience.

The developmental neuroscience view I will present here is that it is the interactions among genes, culture, and opportunity that are the biggest determinants of

- the trajectory our lives take;
- how our brains will change; and
- whether or not we'll be healthy, engaged, and happy throughout our life span.

No matter what age we are, our brains are always changing in response to pressures from genes, culture, and opportunity. The choices we make dictate much of the lives we lead. But we are also affected by random things that happen to us, and the choices that others make.

Opportunity, or lack thereof, is often a matter of luck, governed by large historical forces, such as wealth, plagues, access to clean water, education, and good laws. In ways both large and small your brain has been changed by your life's experiences, whatever they are—by disappointment, love, interactions with key people, successes, illnesses, accidental injuries, pain, environmental toxins. In short, your brain is continually being changed by life itself.

I add to this perspective the rich body of work on individual differences. The story of traits—the ways in which we understand our individual differences—is one of the most fascinating stories in modern science. It traces its roots back to Aristotle, who explained differences in personalities among individuals as differences in their "matter." The eighteenth-century scientist Franz Joseph Gall and the nineteenth-century scientist Sir Francis Galton launched the modern study of individual differences, with Gall even anticipating the modern neuroscientific idea that specific mental functions can be localized to different parts of the brain. (Gall invented phrenology, the study of bumps on the head; this has now been shown to be ridiculous, but his primary hypothesis of localization of brain function still stands today.) Gordon Allport, Hans Eysenck, Amos Tversky, and Lew Goldberg, among many talented others, established individual differences as a science and a rigorous field.

Individual differences psychology seeks to both characterize and quantify the thousands of ways that we humans differ from one another. It uses relatively sophisticated mathematical-statistical tools, such as principal components analysis, and seeks to understand not just the ways we differ from one another, but also the roots of these differences. The goal of this work has always been to predict others' future behaviors—if I know that you're conscientious, for example, will I have a better chance of knowing how you'll react to a certain situation than if I didn't know that about you?

So what can we do to maintain strength of body, mind, and spirit while coming to terms with the limitations that aging can bring? What can we learn from those who age joyously, remaining vital and engaged well into their eighties, nineties, and even beyond? How do we adapt our culture to service the needs of aging generations while also taking greater advantage of their wisdom, experience, and motivation to contribute to society?

Throughout this book, I'll be reinforcing the lifestyle concept that we *can* change our personalities and our responses to the environment, while continually adapting to the random and unpredictable things life throws at us. This concept has five parts: Curiosity, Openness, Associations, Conscientiousness, and Healthy practices, what I call the COACH principle. This is not another book telling you to do sudoku. *Successful Aging* will explain what is going on in our brains as we age, and what we can do about it, based on a rigorous analysis of neuroscientific evidence.

Successful Aging has three aims: first, to harness our knowledge so that we can anticipate changes—both positive and negative—and put systems in place that will ease our transitions and minimize the possibility of unwanted outcomes. These can be as simple as establishing a good relationship with your doctor, taking supplements to improve myelination of the nervous system, and hiding a key in a lockbox in case you forget yours in the house (as I once did in subzero temperatures—*before* I had a lockbox). There are definite things we can do to dampen the ill effects of memory loss, perceptual loss, and the shrinking social circles that often accompany aging. We can fight to reverse the tendency to narrow our interests, to become set in our ways, and to fear even moderate risk taking. We can learn to exploit the

wisdom and skills that we have attained, becoming much-sought-after friends, rather than forgotten old people.

Second, this book aims to stimulate all of us to think about what ingredients presage a feeling of life well-lived when we look back from the end of life. What decisions can we make, both ahead of time and in the present moment, that will maximize our life satisfaction and infuse our lives with meaning? In previous books, I've been vocal about the overuse of social media, including Facebook. Don't get me wrong—I use them, and I think that they are a fantastic way of staying in touch with our friends and family who are scattered across great distances. But when you're at the end of your life, lying on your deathbed, the research literature strongly predicts you won't be saying, "I wish I had spent more time on Facebook." Instead, you'll probably be saying, "I wish I had spent more time with loved ones," or, "I wish I had done more to make a difference in the world."

Ultimately, this book aims to help us think completely differently about aging, as individuals, as community members, as a society; it aspires to advance the evolution of a culture that embraces the gifts of the elderly, weaving cross-generational interactions into the fabric of everyday experience. By looking at the science of the brain—specifically the insights from developmental neuroscience and individual differences psychology—this book seeks to induce a transformative understanding of the aging process, the final chapter of our human story.

When older people look back on their lives and are asked to pinpoint the age at which they were happiest, what do you suppose they say? Maybe age eight, when they had few cares? Maybe their teenage years because of all the activity and the discovery of sex? Maybe their college years, or the first years of starting a family? Wrong. The age that comes up most often as the happiest time of one's life is eighty-two! The goal of this book is to help raise that number by ten or twenty years. Science says it can be done. And I'm with science.

PART ONE

THE CONTINUALLY DEVELOPING BRAIN

What are the determinants in how we age? The different systems in our brains age at different rates. Some systems decline as others actually increase in efficiency and effectiveness. The basic message we hear in popular culture, that aging is a time of unmitigated decline, is not accurate. Yes, some things do slow down, but our health, happiness, and mental sparkle need not. The latest neuroscientific research suggests an entirely new way of thinking about aging—about memory, our perceptual systems, intelligence, even about motivation, pain, and our social lives. You might think, as I used to, that the story of why some of us age better than others has to do with all of these cognitive and emotional factors. In fact, the biggest single determinant of living a productive and happy life is something that you're born with (partly) and something that you can decide to change: your personality.

1

INDIVIDUAL DIFFERENCES AND PERSONALITY

The search for the magic number

I visited a day care center for preschoolers recently and was struck by how early the differences in children's traits and individual dispositions show up. Some children are more outgoing, while others are shy; some like to explore the environment and take risks, while others are more fearful; some get along well with others and some are bullies—even by age four. Young parents who have more than one child see immediate differences in the dispositions of siblings, as well as differences between their offspring and themselves.

At the other end of life, there are clear differences in how people age—some people simply seem to fare better than others. Even setting aside differences in physical health, and the various diseases that might overcome us late in life, some older adults live more dynamic, engaged, active, and fulfilling lives than others. Can you look at a five-year-old and tell whether they will be a successful eighty-five-year-old? Yes, you can.

The discovery that aging and health are related to personality was the result of a lot of work. First, scientists had to figure out how to measure and define personality. What is it? How do you observe it accurately and quantitatively? Here, they may have taken inspiration from Galileo, who said, "The job of the scientist is to measure what is measurable and to render measurable that which is not." And so they did.

Among the most solid findings is that a child's personality affects adult health outcomes later in life. Take, for example, a child who was always getting into trouble in elementary school and continued to do so as a preteen. As a teenager, they might have smoked cigarettes, drunk alcohol, and used marijuana. In personality terms, we might say that this teenager was sensation- and adventure-seeking, high on the quality of extraversion, low on conscientiousness and emotional stability. The kid would have been at increased risk for hard drug use, or being killed in a motor vehicle accident while driving drunk. If they survived these increased risks in young adulthood but didn't change their habits, they'd enter middle age with a highly inflated risk of lung cancer from smoking or liver damage from drinking. Even more subtle behaviors can influence outcomes many decades later: Early and compulsive exposure to the sun and sun tanning; poor dental hygiene; poor exercise habits; and obesity all take their toll.

One of the pioneers in the relationship between personality and aging is Sarah Hampson, a research scientist at the Oregon Research Institute. As Hampson notes, "Lack of self-control may result in behaviors that increase the probability of exposure to dangerous or traumatic situations and adversely affect health through long-lasting biological consequences of stress." She has found that childhood is a critical period for laying down patterns of behavior with biological effects that endure into adulthood. If you want to live a long and healthy life, it helps to have had the right upbringing. Childhood personality traits,

assessed in elementary school, predict a person's lipid levels, blood glucose, and waist size forty years later. These three markers, in turn, predict risk for cardiovascular disease and diabetes. The same childhood traits even predict life span.

Although these correlations between early childhood and late adulthood personality are robust, they tell only a part of the story. People age differently, and part of that story has to do with the interaction of genetics, environment, and opportunity (or luck). Scientists developed a mathematical way of tracking personality, comparing traits as they differ across individuals or change within a person over time. With it, we can talk about age-related, culture-related, and medically induced changes in personality, such as occur with Alzheimer's disease. Often one of the first indications of a problem with your brain is a change in personality.

And in the past few years, developmental science has shown that people, even older adults, can meaningfully change—we do not have to live out a life that was paved for us by genetics, environment, and opportunity. The great psychologist William James wrote that personality was "set in plaster" by early adulthood, but fortunately he was wrong.

The idea that people retain the capacity to change throughout their life span didn't take hold until the midseventies, when an idea first put forward by psychologist Nancy Bayley was popularized by the German developmental psychologist Paul Baltes:

> Most developmental researchers do accept the notion that developmental change is not restricted to any specific stage of the life-span and that, depending upon the function and the environmental context, behavior change can be pervasive and rapid at all ages. In fact . . . the rate of change is greatest in infancy and old age.

Not everyone takes advantage of this capacity, but it is there, like the ability to adjust your diet or your wardrobe. The events of your childhood can be overcome and transformed based on experiences you have later in life. Bayley and Baltes' big idea was that no single period of life holds supremacy over another.

Of course, the idea that people can change is the entire basis of modern psychotherapy. People seek psychiatrists and psychologists because they want to change, and modern psychiatry and psychology are largely effective in treating or curing a great number of mental disorders and stressors, especially phobias, anxiety, stress disorders, relationship problems, and mild to moderate depression. Some of these volitional changes revolve around improved lifestyle choices, while others entail changing our personalities, sometimes only slightly, to give us the best chance of aging well. To implement the changes that will be most effective, each of us might think about the fundamental components of how we are now, how we used to be, and how we'd like to be.

