Range

How Generalists Triumph in a Specialized World

David Epstein

PAN BOOKS

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And he refused to specialize in anything, preferring to keep an eye on *the overall estate* rather than any of its parts. . . . And Nikolay's management produced the most brilliant results.

—Leo Tolstoy, *War and Peace*

No tool is omnicompetent. There is no such thing as a master-key that will unlock *all* doors.

—Arnold Toynbee, *A Study of History*

INTRODUCTION

Roger vs. Tiger

LET'S START WITH a couple of stories from the world of sports. This first one, you probably know.

The boy's father could tell something was different. At six months old, the boy could balance on his father's palm as he walked through their home. At seven months, his father gave him a putter to fool around with, and the boy dragged it everywhere he went in his little circular baby walker. At ten months, he climbed down from his high chair, trundled over to a golf club that had been cut down to size for him, and imitated the swing he'd been watching in the garage. Because the father couldn't yet talk with his son, he drew pictures to show the boy how to place his hands on the club. "It is very difficult to communicate how to putt when the child is too young to talk," he would later note.

At two—an age when the Centers for Disease Control and Prevention list physical developmental milestones like "kicks a ball" and "stands on tiptoe"—he went on national television and used a club tall enough to reach his shoulder to drive a ball past an admiring Bob Hope. That same year, he entered his first tournament, and won the ten-and-under division.

There was no time to waste. By three, the boy was learning how to play out of a "sand twap," and his father was mapping out his destiny. He knew his son had been chosen for this, and that it was his duty to guide him. Think about it: if you felt that certain about the path ahead, maybe you too would start prepping your three-year-old to handle the inevitable and insatiable media that would come. He quizzed the boy, playing reporter, teaching him how to give curt answers, never to offer more than precisely what was asked. That year, the boy shot 48, eleven over par, for nine holes at a course in California.

When the boy was four, his father could drop him off at a golf course at nine in the morning and pick him up eight hours later, sometimes with the money he'd won from those foolish enough to doubt.

At eight, the son beat his father for the first time. The father didn't mind, because he was convinced that his boy was singularly talented, and that he was uniquely equipped to help him. He had been an outstanding athlete himself, and against enormous odds. He played baseball in college when he was the only black player in the entire conference. He understood people, and discipline; a sociology major, he served in Vietnam as a member of the Army's elite Green Berets, and later taught psychological warfare to future officers. He knew he hadn't done his best with three kids from a previous marriage, but now he could see that he'd been given a second chance to do the right thing with number four. And it was all going according to plan.

The boy was already famous by the time he reached Stanford, and soon his father opened up about his importance. His son would have a larger impact than Nelson Mandela, than Gandhi, than Buddha, he insisted. "He has a larger forum than any of them," he said. "He's the bridge between the East and the West. There is no limit because he has the guidance. I don't know yet exactly what form this will take. But he is the Chosen One."

This second story, you also probably know. You might not recognize it at first.

His mom was a coach, but she never coached him. He would kick a ball around with her when he learned to walk. As a boy, he played squash with his father on Sundays. He dabbled in skiing, wrestling, swimming, and skateboarding. He played basketball, handball, tennis, table tennis, badminton over his neighbor's fence, and soccer at school. He would later give credit to the wide range of sports he played for helping him develop his athleticism and hand-eye coordination.

He found that the sport really didn't matter much, so long as it included a ball. "I was always very much more interested if a ball was involved," he would remember. He was a kid who loved to play. His parents had no particular athletic aspirations for him. "We had no plan A, no plan B," his mother would later say. She and the boy's father encouraged him to sample a wide array of sports. In fact, it was essential. The boy "became unbearable," his mother said, if he had to stay still for too long.

Though his mother taught tennis, she decided against working with him. "He would have just upset me anyway," she said. "He tried out every strange stroke and certainly never returned a ball normally. That is simply no fun for a mother." Rather than pushy, a *Sports Illustrated* writer would observe that his parents were, if anything, "pully." Nearing his teens, the boy began to gravitate more toward tennis, and "if they nudged him at all, it was to stop taking tennis so seriously." When he played matches, his mother often wandered away to chat with friends. His father had only one rule: "Just don't cheat." He didn't, and he started getting really good.

As a teenager, he was good enough to warrant an interview with the local newspaper. His mother was appalled to read that, when asked what he would buy with a hypothetical first paycheck from playing tennis, her son answered, "a Mercedes." She was relieved when the reporter let her listen to a recording of the interview and they realized there'd been a mistake: the boy had said "*Mehr CDs*," in Swiss German. He simply wanted "more CDs."

The boy was competitive, no doubt. But when his tennis instructors decided to move him up to a group with older players, he asked to move back so he could stay with his friends. After all, part of the fun was hanging around after his lessons to gab about music, or pro wrestling, or soccer.

By the time he finally gave up other sports—soccer, most notably—to focus on tennis, other kids had long since been working with strength coaches, sports psychologists, and nutritionists. But it didn't seem to hamper his development in the long run. In his midthirties, an age by which even legendary tennis players are typically retired, he would still be ranked number one in the world.

In 2006, Tiger Woods and Roger Federer met for the first time, when both were at the apex of their powers. Tiger flew in on his private jet to watch the final of the U.S. Open. It made Federer especially nervous, but he still won, for the third year in a row. Woods joined him in the locker room for a champagne celebration. They connected as only they could. "I've never spoken with anybody who was so familiar with the feeling of being invincible," Federer would later describe it. They quickly became friends, as well as focal points of a debate over who was the most dominant athlete in the world.

Still, the contrast was not lost on Federer. "His story is completely different from mine," he told a biographer in 2006. "Even as a kid his goal was to break the record for winning the most majors. I was just dreaming of just once meeting Boris Becker or being able to play at Wimbledon some time."

It seems pretty unusual for a child with "pully" parents, and who first took his sport lightly, to grow into a man who dominates it like no one before him. Unlike Tiger, thousands of kids, at least, had a head start on Roger. Tiger's incredible upbringing has been at the heart of a batch of bestselling books on the development of expertise, one of which was a parenting manual written by Tiger's father, Earl. Tiger was not merely playing golf. He was engaging in "deliberate practice," the only kind that counts in the now-ubiquitous ten-thousand-hours rule to expertise. The "rule" represents the idea that the number of accumulated hours of highly specialized training is the sole factor in skill development, no matter the domain. Deliberate practice, according to the study of thirty violinists that spawned the rule, occurs when learners are "given explicit instructions about the best method," individually supervised by an instructor, supplied with "immediate informative feedback and knowledge of the results of their performance," and "repeatedly perform the same or similar tasks." Reams of work on expertise development shows that elite athletes spend more time in highly technical, deliberate practice each week than those who plateau at lower levels:

Tiger has come to symbolize the idea that the quantity of deliberate practice determines success—and its corollary, that the practice must start as early as possible.

The push to focus early and narrowly extends well beyond sports. We are often taught that the more competitive and complicated the world gets, the more specialized we all must become (and the earlier we must start) to navigate it. Our best-known icons of success are elevated for their precocity and their head starts—Mozart at the keyboard, Facebook CEO Mark Zuckerberg at the other kind of keyboard. The response, in every field, to a ballooning library of human knowledge and an interconnected world has been to exalt increasingly narrow focus. Oncologists no longer specialize in cancer, but rather in cancer related to a single organ, and the trend advances each year. Surgeon and writer Atul Gawande pointed out that when doctors joke about left ear surgeons, “we have to check to be sure they don’t exist.”

In the ten-thousand-hours-themed bestseller *Bounce*, British journalist Matthew Syed suggested that the British government was failing for a lack of following the Tiger Woods path of unwavering specialization. Moving high-ranking government officials between departments, he wrote, “is no less absurd than rotating Tiger Woods from golf to baseball to football to hockey.”

Except that Great Britain’s massive success at recent Summer Olympics, after decades of middling performances, was bolstered by programs set up specifically to recruit adults to try new sports and to create a pipeline for late developers—“slow bakers,” as one of the officials behind the program described them to me. Apparently the idea of an athlete, even one who wants to become elite, following a Roger path and trying different sports is not so absurd. Elite athletes at the peak of their abilities do spend more time on focused, deliberate practice than their near-elite peers. But when scientists examine the entire developmental path of athletes, from early childhood, it looks like this:

Eventual elites typically devote *less* time early on to deliberate practice in the activity in which they will eventually become experts. Instead, they undergo what researchers call a “sampling period.” They play a variety of sports, usually in an unstructured or lightly structured environment; they gain a range of physical proficiencies from which they can draw; they learn about their own abilities and proclivities; and only later do they focus in and ramp up technical practice in one area. The title of one study of athletes in individual sports proclaimed "Late Specialization" as "the Key to Success"; another, "Making It to the Top in Team Sports: Start Later, Intensify, and Be Determined."