The collection of dispositions and traits that we have in any given period comprise our personalities. All cultures tend to describe people using trait-based labels, such as *generous, interesting,* and *reliable* (on the positive side) or *stingy, boring,* and *erratic* (on the negative side), along with more or less neutral or context-dependent terms such as *boyish* and *breezy*. This "trait" approach, however, can obscure two important facts: (1) we often display different traits as situations change, and (2) we can change our traits.

Few people are generous, interesting, or reliable all the time—opportunity and the fluidly evolving situations in which we find ourselves can exert a strong pull on what may be genetic predispositions toward certain behaviors and certain habitual ways of presenting ourselves to the world. Traits are probabilistic descriptions of behavior. Someone who is described as high on one trait (having a lot of it) will display that trait more often and more intensely than

someone low on that trait. Someone who is agreeable has a greater probability of displaying agreeableness than someone who is disagreeable, but disagreeable people are still agreeable some of the time, just as introverts are extraverted some of the time.

Culture plays a role as well, both macro- and microculture. What is considered shy, reserved behavior in the United States (macrolevel culture) might be regarded as perfectly normal in Japan. And staying within the United States for the moment (microlevel culture), behavior that is considered acceptable in a hockey game might not be acceptable in the boardroom.

Booker T. Washington wrote that "character, not circumstance," makes the person. Ralph Waldo Emerson wrote, "No change of circumstances can repair a defect of character." While character makes for a good story or poem, in reality we are less shaped by character traits than we think, and more than we realize by the circumstances that life deals us—and our responses to those circumstances. It would be nice to be able to grade these circumstances from severely deleterious to benign, but what makes that impossible to do is individual differences in the way we respond to things. Some children who were (or felt) abandoned by their parents grow up to be well-adjusted, do-gooding members of society; others become axe murderers. Resilience, grit, and gratitude for the small things in life ("at least I still have food to eat") are personality traits that are unevenly distributed in the population.

We think of our genes as influencing physical traits, like hair color, skin color, and height. But genes also influence mental and personality traits, such as self-assuredness, a tendency toward compassion, and how emotionally variable we are. Look at a room full of one-year-olds and it is apparent that some are more calm than others, some more independent, some loud, some quiet. Parents with more than one child marvel at how different their personalities were from the start. I carefully referred to genes *influencing* traits because the effect of genes is not chiseled in stone. Your genes don't *dictate* how you'll be, but they do provide a set of constraints, limits on how your personality will be shaped. Genetics is not an edict—the traits that our genes contribute to still need to navigate the twisty and unpredictable roads of culture and opportunity. Complex traits are best described as emergent properties that you cannot read in any one gene, nor even in a large set of genes, because how the genes express themselves over time is critical to the development of the trait as a social reality.

Genes can be present in your body but in a dormant state, waiting for the right environmental trigger to activate them—what is called gene expression. A traumatic experience, a good or bad diet, how and when you sleep, or contact with an inspiring role model can cause chemical modifications to your genes that in turn cause them to wake up and become activated, or to go to sleep and turn off. The way the brain wires itself up, both in the womb and throughout the life span, is a complex tango between genetic possibilities and environmental factors. Neurons become connected whenever you learn something, but this is subject to genetic constraints. If you've inherited genes that contribute to making you five feet tall, no amount of learning is likely to get you into the NBA (although Spud Webb is five foot seven and Muggsy Bogues is five foot three). More subtly, if your genes constrain the auditory memory circuits in your brain—perhaps because they favor visual-spatial cognition—you're unlikely to become a superstar musician no matter how many lessons you take, because musicianship relies on auditory memory.

One way to think about gene expression is to think of your life as a film or multiyear TV series. Think of your DNA as the script: the set of instructions, dialogue, and stage directions for all the participants in the film. Your cells are the actors. Gene expression is the way that

the actors decide to express that script. The actors may bring a certain interpretation to those words, based on their experience, and might surprise even the writers.

And, of course, the actors interact with and play off one another, for better or for worse. Jason Alexander, the actor who played George Costanza on *Seinfeld,* complained about how difficult it was to work with Heidi Swedberg (who played George's fiancée, Susan). "I couldn't figure out how to play off of her. . . . Her instincts for doing a scene, where the comedy was, and mine were always misfiring." Julia Louis-Dreyfus and Jerry Seinfeld had similar complaints and reportedly said that doing scenes with her was "impossible." But the chemistry between Alexander, Louis-Dreyfus, Seinfeld, and Michael Richards (Cosmo Kramer) was palpable, making *Seinfeld* the most successful comedy series in history.

Your genes, then, give you a kind of life script with only the most general things sketched out. And from there, you can improvise. Culture affects the ways you interpret that script, as do opportunity and circumstance. And then, once you interpret the script, it influences the way others respond to you. Those responses in your social world can change your brain's wiring and chemistry, in turn affecting how you'll respond to future events and which genes turn on and off—over and over again, cascading in complexity.

The second feature in the triad, *culture,* plays an important role in our understanding of traits. Humility is more valued in Mexico than in the United States, and more valued in rural Wisconsin than on Wall Street. Polite in Tel Aviv might be thought of as rude in Ottawa. The terms we use to describe others are not absolutes; they are culturally relative—when we describe differences in personality traits, we're necessarily talking about how an individual compares to their society and to their societal norms.

Family is a microculture, and traditions, outlook, political and social views differ widely, especially within large industrialized countries. Go door to door in any town or city and you'll find a wide range of attitudes about things as mundane as whether friends can just drop by or need to schedule in advance; how often teeth should be flossed (if at all); or whether TV and device time are regulated. And these unique family cultural values map onto particular personality traits: spontaneity, conscientiousness, and willingness (or at least ability) to follow rules. Culture is a potent factor in who we become.

The third part of the developmental triad is *opportunity*. Opportunity and circumstance play a larger part in behavior than most of us appreciate, and they do this in two different ways: how the world treats us, and the situations we find (or put) ourselves in.

Fair-skinned children burn more quickly in the sun than dark-skinned children and so may spend less time outdoors; skinny children can explore the insides of drainage pipes and the tops of trees more easily than heavy children. You may start out with an adventure-seeking personality, but if your body won't let you realize it, you may seek other experiences, or adventure in less physical ways (like video games—or math).

Apart from these physical features, we all play roles, in our families and in society. The eldest child in a multichild household tends to take on some of the parenting and instruction of the younger ones; the youngest child may be relatively coddled or ignored, depending on the parents; the middle child may find herself thrust into the role of peacemaker. These factors influence our development, but again, as with genes, they are not deterministic—we can break free of them to improvise, to create our own futures, but it takes some effort (and for some, a lot of false starts, failures, and therapy).

How the World Treats Us

You might assume that identical twins end up with similar personalities just because they share identical (or near-identical) genes. But it might also be due to the fact that, to some extent, the world treats people who look alike in similar ways. People generally react with certain biases to the way you look, and by the time you were twelve or so, you probably recognized a pattern in how others reacted to you. Skin color, weight, and attractiveness are key determinants of how people are treated by teachers, strangers, and, unfortunately, the police. In one study of St. Petersburg, Florida, police department operations, male, nonwhite, poor, and younger suspects were all treated with more physical force, irrespective of their behavior.

Suppose there is something about your face and physique that makes you look mean—a certain way that your eyebrows curl downward toward your eyes, a squinty look to your eyelids, deep creases around your mouth—what is colloquially known as "resting bitch face." According to *The Washington Post,* actress Kristen Stewart is the poster child for it, and Anna Kendrick is a self-described sufferer. (It applies to males as well, including Kanye West.) You may find that people are wary around you and even fear you. You may be kind and gentle on the inside, but after a lifetime of being misjudged, of people treating you suspiciously, you could turn cold in your social interactions, a real-life Shrek—the ogre who looks mean and frightens people but has a heart of gold.

One way this has been studied experimentally is to look at inter-rater agreement. Participants in an experiment meet strangers, or view photographs or videos of strangers, and then have to describe those strangers using a range of personality terms. The assumption is that, if you don't know someone, your judgments of them will be based on their physical appearance—the particulars of their face, body type, dress, and body language. Studies like these go back to the early work in the sixties of Lew Goldberg at the University of Oregon and the Oregon Research Institute. These studies found consistent agreement across a variety of personality traits, such as *sociable, extraverted, good-natured, responsible, calm, conscientious,* and *intellectual* just based on what someone looked like. There is far less consistency in judgments for other terms such as *agreeable, neurotic,* and *emotionally stable.*

Of course, a bunch of strangers agreeing that someone is *responsible* doesn't make them so. All that these experiments show is that when we interact with strangers, we bring some social-psychological baggage. The consensus about that baggage suggests that people within a culture share beliefs about how personality traits are linked to physical characteristics. When participants' ratings of themselves were compared to the strangers' ratings, some terms show high agreement, especially *sociable* and *responsible.* And although our self-perceptions are often flat-out wrong or distorted by ego needs, sometimes they are accurate —the problem is, we don't know which times.

The culture we live in has a great deal of influence on how we categorize and evaluate traits. A body type that one culture finds threatening another might find nurturing; a face that one culture finds honest another may view as mocking.

The Search for the Magic Number

How do scientists study such a personal and seemingly subjective thing as personality? I wondered this for many years, until as fate would have it—*opportunity,* you might say—I met someone who was in the thick of figuring this out.

In 1980, I was looking to rent a cabin on the Oregon coast for a short while. I picked up the local newspaper, found an ad for one, and called the landlord on a pay phone. We met later that day. The landlord turned out to be Lew Goldberg—the psychology professor who had done much of the seminal work on measuring personality. He was leaving on sabbatical and wanted to rent out his weekend house. Although he ended up not renting to me—he chose an older, more financially stable renter—we ended up becoming friends. He introduced me to Sarah Hampson, who was his research colleague at the Oregon Research Institute. The mere fact that I got to know Sarah and Lew speaks to their gregariousness and their openness to meeting new people, even a young, ignorant student like me.

Lew doesn't usually like talking about himself. He is outgoing and enthusiastic, but modest. After we had known each other for a while, I got him to talk about his work in measuring personality. Lew began by asking, "How would *you* study personality?" (You might stop for a moment and think about this before reading further.)

I thought: Maybe you could put somebody in a brain scanner and show them pictures of homeless people asking for money. If the part of the brain that's responsible for feelings of generosity becomes excited, you might infer the person is generous, and if that same part of the brain is repulsed, you might infer they're stingy. But how do we know which part of the brain is the "generosity" region? The truth is we don't, and if we were to set about discovering *that,* we'd have to *start out* with generous people in order to locate that brain part. So we're left back where we started: How do you know if someone is generous?

Maybe you could put them in a situation where they have an opportunity to demonstrate generosity. For example, on their way to your office, they pass by a homeless person and you secretly watch what they do.

There are three problems here, though. First, a person could be generous in a whole lot of situations but not the one you're observing. Imagine someone philanthropically minded who prefers to donate to established charities. That person may have given a thousand dollars to a homeless shelter just yesterday, and another thousand dollars to a soup kitchen, and more money to the Red Cross, Oxfam, Habitat for Humanity, and United Way. Yet that person might fail your test. Or maybe the person just had their wallet stolen and doesn't *have* any money to hand out today, although on any other day they would have given.

Second problem: How do you distinguish personality traits that might be triggered by the same scenario but are different? A person might *not* be generous but the scenario triggers something that looks like it: compassion—maybe this particular homeless person reminds her of her dear, departed sister, causing her to reach into her wallet for a few loose dollars. Or maybe due to a brain injury, a man lacks impulse control and simply can't say no to any request of any kind—again, he's not what you might conventionally consider *generous;* he simply appears that way in the particular circumstance you're viewing.

Third problem: The sheer number of possible traits that a person can have would mean that we'd have to experiment on thousands of behaviors, making the research unwieldy and impractical. There must be an easier way.

I was not able to figure out this problem myself, but Lew had an elegant answer. He starts with an assumption, first popularized by Sir Francis Galton in the 1800s. Here's Lew:

> Let's assume that those individual differences that are of the most significance in the daily transactions of persons with each other will eventually become encoded into their language. This is the lexical hypothesis. The more important such a difference is, the more will people notice it and wish to talk about it, with the result that eventually they will invent a word for it, such as those nouns (e.g.,

> *bigot, bully, fool, grouch, hick, loafer, miser, sucker*) and adjectives (e.g., *assertive, brave, energetic, honest, intelligent, responsible, sociable, sophisticated*) that are used to describe persons.

Is Lew's assumption true? Maybe not. But it's a good starting point. Maybe there are some personality traits not captured in words, either because they are relatively rare (in which case we don't need to worry about them now) or because they represent things that we're uncomfortable talking about (in which case we need to create different assessment instruments). Let's assume that the lexical hypothesis doesn't mean we'll identify every single personality trait possible, only that we'll get most of the really important ones.

If you're thinking that such terms might be culturally dependent—consistent with the triad of the developmental approach—you get a gold star (and, at least based on this example, you are *clever, intelligent,* and *sophisticated*). The cultural dependence might be obvious with a term such as *hick*. In a remote, closed community that doesn't interact with outsiders, it would be difficult to imagine calling someone a *hick* or a *bigot*. Those seemingly depend on living in a more urbanized culture with opportunities to contrast city folk with country bumpkins, and tolerant, open-minded people with bigots. Similarly, a strictly monogamous society might not need a word for *bigamy,* and a society that stresses communal ownership of all property might not need a word for *thief*.

The possibility that personality traits are influenced by culture doesn't doom the enterprise of measuring them—it all depends on what you want to use the information for. If you want to understand the personality traits that people exhibit in your own culture, or how they might change across the life span for you and your friends, there's no problem. If, like some cross-cultural psychologists, you want to understand how personality varies from one culture to another, or if there are personality universals that show up in all cultures, then you take whatever tests you've come up with and administer them to as diverse a range of humans as possible. As Lew says:

> The more important an individual difference is in human transactions, the more languages will have a term for it.

And so intrepid researchers, explorers of the personality domain, have gone off and studied the languages of diverse cultures from around the globe. Consider one type of individual difference, mental illness. It seems rather important to know whether a person you're interacting with is *sane, rational,* and *emotionally stable,* or *hears voices in their head*. It turns out that peoples as diverse as the Inuit, in northwest Alaska; the Yoruba tribes of rural Nigeria; and the Pintupi aborigines of central Australia, who until a generation or two ago lived like Paleolithic hunter-gatherers, have words in their languages for these important personality descriptors. Furthermore, there is very little that is distinctive culturally in these societies' attitudes and actions toward the mentally ill. Even words for more common and minor forms of mental illness, such as anxiety and depression, are found throughout the world.

Once scientists figured out *how* to measure personality, and how to describe people, another problem arose. There are thousands and thousands of different words used to describe personality traits—in English, there are 4,500 of them in *Webster's Unabridged Dictionary,* and more than 450 in current and common use. The sheer number can make a science of trait descriptions unwieldy—difficult to summarize, talk about, or make

predictions with. This was one of the first "big data" problems, decades before there was Facebook or climate change data to analyze.

What scientists typically do with such mounds of data is to use mathematical techniques for data reduction, merging similar items into the same category or dimension. Doing so can allow us to discuss the data using a shorthand. We don't discard the original data, so we can always go back to it.

Consider by analogy the shorthand we use to talk about spatial location—where people and things are in the world. We could use a three-dimensional coordinate system, such as latitude, longitude, and height above sea level, and for some things we do. But it is a cumbersome system that provides more information than we usually need. Instead, we divide the world into continents, countries, cities, neighborhoods, and so on, and this is usually enough.

Suppose you're trying to schedule a meeting with people in your Houston-based organization and you haven't been able to reach Terry. Briana says, "Oh, Terry is in Europe for the next couple of weeks." That's really all you need to know—you don't need to know if he's in Portugal or Macedonia, or if he's staying on rue des Capuchins in Lyon, but presumably you could find out his exact location if you wanted to FedEx him some meeting notes—or maybe you only need his email address. And just because we've described Terry's location simply as *Europe* doesn't mean we'll confuse Terry's location with that of other people or things in Europe. If Doug says, "Oh—my cousin's suitcase was just sent to Europe by mistake; maybe Terry will run into it there," we see the folly: Europe is big. And so it goes with personality descriptions.

Even if we could find a way to summarize personality descriptions, to give us a shorthand for talking about them, it wouldn't mean that everyone who is included in a personality description category is alike. But there may exist broad and meaningful trends we can talk about that, in general, distinguish a North American temperament or outlook from, say, an Asian or African one, without losing sight of individual differences and variability. And personality traits fall along a continuum: We can use modifiers to say that a person is more or less charming, more or less grouchy, more or less European.

Dozens of researchers spanning several countries set about trying to understand the best way to organize personality terms, to create a useful taxonomy. Ideally, whatever system we come up with would work across languages and cultures, which would greatly facilitate comparisons. It took more than fifty years for scientists to come to a consensus about this.

One prominent scientist argued for twenty to thirty dimensions; several others for two. Some argued for five or thirteen. Our friend Lew Goldberg initially gravitated toward a three-factor (three-dimensional) model proposed by psychologist Dean Peabody, rejecting the five-factor model, now known as the Big Five. "To my scientific tastes," Lew said, "the Peabody model was elegant and beautiful, whereas the five-factor structure was a nightmare: All of the Big-Five factors but the first, extraversion, were highly related to evaluation [good-bad], meaning that they weren't truly independent dimensions." From roughly 1975 to 1985, he worked on collecting and analyzing data from a variety of sources to support the Peabody three-factor model, but no matter what he did, a five-factor model emerged from the analyses. Lew appealed to Dean Peabody to set up an experiment that would help them choose between three and five dimensions, something they designed together. When the data came in, they published a paper together showing that five dimensions comprised a more useful system (and it incorporated the original Peabody three). Goldberg became a reluctant convert, as did Peabody himself.

This never would have happened if Goldberg and Peabody had not been *collaborative, open to new experience, agreeable,* and at least slightly *extraverted.*

Collaborating with someone you disagree with represents a scientific ideal. When two or more researchers who are pursuing different theories, and who disagree with one another, decide to work together, the results can transform a field. Today many consider Lew the father of the Big Five personality categories. There have been cross-cultural replications in dozens of languages and cultures, including Chinese, German, Hebrew, Japanese, Korean, Portuguese, and Turkish. As you might expect, some minor differences emerge in disparate cultures, but the Big Five remain the best description.

The Big Five dimensions are:

I. Extraversion
II. Agreeableness
III. Conscientiousness
IV. Emotional Stability versus Neuroticism
V. Openness to Experience + Intellect (also called Imagination)

Each of these categories includes many dozens of individual traits. As you can see, there has been some controversy around what to call the last one, but don't let that bother you—it is a well-defined dimension that includes a number of traits that cohere in real life.

EXTRAVERSION includes *talkative, bold, energetic,* and their opposites, *quiet, timid,* and *lethargic.* People who score high on the Extraversion dimension tend to be comfortable around other people, start conversations, and don't mind being the center of attention.

AGREEABLENESS includes *warm, cooperative, generous,* and the opposites *cold, adversarial,* and *stingy.* People who score high on this dimension tend to be interested in other people, sympathize with others' feelings, and make people feel at ease.

CONSCIENTIOUSNESS includes *organized, responsible, careful,* and *practical,* and the opposites *disorganized, irresponsible, sloppy,* and *impractical.* People who score high on this dimension tend to be prepared, be diligent, pay attention to details, and do what they say they will do.