When I began to write about these studies, I was met with thoughtful criticism, but also denial. "Maybe in some other sport," fans often said, "but that's not true of *our* sport." The community of the world's most popular sport, soccer, was the loudest. And then, as if on cue, in late 2014 a team of German scientists published a study showing that members of their national team, which had just won the World Cup, were typically late specializers who didn't play more organized soccer than amateur-league players until age twenty-two or later. They spent more of their childhood and adolescence playing nonorganized soccer and other sports. Another soccer study published two years later matched players for skill at age eleven and tracked them for two years. Those who participated in more sports and nonorganized soccer, "but not more organized soccer practice/ training," improved more by age thirteen. Findings like these have now been echoed in a huge array of sports, from hockey to volleyball.

The professed necessity of hyperspecialization forms the core of a vast, successful, and sometimes well-meaning marketing machine, in sports and beyond. In reality, the Roger path to sports stardom is far more prevalent than the Tiger path, but those athletes' stories are much more quietly told, if they are told at all. Some of their names you know, but their backgrounds you probably don't.

I started writing this introduction right after the 2018 Super Bowl, in which a quarterback who had been drafted into professional baseball before football (Tom Brady), faced off against one who participated in football, basketball, baseball, and karate and had chosen between college basketball and football (Nick

Foles). Later that very same month, Czech athlete Ester Ledecká became the first woman ever to win gold in two different sports (skiing and snowboarding) at the same Winter Olympics. When she was younger, Ledecká participated in multiple sports (she still plays beach volleyball and windsurfs), focused on school, and never rushed to be number one in teenage competition categories. The *Washington Post* article the day after her second gold proclaimed, “In an era of sports specialization, Ledecká has been an evangelist for maintaining variety.” Just after her feat, Ukrainian boxer Vasyl Lomachenko set a record for the fewest fights needed to win world titles in three different weight classes. Lomachenko, who took four years off boxing as a kid to learn traditional Ukrainian dance, reflected, “I was doing so many different sports as a young boy—gymnastics, basketball, football, tennis—and I think, ultimately, everything came together with all those different kinds of sports to enhance my footwork.”

Prominent sports scientist Ross Tucker summed up research in the field simply: “We know that early sampling is key, as is diversity.”

In 2014, I included some of the findings about late specialization in sports in the afterword of my first book, *The Sports Gene*. The following year, I got an invitation to talk about that research from an unlikely audience—not athletes or coaches, but military veterans. In preparation, I perused scientific journals for work on specialization and career-swerving outside of the sports world. I was struck by what I found. One study showed that early career specializers jumped out to an earnings lead after college, but that later specializers made up for the head start by finding work that better fit their skills and personalities. I found a raft of studies that showed how technological inventors increased their creative impact by accumulating experience in different domains, compared to peers who drilled more deeply into one; they actually benefited by proactively sacrificing a modicum of depth for breadth as their careers progressed. There was a nearly identical finding in a study of artistic creators.

I also began to realize that some of the people whose work I deeply admired from afar—from Duke Ellington (who shunned music lessons to focus on drawing and baseball as a kid) to Maryam Mirzakhani (who dreamed of becoming a novelist and instead became the first woman to win math's most famous prize, the Fields Medal)—seemed to have more Roger than Tiger in their development stories. I delved further and encountered remarkable individuals who succeeded not in spite of their range of experiences and interests, but because of it: a CEO who took her first job around the time her peers were getting ready to retire; an artist who cycled through five careers before he discovered his vocation and changed the world; an inventor who stuck to a self-made antispecialization philosophy and turned a small company founded in the nineteenth century into one of the most widely resonant names in the world today.

I had only dipped my toe into research on specialization in the wider world of work, so in my talk to the small group of military veterans I mostly stuck to sports. I touched on the other findings only briefly, but the audience seized on it. All were late specializers or career changers, and as they filed up one after another to introduce themselves after the talk, I could tell that all were at least moderately concerned, and some were borderline ashamed of it.