EMOTIONAL STABILITY includes *stable, contented,* and *at ease,* and *unstable, discontented,* and *nervous.* People who score high on this dimension are not easily bothered by things, are relaxed, and don't change their moods a lot.

OPENNESS (also called INTELLECT and IMAGINATION) includes *curious, intelligent,* and *creative,* as well as *uninquisitive, dumb,* and *uncreative.* It includes cognitive and behavioral flexibility. People who score high on this dimension are quick to understand things, have a vivid imagination, and like trying new things, new restaurants, and going to new places. It is separate from intellectual ability but speaks to a propensity to enjoy intellectual, cultural, aesthetic, and artistic experiences.

If you want to sound like a personality researcher, you can use the shorthand of the factor numbers, such as, "Oh, that Nancy is very low on Factor II," or, "I think you should promote

Stan in accounting—he's high on Factors II and III."

The drive to organize people's traits into categories is ancient; astrology is one such attempt to assign personalities to people systematically, depending on when they were born. While it is still popular throughout the world, it has no scientific basis. Sure, you may know a Capricorn who is stubborn, but statistically, you're just as likely to find stubborn Leos, Libras, and Sagittarians.

One point that often gets confused is that people tend to think of the Big Five as a typology (the extraverted type, the neurotic type, etc.). That's not the case—it's the configuration (or profile) of the five factors that represents someone's personality. Just as we can describe physical objects in terms of length, width, and height, the Big Five framework allows us to describe human personality in terms of the five factors. Proponents of the Big Five never intended to reduce the rich tapestry of personality to a mere five traits. Rather, they seek to provide a framework in which to organize the myriad individual differences that characterize human beings. This organization reveals a great deal about things that have historically been important for humans to know about one another.

Factor I. Is Jason *active* and *dominant* or *passive* and *submissive*? (Can I bully Jason or will Jason try to bully me?)

Factor II. Is Mari *agreeable* or *disagreeable*? (Will my interactions with Mari be warm and pleasant or cold and distant?)

Factor III. Is Letitia *responsible* and *conscientious* or *negligent* and *erratic*? (Can I count on Letitia?)

Factor IV. Is Hannah *crazy* or *sane*? (Can I predict what Hannah will do, and will her actions make sense to me?)

Factor V. Is Felix *smart* or *dumb*? (How easy will it be for me to teach Felix? Is there anything I can learn from him?)

So What?

What does all this mean for us, people who are interested in the science of aging? The Big Five gives us a universally recognized structure for organizing what would otherwise be an unwieldy number of traits.

Whenever genes, situations, or therapy changes our personalities, they must do so by changing the brain. In that sense, all personality differences are biological, regardless of whether they are influenced by genetics or not, because they must go through the brain. These neurobiological changes are accompanied by chemical changes in the brain. As an example, assertiveness, competitiveness, dominance, and belligerence all are influenced by testosterone across genders. Higher levels lead us toward aggressive behaviors; lower levels lead us toward politeness. Testosterone levels are affected by the triad of factors—genes, culture, and opportunity. Situations such as a successful hunt, driving a fast car, being in the public eye, or being in charge of a large number of people can increase testosterone levels. The normal process of aging tends to lower them. A typical professional career trajectory finds one gaining more power as one gets older—this can compensate for biologically lowered levels of testosterone in some individuals.

Conscientiousness, Agreeableness, and Emotional Stability can be thought of as reflecting a tendency toward reducing unwanted drama in our lives, and evidence is mounting that these are influenced by serotonin. Openness and Extraversion reflect a general tendency to explore and engage with possibilities, and these appear to be influenced by dopamine. Drugs that increase dopamine can cause us to want to explore more and engage in riskier behaviors. Low levels of serotonin are associated with aggression, poor impulse control, and depression, and drugs that improve serotonergic function are often prescribed to treat these.

The structure of genes has also been shown to influence personality. Alterations to the gene known as *SLC6A4* are associated with neuroticism-related traits including anxiety, depression, hopelessness, guilt, hostility, and aggression. Other genes with hard-to-pronounce names are associated with self-determination and self-transcendence and with novelty seeking. The novelty-seeking genes are involved in dopamine regulation. An active area of research is dedicated to mapping these kinds of interactions between genes, brain, neurochemicals, and personality.

Temperament versus Personality

Babies are born with certain predispositions—a pattern of individual differences in how they react to different situations, as well as the regulation of those patterns. In babies and children, these patterns are usually called temperament, whereas in adults these patterns are called personality. Temperament and the young child's early life experiences contribute to growing a personality. That personality will be based on the child's developing views of self and others as they are shaped by experience. A child who grows up in an environment with many dangers and hazards will surely view the world differently than one who is nurtured and sheltered. The fascinating thing is that personality development doesn't always go the way one might predict.

You might think that a child who grows up in a dangerous environment will learn to be fearful and will develop a fearful, anxious, and perhaps neurotic personality. This can certainly occur. But a different child, with different genetic predispositions, uterine environment, and parenting may become fearless, brave, and challenge seeking. Temperament becomes personality as the child develops its own values, attitudes, and coping strategies. And it is biologically based, linked to, but not completely determined by, an individual's genetic makeup.

Temperament is typically measured in young children along dimensions that parallel temperament in animals. These include surgency (activity level, or Factor I), sociability (Factor II), self-regulation (Factor III), and curiosity (Factor V). These have been found to correlate highly with the Big Five. Factor IV, whether a person is crazy or sane, is more difficult to assess in animals and infants. (Although at times, I think every parent of a two-year-old thinks their child must be crazy. And, of course, they are! Babies are entirely egocentric, true psychopaths, who don't care about anyone but themselves.)

Age-Related Personality Changes

There are a number of ways in which the natural aging process itself tends to cause some personality changes. In a meta-analysis of ninety-two research papers, covering the life course from age 10 to 101, 75 percent of personality traits studied changed significantly after

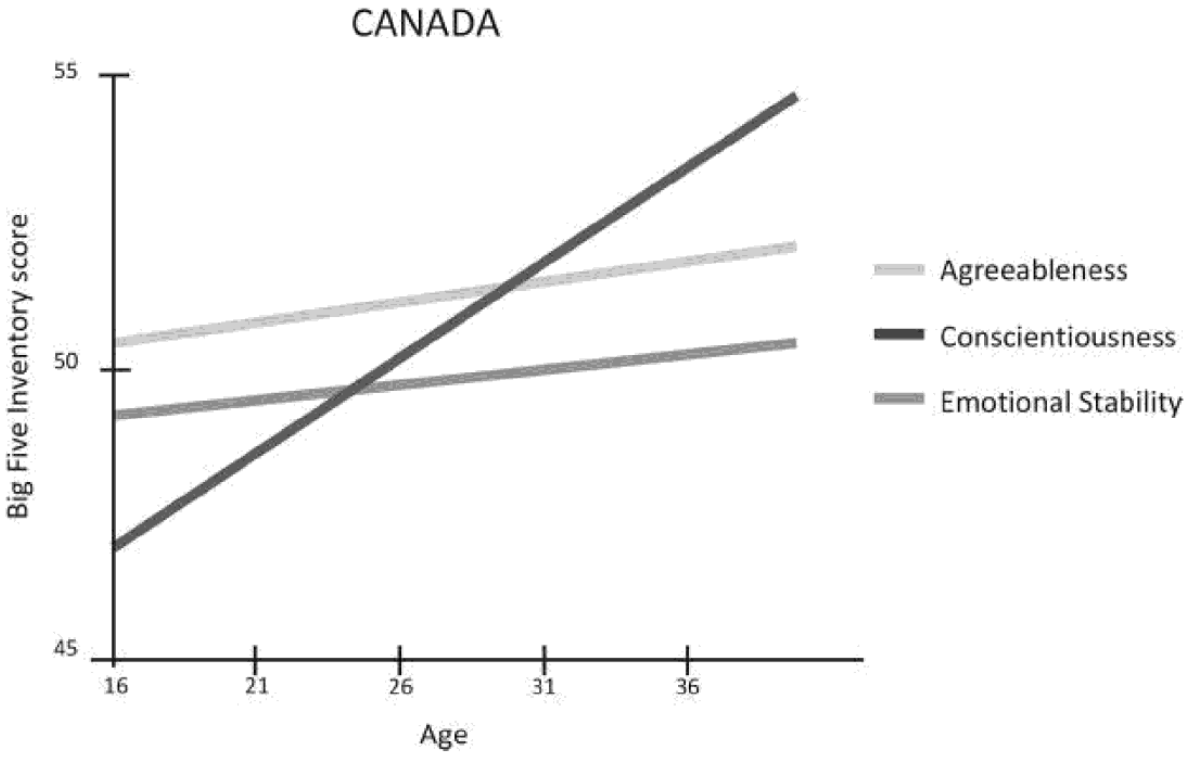
the age of forty and well beyond sixty. (These tendencies will not apply to all people. Some people don't change at all, and some change in ways that contradict statistical trends.) Some changes result from diseases and injuries, such as Alzheimer's, Pick's disease, stroke, or concussion due to falling.

So what are the trends? Older adults tend to be better at controlling impulses; that is, they're better at self-control and self-discipline and tend to be better at rule-following than young adults—traits that have to do with Factor III (Conscientiousness). Self-control increases steadily every decade after the age of twenty. Some of this has to do with the development of the prefrontal cortex, which continues through the early twenties, and yet we see additional age-related dispositional changes in impulse control that we haven't found a cause for yet.

Flexibility—your ability to easily adapt to changes in plans or to your environment—decreases steadily in every decade after twenty. With age, men typically show increased emotional sensitivity, and women experience decreasing emotional vulnerability. As you might expect—and may have experienced yourself—Openness increases around adolescence, but then declines with age.

In addition, older adults are generally more concerned with making a good impression and with cooperating and getting along with others—Agreeableness increases substantially. They show increased Emotional Stability and calm as well. I'm sure you can think of exceptions—remember, these are just averages. One of my favorite pictures in social neuroscience comes from a study of nearly 1 million individuals from sixty-two countries, showing how consistently Emotional Stability, Agreeableness, and Conscientiousness increase with age throughout early adulthood. The chart for one country, Canada, is shown on the next page.

Conscientiousness, Openness, and Extraversion decreased during old age, whereas Agreeableness and Emotional Stability increased substantially. Similarly, these results suggested that the initially increasing levels of Conscientiousness may in fact start to decrease following the age of fifty. Individuals appear to become more self-content in old age, an aspect of Emotional Stability called the La Dolce Vita effect: the sweet life. Older adults are more content with what they have, more self-contained and laid-back, less driven toward productivity. Mood disorders, anxiety, and behavioral problems decrease past age sixty, and onset of these problems after that age is very rare.



Older adults are less likely to engage in risky or thrill-seeking behaviors and tend to be more morally responsible and less open to new experience. In terms of the Big Five factor model, older people show declines in Extraversion and Openness and increases in Emotional Stability and Agreeableness.

Some of these age-related changes are based on microculture and opportunity—the social roles that we and our cohort of friends invest in during earlier life stages. By late adolescence and early adulthood, people become more independent and begin investing in their education and career. Success in these domains depends very much on being reliable, dependable, and competent. Prior to this period, there is probably less need to behave conscientiously because parents and institutions are in place to guide people through life. For some, Conscientiousness declines after retirement not because the brain has changed but because there is less need to be a hardworking, driven personality—it seems okay to loosen one's grip a bit and enjoy la dolce vita. And many transitions in social roles occur in older adulthood, when we might become grandparents, retire from full-time work, or take up new hobbies. Health challenges present us with a stark choice and an opportunity to mold our personalities: Am I someone who folds up and gives in, or do I double down, embrace resilience and optimism, and try to make the best of the time I have left?

Optimism predicts longevity. But too much optimism can lead to bad health outcomes. If you're unrealistically optimistic, you might not have that dark spot on your forehead checked for cancer; you might ignore the fact that you've been putting on ten pounds every decade since you were forty, figuring it will all work out just fine. Although optimism is a crucial part of disease recovery, tissue repair, and so on, it needs to be tempered with realism and conscientiousness.

Illness often causes us to change our personalities. In Sarah Hampson's work on people with type 2 diabetes, it was not uncommon for people to say that the onset of this disease made them take better care of themselves. Aspiring to a healthier lifestyle may thus lead to personality change—an increase in self-control, methodicalness, and conscientiousness.

I'm reminded of another story, of a man who was born poor in Indiana in 1890 and whose father died when he was five. An unmotivated child, he dropped out of school in the middle of seventh grade and never went back. By age seventeen, he had already been fired from four jobs. He became a drifter, moving from one unskilled job to another, finding himself broke most of his life. If early childhood and young adult experiences were all there was to a life story, you could predict that his life would be characterized by one disappointment after another. Indeed, he appeared aimless and unfocused. Among other things, he found work as a steam engine stoker, farmhand, blacksmith, soldier, railroad fireman, buggy painter, streetcar conductor, janitor, insurance salesman, and filling station operator, but never managed to hold on to a job or to save any money. At age fifty, he started another doomed job, a roadside eatery in Corbin, Kentucky. The restaurant eked along and then finally gave its last gasp, going out of business when he was sixty-two. There he was, pushing retirement age, broke (again), and living out of his car. How many of us would give up at that point? He had never had a success in his life, and the life expectancy for a sixty-two-year-old in 1952 was just another 3.2 years.

One day he took an old family recipe and, imagining the potential of franchised restaurants, opened one in Utah with borrowed money. That might be the end of the story, except that his name was Harland Sanders, and the restaurant was Kentucky Fried Chicken, now known as KFC and one of the largest suppliers of food in the world. Sanders sold the company at age seventy-four for $2 million, about the equivalent of $32 million in today's dollars. The company he conceived of at age sixty-two now has annual revenues of $23 billion and is known throughout the world. He continued advising the company and working as a brand ambassador into his nineties.

At age eighty-nine, Colonel Sanders was asked, "You don't believe in retirement?" "No," he answered adamantly. "Not a bit in the world. When the Lord put Father Adam here he never told him to quit at 65, did he? He worked into his final years. I think as long as you've got health, and ability, use it . . . to the end."

Trying something new later in life, like competitive sports, business enterprises, or artistic endeavors, can dramatically increase both your quality of life and how long you live. Openness and curiosity correlate highly with good health and long life. People who are curious are more apt to challenge themselves intellectually and socially and reap the rewards of the mental calisthenics that result. They are also more likely to be interested and engaged, which makes them more fun to be around, and interacting with others socially is a good way to stay mentally agile and alert.

Conscientiousness

Perhaps the most important traits to foster and develop throughout the life span are those in Factor III, Conscientiousness. Conscientious people are more likely to have a doctor and to go see one when they're sick. They're more likely to get regular medical checkups and to reliably keep up with their professional, family, and financial commitments. This may sound like a mostly practical matter, but Factor III traits are highly correlated with a panoply of positive life outcomes, including longevity, success, and happiness. Conscientiousness has been linked to lower all-cause mortality. Conversely, lower childhood conscientiousness predicts greater obesity, physiological dysregulation, and worse lipid profiles in adulthood. To become more conscientious, one must change underlying cognitive processes such as self-regulation (controlling impulsive behaviors) and self-monitoring (noticing which

circumstances lead to successful self-regulation and which circumstances sabotage self-regulation). If you wish you had more of these, a number of different methods have been shown to work for adults of any age, from cognitive behavioral therapy to David Allen's book *Getting Things Done*.

A recent psychological study, published in the flagship journal of the Association for Psychological Science, corroborated what Charles Koch, CEO of one of the largest companies in the world, says: "I'd rather hire someone who is conscientious, curious, and honest than someone who is highly intelligent but lacks those qualities. Runaway intelligence without conscientiousness, curiosity and honesty, I learned, can lead to dismal outcomes."

IQ, one's intelligence quotient, is a familiar metric. Increasingly, so too is EQ, the emotional intelligence quotient, thanks in part to the popular writings of Daniel Goleman. Cognitive scientists now talk about a third metric, CQ, the curiosity quotient, and it predicts life success as well as, and often better than, IQ or EQ.

As you might imagine, there are limits to both Conscientiousness and Curiosity. Too much of either can cause trouble. Someone who is too conscientious might stray into obsessive compulsive disorder behaviors; it's helpful to distinguish healthy conscientiousness from extreme rigidity or compulsion. Systemic conscientiousness, if it involves blind adherence to faulty rules, is also a problem, such as when the medical community recommends policies that can cause harm. Screening for prostate cancer with the prostate-specific antigen (PSA) biomarker is probably the most notorious case of causing significant harm to patients. Most men with elevated PSA levels will never develop symptoms of prostate cancer, but many have died or suffered serious health problems after receiving unnecessary treatment. The ratio of those helped versus harmed by PSA screening is around one in a hundred. Overdiagnosis is common in other "conscientious" cancer screenings as well.

Openness

Can too much openness lead someone to engage in risky, dangerous behaviors? Yes. John Lennon was famously open to new experiences and at one point considered an untested form of therapy that involved having a hole drilled in his skull. Amy Winehouse, who faced great difficulties with impulse control, died at twenty-seven from alcohol poisoning. Steve Jobs, also famous for his openness, pursued an untested treatment for his pancreatic cancer, and that openness—rather than a reliance on scientifically validated medical treatments—killed him.

Fortunately, our traits and personalities are malleable, like the brain itself. We can change. We can learn from our experiences. All of us have an internal monologue, a narrator in our heads keeping track of things such as "I'm hungry" or "I'm cold." The internal narrator also tells us, "This is what I'm like—these are the things I like to do, these are the ways I respond to certain situations." Knowing this about ourselves is the first step toward change, toward affirming that our past behavior does not necessarily determine our future behavior. Even models we learn about through the media can help us to make aspirational changes. And personal affirmations ("I am generous, I am kind") can help us to become what we're not. A famous old psychology experiment showed that people who *act* as if they're happy end up *being* happy. The zygomatic facial muscle is what you use to smile when you're genuinely happy. In one experiment people who forced a smile actually felt happier than people who forced a frown, just because that muscle was engaged. It turns out that the nervous system is

bidirectional. It doesn't matter whether the brain makes the mouth smile or the mouth makes the brain smile. So smile, think positive thoughts, and try new things. If you're not feeling good, act as if you are. A cheerful, positive, optimistic outlook—even if it starts out fake—can end up becoming real.

Compassion

There is an inherent asymmetry in the amount and kind of information we have about ourselves versus what we know about others. You have unique access to your past actions and to your current mental states and motivations, but you do not have this level of access to others' memories and states of mind (except in a good movie or novel). They have the same lack of access when judging you. Imagine you're driving a fancy car and a homeless person walks up and asks for a dollar as you're waiting at a stoplight. Imagine also that you don't give it to him. He may conclude that you're a tightwad. You may have wanted to help but not have had any cash on you. One behavior, two different interpretations.

One tangible thing that we can all do to avoid misjudging others is to exercise compassion, to allow for the possibility that you might be wrong in attributing a trait to someone's behavior. Indeed, this is *the* core principle at the heart of both social psychology and the teachings of the Dalai Lama. "Compassion is the key to happiness," he says. "We are a social species and our happiness is defined by our relationship with others." The Dalai Lama believes this comes from the biology of our species, of the importance of social interactions to all primates. He tries to avoid feeling anger, suspicion, and distrust and instead practices patience, tolerance, and compassion. In addition, he avoids thinking of himself as privileged or special, and this increases his happiness a great deal:

> I never considered myself as something special. If I consider myself to [be] something different from you, like, 'I am Buddhist' or even more [with haughty voice] 'I am His Holiness the Dalai Lama' or even if I consider that 'I am a Nobel laureate,' then actually you create yourself as a prisoner. I forget these things—I simply consider I am one of seven billion human beings.