They had been brought together by the Pat Tillman Foundation, which, in the spirit of the late NFL player who left a professional football career to become an Army Ranger, provides scholarships to veterans, active-duty military, and military spouses who are undergoing career changes or going back to school. They were all scholarship recipients, former paratroopers and translators who were becoming teachers, scientists, engineers, and entrepreneurs. They brimmed with enthusiasm, but rippled with an undercurrent of fear. Their LinkedIn profiles didn't show the linear progression toward a particular career they had been told employers wanted. They were anxious starting grad school alongside younger (sometimes much younger) students, or changing lanes later than their peers, all because they had been busy accumulating inimitable life and leadership experiences. Somehow, a unique advantage had morphed in their heads into a liability.

A few days after I spoke to the Tillman Foundation group, a former Navy SEAL who came up after the talk emailed me: "We are all transitioning from one career to another. Several of us got together after you had left and discussed how relieved we were to have heard you speak." I was slightly bemused to find that a former Navy SEAL with an undergraduate degree in history and geophysics pursuing graduate degrees in business and public administration from Dartmouth and Harvard could feel behind. But like the others in the room, he had been told, implicitly or explicitly, that changing directions was dangerous.

The talk was greeted with so much enthusiasm that the foundation invited me to give a keynote speech at the annual conference in 2016, and then to small group gatherings in different cities. Before each occasion, I read more studies and spoke with more researchers and found more evidence that it takes time—and often forgoing a head start—to develop personal and professional range, but it is worth it.

I dove into work showing that highly credentialed experts can become so narrow-minded that they actually get worse with experience, even while becoming more confident—a dangerous combination. And I was stunned when cognitive psychologists I spoke with led me to an enormous and too often ignored body of work demonstrating that learning itself is best done slowly to accumulate lasting knowledge, even when that means performing poorly on tests of immediate progress. That is, the most effective learning looks inefficient; it looks like falling behind.

Starting something new in middle age might look that way too. Mark Zuckerberg famously noted that "young people are just smarter." And yet a tech founder who is fifty years old is nearly twice as likely to start a blockbuster company as one who is thirty, and the thirty-year-old has a better shot than a twenty-year-old. Researchers at Northwestern, MIT, and the U.S. Census Bureau studied new tech companies and showed that among the fastest-growing start-ups, the average age of a founder was forty-five when the company was launched.

Zuckerberg was twenty-two when he said that. It was in his interest to broadcast that message, just as it is in the interest of people who run youth sports leagues to claim that year-round devotion to one activity is necessary for success, never mind evidence to the contrary. But the drive to specialize goes beyond that. It infects not just individuals, but entire systems, as each specialized group sees a smaller and smaller part of a large puzzle.

One revelation in the aftermath of the 2008 global financial crisis was the degree of segregation within big banks. Legions of specialized groups optimizing risk for their own tiny pieces of the big picture created a catastrophic whole. To make matters worse, responses to the crisis betrayed a dizzying degree of specialization-induced perversity. A federal program launched in 2009 incentivized banks to lower monthly mortgage payments for homeowners who were struggling but still able to make partial payments. A nice idea, but here's how it worked out in practice: a bank arm that specialized in mortgage lending started the homeowner on lower payments; an arm of the same bank that specialized in foreclosures then noticed that the homeowner was suddenly paying less, declared them in default, and seized the home. "No one imagined silos like that inside banks," a government adviser said later. Overspecialization can lead to collective tragedy even when every individual separately takes the most reasonable course of action.

Highly specialized health care professionals have developed their own versions of the "if all you have is a hammer, everything looks like a nail" problem. Interventional cardiologists have gotten so used to treating chest pain with stents—metal tubes that pry open blood vessels—that they do so reflexively even in cases where voluminous research has proven that they are inappropriate or dangerous. A recent study found that cardiac patients were actually less likely to die if they were admitted during a national cardiology meeting, when thousands of cardiologists were away; the researchers suggested it could be because common treatments of dubious effect were less likely to be performed.

An internationally renowned scientist (whom you will meet toward the end of this book) told me that increasing specialization has created a "system of parallel trenches" in the quest for innovation. Everyone is digging deeper into their own trench and rarely standing up to look in the next trench over, even though the solution to their problem happens to reside there. The scientist is taking it upon himself to attempt to despecialize the training of future researchers; he hopes that eventually it will spread to training in every field. He profited immensely from cultivating range in his own life, even as he was pushed to specialize. And now he is broadening his purview again, designing a training program in an attempt to give others a chance to deviate from the Tiger path. "This may be the most important thing I will ever do in my life," he told me.

I hope this book helps you understand why.