Buddhism, like most of the world's religions, teaches you how to change your personality. You may feel that your personality is fixed, inflexible, and was determined in childhood, but science has shown otherwise. In particular, studies since Bayley and Baltes have found that volitional (not disease-induced) personality change is possible at least through one's eighties, in the three continents so far studied, North America, Europe, and Asia.

The compassionate attitude and outlook are also related to experiencing less stress. You can choose not to be stressy—or learn how—and this can save your life. The HPA (hypothalamic-pituitary-adrenal) axis is an endocrine system that controls the secretion of stress hormones (glucocorticoids) including cortisol. Exposure to high levels of glucocorticoids can be particularly detrimental for the aging hippocampus and is associated with decrements in learning and memory. Among the things that psychotherapy is best at, stress reduction is one of the most important things you can do for your overall health. And yet, there can be too much of a good thing. Too much stress reduction, like too much optimism, may cause you to ignore important health issues or to become unmotivated to work or seek social contact. Moderate amounts of stress impel us to do things—to exercise, eat well, and nurture our mental health by making friends and spending time with them.

Is a Good Personality Sufficient?

Curiosity, Openness, Associations (as in sociability), Conscientiousness, and Healthy practices are the five lifestyle choices that have the biggest impact on the rest of our lives. The first four are elements of anyone's personality. The acronym they make is COACH, a term I use a few times in these pages and which comes ultimately from reading thousands of pages on aging research. I will return to its many implications in subsequent chapters. But one infamous aspect of aging does not fit into a personality trait: memory. It's a topic that gets at the core of who we are and how we experience life. Many of us wouldn't mind having someone else's hair, maybe someone else's intellect or emotional composure, but someone else's memories? We'd cease being who we are. So what do we know about the brain basis of memory, and why does memory seem to be the first thing to go?

2

MEMORY AND YOUR SENSE OF "YOU"

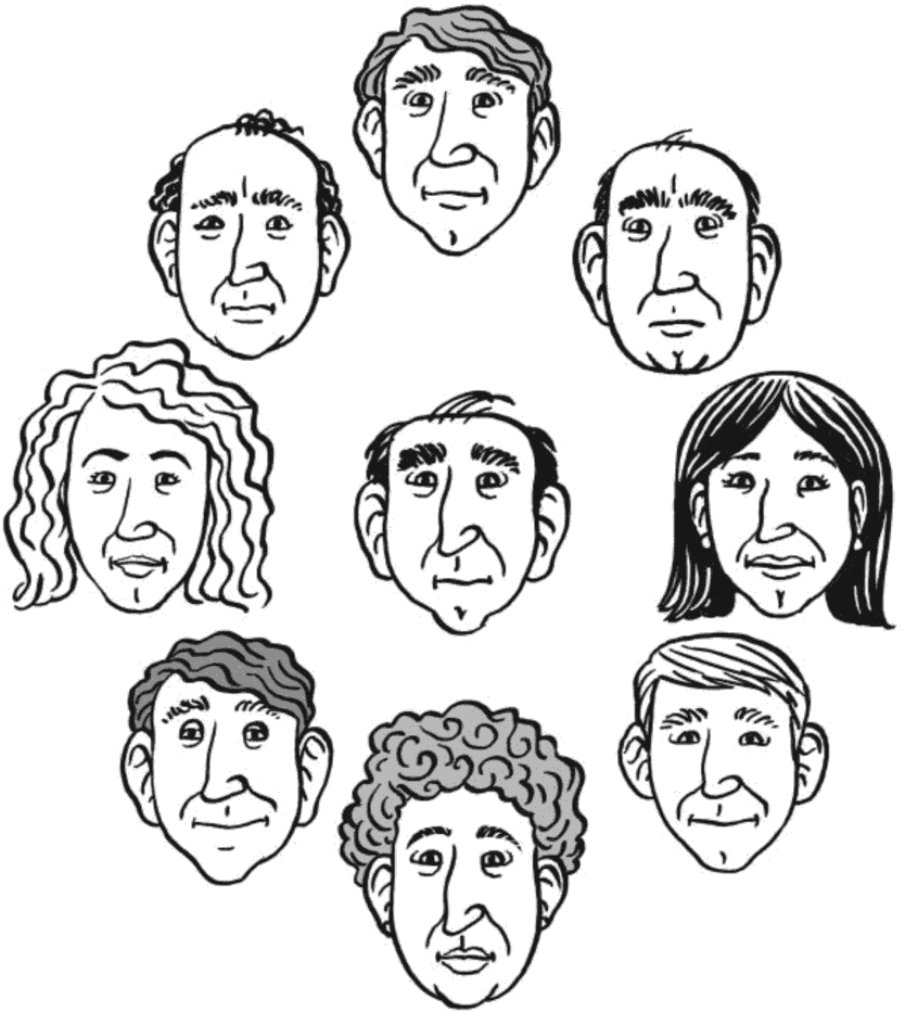
The myth of failing memory

I'm standing in front of the hall closet. I was packing my suitcase in the bedroom and came here to find something, and I now can't remember what. I walk back to the bedroom to see if something there will remind me. My mind is blank. I walk to the kitchen thinking maybe I had stopped at the hall closet by accident on my way here, hoping that there will be some object, something in plain view, that will remind me why I'm here. I go back to the bedroom and stare at the suitcase and piles of clothes, but there is no clue there either.

This is not the first time it's happened. In fact, it's nothing new—I used to do this in my thirties, but back then, I just figured I was distracted. If I wasn't a neuroscientist, I'd be worried now, in my sixties, that this was a sure sign that my brain is decaying and that I'll soon be in an assisted living facility waiting for someone to feed me my dinner of smashed peas and pulverized carrots. But the research literature is comforting—these kinds of slips are normal and routine as we age and are not necessarily indicative of any dark, foreboding illness. Part of what explains this is a general neurological turn inward—every decade after our fortieth birthday, our brains spend more time contemplating our own thoughts versus taking in information from the external environment. This is why we find ourselves standing in front of an open closet door with no memory of what we went there for. This is part of the normal developmental trajectory of the aging brain and not always a sign of something more sinister.

The panic that we feel upon forgetting something, particularly when we're older, is visceral and disturbing. It underscores how important and fundamental memory is—not just to getting things done, but to our deep sense of self. Memories tell us who we are in moments of conflict or doubt. Good memories comfort us. Bad ones haunt us. And the feelings they invoke in us are very personal and intimate.

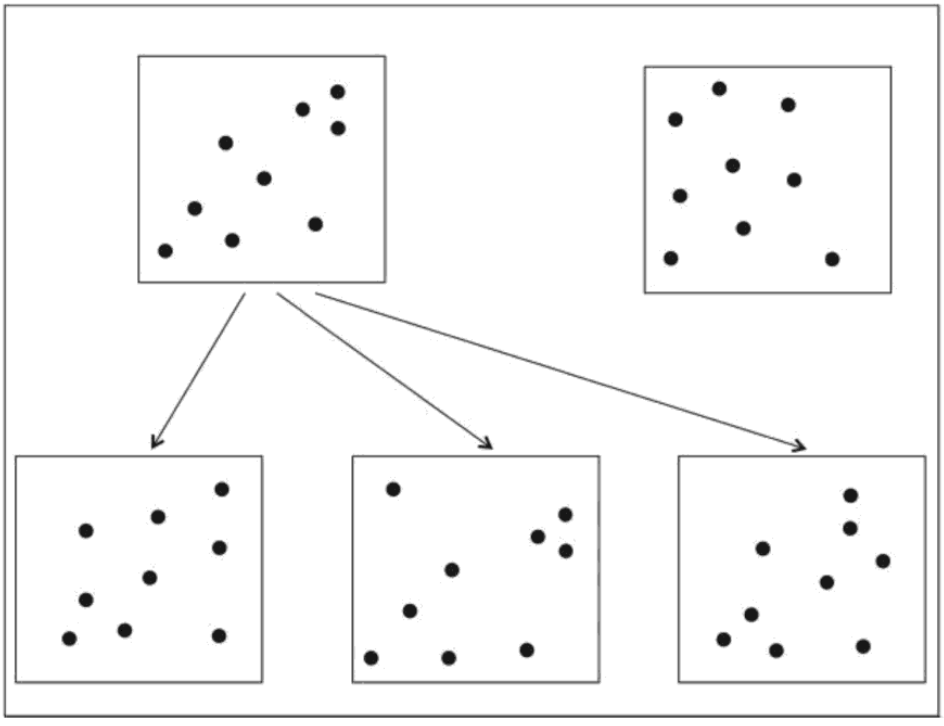
As philosophers and writers have long known, without memory we lack identity. The Christopher Nolan film *Memento* makes a vivid case for this, as does the current Netflix hit *Westworld,* by Christopher's brother Jonathan. (Now, *there's* an argument for the genetic basis of talent. Or is it an argument for shared home environment? Of course, it is the interaction of these two things.) Our very conception of ourselves and who we are is dependent on a continuous thread, a mental narrative of the experiences we've had and the people we've encountered. Without memory, you don't know if you're someone who likes chocolate or not, if clowns amuse or terrify you; you don't know who your friends are or whether you have the skill to prepare chocolate pots de crème for ten people who are going to arrive at your apartment in an hour.



Family resemblance includes variability around a prototype—here the prototype, or patriarch, is in the center.

As cognitive psychologists do, Posner and Keele started out with very simple items, much less complex than a human face. They presented computer-generated patterns of dots that they had made by starting with a parent, or prototype, and then shifted some of the dots one millimeter or so in a random direction. This created patterns that all shared a family resemblance with the original—very much like the variation in faces that we see in parents and their children. On the following page is an example of the one they began with (the prototype, upper left) and some of the variations (at the ends of the arrows). The one on the upper right is an unrelated pattern, used as a control in their experiment.

If you look carefully, you'll see a kind of family resemblance across the four related squares—all have a kind of triangular pattern of three dots in the lower left, although the dots vary in how close together they are. All have a diagonal of three dots running down the center roughly from the upper left to the lower right, and they vary in how stretched out they are and where the first dot begins.



In the experiment, people were shown version after version of squares with dot patterns in them, each of them different. The participants weren't told how these dot patterns had been constructed. Here's the clever part: Posner and Keele showed people the descendants (like the ones on the bottom row) and didn't show them the parents (like the one on the upper left, the parent). A week later the same people came back in and saw a bunch of dot patterns, some old and some new, and simply had to indicate which ones they'd seen before. Although the participants didn't know this, some of the "new" patterns were actually the parents, the prototypes used to generate the other dot patterns. If people are storing the exact details of the figures—if their memories are like video recordings—this task would be easy. On the other hand, if what we store in memory is an abstract, generalized version of objects, people ought to recall seeing the parent even if they hadn't—it constitutes an abstract generalization of the children that were created from it. That's exactly what they found.

As we age, our brains become better and better at this kind of pattern matching and abstraction, and although dot patterns seem pretty far removed from anything of real-world importance, the experiment illuminates that abstraction occurs without our conscious awareness, and it accounts for one of the most widespread traits that oldsters have: wisdom. From a neurocognitive standpoint, wisdom is the ability to see patterns where others don't see them, to extract generalized common points from prior experience and use those to make predictions about what is likely to happen next. Oldsters aren't as fast, perhaps, at mental calculations and retrieving names, but they are much better and faster at seeing the big picture. And that comes down to decades of generalization and abstraction.

Now, you might object and say that you have very precise memories for *particular* objects. You'd recognize if someone switched your wedding ring on you. You know the feel of your favorite pair of shoes. If you have a fancy pen that someone gave you as a gift, you would be sad if you lost it. But if you lost a ten-cent Bic disposable pen, you probably would just reach into your drawer and take out another because they're interchangeable, which is just another way of saying you've generalized them. If you've ever tried to take away the favorite fuzzy blanket from a young child, replacing the frayed, worn, and tattered one with a

brand-new one, you know that they freak out—to them a blanket is not just a blanket and they don't generalize: This particular blanket is *their* special blanket.

In most cases of generalization, it's not that we can't *notice* the difference between this pen and that pen if we were asked to study them, nor is it necessarily that we can't remember differences—it's just that we don't need to. Our memory systems strive to be efficient in the service of not cluttering our minds with unnecessary detail.

Again, we see individual differences in how we generalize. To Lew Goldberg, a car is a car is a car. Its only value is in getting you from one place to another. He doesn't understand people who collect cars or who have more than one. "Why would you want to have two cars?" he would ask. "It would be like having two dishwashers." He sees the world of objects transactionally, with little sentimentality or interest in their differences. He does not seem to see the irony that someone whose lifework is studying individual differences in human beings has little interest in the individual differences in human-made objects. He does get excited at the individual differences he finds in nature, between trees, mountains, lakes, rocks, and sunsets. He's just not a manufactured-objects guy.

Some people do have obsessions with objects in their lives—a favorite pair of boots that you wear way beyond the time when they should probably have been replaced; a favorite sofa that long ago needed re-covering. In cases like these, it's not that we fail to generalize; it's that the objects have taken on a special, personal meaning beyond their utility, a sentimentality. And they've activated a privileged circuit in memory.

Generalization promotes cognitive economy, so that we don't focus on particulars that don't matter. The great Russian neuropsychologist Alexander Luria studied a patient, Solomon Shereshevsky, with a memory impairment that was the opposite of what we usually hear about—Solomon didn't have amnesia, the loss of memories; he had what Luria called hypermnesia (we might say that his superpower was superior memory). His supercharged memory allowed him to perform amazing feats, such as repeating speeches word for word that he had heard only once, or complex mathematical formulas, long sequences of numbers, and poems in foreign languages he didn't even speak. Before you think that having such a fantastic memory would be great, it came with a cost: Solomon wasn't able to form abstractions because he remembered every detail as distinct. He had particular trouble recognizing people. From a neurocognitive standpoint, every time you see a face, it is likely that it looks at least slightly different from the last time—you're viewing it at a different angle and distance than before, and you might be encountering a different expression. While you're interacting with a person, their face goes through a parade of expressions. Because your brain can generalize, you see all of these different manifestations of the face as belonging to the same person. Solomon couldn't do that. As he explained to Luria, recognizing his friends and colleagues was nearly impossible because "everyone has so many faces."

Memory Systems

The recognition that memory is not one thing, but many different things, has been one of the most important discoveries in neuroscience. Each is influenced by different variables, governed by different principles, stores different kinds of information, and is supported by different neural circuits. And some of these systems are more robust than others, allowing us to preserve accurate memories for a lifetime, whereas others are more fickle, more affected by emotion, and are inconstant.

Remember that evolution happens in fits and starts; it doesn't start out with a plan or goal. After hundreds of thousands of years of brain evolution, we don't end up with the kind of neat-and-tidy system we would have if everything had been engineered from the start. It's likely that the different human memory systems we have today followed separate evolutionary trajectories, as they addressed distinct adaptive problems. So we end up today with one memory system that keeps track of where you are in the world (spatial memory), another that keeps track of which way you turn a faucet on and off (procedural memory), and another that keeps track of what you were just thinking thirty seconds ago (short-term memory). Those age-related memory lapses start to make sense as we see that they tend to affect one memory system but not another.

Our memory systems form a hierarchy. At the highest level are explicit memory and implicit memory. They contain what they sound like—explicit memory contains your conscious recollections of experiences and facts; implicit memory contains things that you know without your being aware of knowing them.

An example of implicit memory is knowing how to perform a complex sequence of actions, such as touch-typing or playing a memorized song on the piano. Normally, we can't break these down into their subcomponents, the conscious movements of each finger—they are bound together as a bundled sequence in our memories. Even more implicit is conditioning, such as salivating when you open a jar of pickles, or showing aversion to the smell of a food that previously made you sick—you may not be conscious of this, but your body remembers.

Explicit memory comes in two broad types, reflecting two different neurological systems. One of these is general knowledge—your memory of facts and word definitions. The other is episodic knowledge—your memory of specific episodes in your life, often autobiographical. Scientists call the memory for general knowledge *semantic memory* and the memory for the specific episodes in your life *episodic memory*. (I think they got the name right for *episodic memory,* but the term *semantic memory* has always bothered me because I find it less descriptive. I prefer to think of it as generalized memory, but at this point we're stuck with the name.)

Semantic memory, your general knowledge store, is all those things that you know without any memory of when you actually learned them. This would be things like knowing the capital of California, your birthday, even your times tables ($3 \times 1 = 3$; $3 \times 2 = 6$; $3 \times 3 = 9$; etc.).

In contrast, episodic memory is all those things you know that involve a particular incident or episode. This would be things like remembering your first kiss, your twenty-first birthday party, or what time you woke up this morning. These events happened to you, and you remember the instance of them and the *you* in them. That's what distinguishes them from semantic memories—they have an autobiographical component. Do you remember when you learned that $4 + 3 = 7$, or when you learned your birth date? Probably not. These are things that you *just know,* so they're your semantic memories.

Of course there are variations across people, and exceptions. I was talking about the different types of memory with my friend Felix last year, when he was age nine. By way of demonstration, I asked if he knew what the capital of California was. He said, "Yes, it's Sacramento." I then asked if he remembered when he learned it. He said, "Yes." I slightly skeptically asked if he remembered the actual day that he learned it, assuming he meant that he learned it last year in school or some other general time. He said yes, he remembered the actual day. I asked what day that was. He answered, "Today." So for Felix, the capital of California was an episodic memory, not a semantic one. It might even stay that way for him,

since all of us—my wife and I and Felix and his parents—got a laugh out of how suddenly a college professor was bested by a nine-year-old. A detail that would normally fade into obscurity in the annals of Felix's brain might become elevated to a kind of special status because emotions were attached to it. This is one of the rules of memory that is now well established: We tend to remember best the episodic component of those things that were imprinted with an emotional resonance, positive or negative, regardless of whether the learning would have normally become *semantic* or *episodic*.

But for most people, such episodic memories as this—ones that involve information literacy and general knowledge—become semantic memories over time, and the specific moment of learning becomes lost.

Think how overwhelming it would be if you remembered not just the meaning of every word you knew, and your whole treasure trove of basic knowledge about the world (What continent is Portugal in? Who was born first, Beethoven or Mozart? Who wrote *War and Peace*?), *and* you also remembered exactly when and how you learned it. The brain evolved efficiencies to jettison this (normally) unnecessary contextual information, selectively retaining the parts of the knowledge that are likely to come in most handy—the facts. Some people, however, including some with autism spectrum disorders, don't do this jettisoning and retain all of the details, and it can be either a source of comfort and success for them or a source of irritation and debilitation.

There are some gray areas. Memory for things such as an allergy to ragweed, or your favorite cut of steak, may be semantic—just something you know—or they may be episodic, in that it's possible that you recall the specific instances involved, the time and place, and conjure them up in memory; for example, the very moment you realized, after swelling like a puffer fish with an allergic reaction, that you can't brush your bare skin against ragweed on a hike. The biological distinction is that different parts of the brain hold semantic memories versus episodic ones, and this is a critical step toward understanding why memory failure tends to happen to one system rather than the whole of memory—it's because memory is not just one thing, but several.

Two particular brain regions, crucial to some kinds of memory, are the ones that decay and shrink with age and with Alzheimer's disease: They are the hippocampus (Greek for *seahorse,* because its curved shape resembles that sea creature) and the medial temporal lobe (neurology-speak for the middle part of a structure just behind and above your ears). The hippocampus and medial temporal lobe are important for forming some of the kinds of explicit memory, and they're not needed for implicit memory. This is why eighty-eight-year-old Aunt Marge, lost in a fog of amnesia-induced disorientation, cannot remember you, where she is, or what year it is but still knows how to use a fork, adjust the television station, read, and is excited to see appetizing food, all forms of implicit memory. The impaired brain structures affect her explicit memory but not her implicit memory.

The hippocampus is also necessary for storing spatial navigation and memory for places. Damage to this and to associated temporal lobe regions, as often happens with age, can lead to disorientation and getting lost. In most cases, it doesn't shrink or decay all at once, and so patients are left with fragmented spatial memories, wandering around, registering some landmarks and familiar sights but not able to string them all together into a meaningful mental map.

All of what I've been talking about to this point applies to long-term memory—that more-or-less durable storehouse of memories that can last a lifetime. Short-term memory is another animal entirely. It contains the contents of your thoughts right now and maybe for a few seconds after. If you're doing some mental arithmetic, thinking about what you'll say

next day it turns on you, biting you and your sister and making off with that piece of meat that was roasting on the fire. If your memory dwells on the earlier, more pleasant time, you might make the same mistake. Better for you to rewrite your memory of the jackal as an unpredictable predator, not to be taken lightly. (Dogs won us over, but it was a slow process.)

Autobiographical memory is perhaps the system that is most closely associated with your sense of self, of who you are and what experiences shaped you. The autobiographical memory system informs your life choices in important ways. Without it, you wouldn't know if you are capable of hiking for two hours, if you can eat food with peanuts in it, or whether or not you're married.

And yet, the autobiographical memory system is prone to huge distortions. It's a goal-oriented system. It recalls information that is consistent with your goals or perspective. We all tend to recontextualize our own life stories and the memories that formed them, based on the stories we tell ourselves or others tell us. Our original memories become corrupted, in effect, to conform to the more compelling narrative.

We also do a lot of filling in based on logical inferences. I don't have many specific memories of the last time I visited London, but using my semantic memory, my general knowledge of London travel, I assume I took the Tube, that it was gray-skied, that I was jet-lagged, and that I drank especially good tea. Because I can easily picture myself riding the Tube from all the times that I have over the last forty years, that image can become grafted into my autobiographical memory for the most recent trip to London, and before I know it, I have a "memory" of riding the Tube last year that isn't really my memory—it's an editorial insertion, and we're usually not aware that we're doing it.

Memories can also be affected and rewritten by the mood you're in. Suppose you're in a grumpy, irritable mood—maybe because you've just arrived in Los Angeles from London (with its great public transit), and you are fed up with the lousy public transit system in LA. To cheer yourself up you recall a time walking in Griffith Park with a friend that ordinarily is a happy memory. But your current mood state can cause a reevaluation of that as a less happy time—instead of focusing on the great walk, you conjure up the memory of all the traffic on the way there, the difficulty you had parking. All this rewrites the extracted memory before it gets put back in the storage locker of your brain, so that the next time you retrieve the memory, it is no longer as happy as it was before.

There is a famous case of mass memory rewriting involving the attacks on the Twin Towers of the World Trade Center in New York City on September 11, 2001. You'll notice that it conceptually parallels the story I described about finding a new freshwater spring.

Eighty percent of Americans say that they remember watching the horrifying television images of an airplane crashing into the first tower (the North Tower), and then, about twenty minutes later, the image of a second plane crashing into the second tower (the South Tower). But it turns out this memory is completely false! The television networks broadcast real-time video of the South Tower collision on September 11, but video of the North Tower collision wasn't discovered until the next day and didn't appear on broadcast television until then, on September 12. Millions of Americans saw the videos out of sequence, seeing the video of the South Tower impact twenty-four hours earlier than the video of the North Tower impact. But the narrative we were told and knew to be true, that the North Tower was hit about twenty minutes *before* the South Tower, causes the memory to stitch together the sequence of events *as they happened,* not as we experienced them. This caused a false memory so compelling that even President George W. Bush falsely recalled seeing the North Tower collapse on September 11, although television archives show this to be impossible.

And so a huge misunderstanding that most of us have about our personal memories is that they are accurate. We think it because some of them *feel* accurate; they *feel* as though they are like video recordings of things that happened to us, and that they haven't been tampered with. And that's because our brains present them to us that way.

Another way that our memories are defective is that we often store only bits and pieces of events or facts, and then our brains fill in the missing pieces based on logical guesses. Again, our brains do this so often that we don't even notice that they're doing it. So much of our mental activity has gaps in it. Speech sounds may be obscured by noise, your view of something may be occluded by other objects, not to mention your momentary view of the world being interrupted, on average, fifteen times a minute by blinking. The brain mixes up—confabulates—what it really knows with what it infers, and doesn't often make a meaningful distinction between the two.

When we age, we begin to confabulate more, as our brains slow down and the millions of memories we hold begin to compete with one another for primacy in our recollection, creating an information bottleneck. We all have, etched in our minds as true, things that never happened, or are combinations of separate things that did.

Confabulation shows up particularly vividly in people who have had a stroke or other brain injury and are having trouble piecing fragmented memories together. Neuroscientist Michael Gazzaniga has written about this as a lesson in lateralization—the idea that the left and right hemispheres perform some distinct functions. (If you're right-handed, confabulation takes place in your left hemisphere. If you're left-handed, the confabulation could be taking place in either hemisphere—lefties have a less predictable lateralization of brain function than righties do.)

Gazzaniga tells the story of a patient who was in the hospital after a right-hemisphere stroke but had no memory of what brought her there—she was convinced that the hospital was her home. When Gazzaniga challenged her by asking about the elevators just outside her room, she said, "Doctor, do you have any idea how much it cost me to have those put in?" That's the left hemisphere confabulating, making things up, in order to keep a coherent story that fits with the rest of our thoughts and memories. She had no memory of being brought to the hospital, and no ability to process this new information, and so, as far as her left hemisphere was concerned, she was still at home.

Think about the last children's birthday party you were at, and try to remember as many details as you can—walk through the sequence of events in your mind. This is what an attorney might ask you to do at a trial if you were a witness. You might remember things like whether the attendees played pin the tail on the donkey, whether there was cake, whether the birthday kid opened all the presents in front of everyone or decided to do that later. But other details may be lost—whether there was a trampoline in the backyard, whether the other kids were given party favors. Other people and photographs might remind you of things, and those help to trigger some memories.

But still there are gaps. How many different kinds of beverages were served? If you were a bartender or ran a catering company you might have noticed; otherwise not. What color temperature was the light bulb in the bathroom? If you were in the lighting business you might have noted whether it was cool white or warm white or daylight or yellowish. But otherwise, probably not. Memory is filtered by your own interests and expertise. Other gaps: Did the lights in the living room flicker at one point? The insurance investigator wants to know because there was an electrical fire the next day. I suppose that they could have flickered, you think. Yes, now that I think about it, they did. I distinctly remember it. I can *picture* it happening. But there *were* no lights on in the living room—the fuse had previously

blown. Your memory's not as reliable as you think, is it? Once you've lived awhile, and collected a number of experiences, it's quite easy to *imagine* things happening the way they're described, and these imaginings become grafted on your memories. Trial attorneys know this and use it as a way to make juries doubt a witness's testimony. Human memory makes logical inferences from the available information, and it delivers them to you with a potent mix of fact and confabulatory fiction.

I had surgery a few years ago and spent several days in bed on pain-killing opioids. They left me a bit disoriented, to say the least. I couldn't remember what day of the week it was, or even what month it was. I recall looking out the window and seeing garbage trucks. Ah! It must be Monday, garbage day. My semantic memory of garbage day was intact, even if my awareness of the day of the week was compromised. I saw that lettuce and onions in the vegetable garden outside were just getting started—in Los Angeles, that means it must be February. I could answer the kinds of questions that doctors ask in order to get a read on your cognitive state, without actually knowing the answers, but by inferring them from my surroundings.

A friend suffered a stroke and is now making these kinds of inferences all the time, masking her inabilities and confounding her doctors. She was a woman with great dignity and independence before the stroke, and these kinds of questions make her feel trapped. When the two of us were alone, I asked her what year it was and I saw that she surreptitiously glanced at a magazine on her table and used that date. I asked her the time of day, and seeing the crust of a sandwich on a plate nearby, she guessed "early afternoon." I asked who the president was and she said she didn't know but could probably figure it out. That seemed unlikely to me, and I didn't want to embarrass her, so I dropped it.

So is your autobiographical memory accurate? Are any of our memory systems? Yes and no. Our memory for perceptual details can be strikingly accurate, particularly in domains we care about. I knew a housepainter in Oregon, Matthew Parrott, who could walk into a house and identify the finish (flat, eggshell, satin, semigloss, or high-gloss), the brand (Benjamin Moore, Sherwin-Williams, Pratt and Lambert, Glidden), and often the precise shade of white, just by looking at the walls. And he could study the texture on the drywall and infer how many different "mudders" (drywall texture contractors) had worked on the house. "Look here," he said, "notice these swirls—they were done by a left-handed mudder." This was his business and he was especially good at it. (He told me that his father had been in the business before him. "My fadder was a mudder," he said.) A lighting designer might remember particular colors and intensities of bulbs. A musician might know, just by listening, the brand and model of the instrument being played.

I conducted an experiment in 1991 in which I simply asked random college students to sing their favorite song from memory. I compared what they sang to the CD recordings of those songs to see how accurate their musical memories were. The astonishing finding was that most people hit the exact notes, or very near to them. And these were people without musical training. But, of course, if it's your *favorite* song, you probably know it well. This finding contradicted decades of work on memory that showed the great inaccuracies in recollections. So we are left with a bit of a messy picture—memories are astonishingly accurate, except when they aren't. Paul McCartney and George Martin have completely different memories of who played what instrument on something as important as a Beatles album. But fans can sing near-perfect versions of those same Beatles songs.

The way that memories are organized in the brain is mediated by memory tags. No one has ever seen a memory tag in the brain, so at the moment, they are just a theory that helps