When the Tillman Scholars spoke of feeling unmoored, and worried they were making a mistake, I understood better than I let on. I was working on a scientific research vessel in the Pacific

Ocean after college when I decided for sure that I wanted to be a writer, not a scientist. I never expected that my path from science into writing would go through work as the overnight crime reporter at a New York City tabloid, nor that I would shortly thereafter be a senior writer at *Sports Illustrated,* a job that, to my own surprise, I would soon leave. I began worrying that I was a job-commitment-phobic drifter who must be doing this whole career thing wrong. Learning about the advantages of breadth and delayed specialization has changed the way I see myself and the world. The research pertains to every stage of life, from the development of children in math, music, and sports, to students fresh out of college trying to find their way, to midcareer professionals in need of a change and would-be retirees looking for a new vocation after moving on from their previous one.

The challenge we all face is how to maintain the benefits of breadth, diverse experience, interdisciplinary thinking, and delayed concentration in a world that increasingly incentivizes, even demands, hyperspecialization. While it is undoubtedly true that there are areas that require individuals with Tiger's precocity and clarity of purpose, as complexity increases—as technology spins the world into vaster webs of interconnected systems in which each individual only sees a small part—we also need more Rogers: people who start broad and embrace diverse experiences and perspectives while they progress. People with range.

CHAPTER 1

The Cult of the Head Start

ONE YEAR AND FOUR DAYS after World War II in Europe ended in unconditional surrender, Laszlo Polgar was born in a small town in Hungary—the seed of a new family. He had no grandmothers, no grandfathers, and no cousins; all had been wiped out in the Holocaust, along with his father's first wife and five children. Laszlo grew up determined to have a family, and a special one.

He prepped for fatherhood in college by poring over biographies of legendary thinkers, from Socrates to Einstein. He decided that traditional education was broken, and that he could make his own children into geniuses, if he just gave them the right head start. By doing so, he would prove something far greater: that any child can be molded for eminence in any discipline. He just needed a wife who would go along with the plan.

Laszlo's mother had a friend, and the friend had a daughter, Klara. In 1965, Klara traveled to Budapest, where she met Laszlo in person. Laszlo didn't play hard to get; he spent the first visit telling Klara that he planned to have six children and that he would nurture them to brilliance. Klara returned home to her parents with a lukewarm review: she had "met a very interesting person," but could not imagine marrying him.

They continued to exchange letters. They were both teachers and agreed that the school system was frustratingly one-size-fitsall, made for producing "the gray average mass," as Laszlo put it. A year and a half of letters later, Klara realized she had a very special pen pal. Laszlo finally wrote a love letter, and proposed at the end. They married, moved to Budapest, and got to work. Susan was born in early 1969, and the experiment was on.

For his first genius, Laszlo picked chess. In 1972, the year before Susan started training, American Bobby Fischer defeated Russian Boris Spassky in the "Match of the Century." It was considered a Cold War proxy in both hemispheres, and chess was suddenly pop culture. Plus, according to Klara, the game had a distinct benefit: "Chess is very objective and easy to measure." Win, lose, or draw, and a point system measures skill against the rest of the chess world. His daughter, Laszlo decided, would become a chess champion.

Laszlo was patient, and meticulous. He started Susan with "pawn wars." Pawns only, and the first person to advance to the back row wins. Soon, Susan was studying endgames and opening traps. She enjoyed the game and caught on quickly. After eight months of study, Laszlo took her to a smoky chess club in Budapest and challenged grown men to play his four-year-old daughter, whose legs dangled from her chair. Susan won her first game, and the man she beat stormed off. She entered the Budapest girls' championship and won the under-eleven title. At age four she had not lost a game.

By six, Susan could read and write and was years ahead of her grade peers in math. Laszlo and Klara decided they would educate her at home and keep the day open for chess. The Hungarian police threatened to throw Laszlo in jail if he did not send his daughter to the compulsory school system. It took him months of lobbying the Ministry of Education to gain permission. Susan's new little sister, Sofia, would be homeschooled too, as would Judit, who was coming soon, and whom Laszlo and Klara almost named Zseni, Hungarian for "genius." All three became part of the grand experiment.

On a normal day, the girls were at the gym by 7 a.m. playing table tennis with trainers, and then back home at 10:00 for breakfast, before a long day of chess. When Laszlo reached the limit of his expertise, he hired coaches for his three geniuses in training. He spent his extra time cutting two hundred thousand records of game sequences from chess journals—many offering a preview of potential opponents—and filing them in a custom card catalog, the "cartotech." Before computer chess programs, it gave the Polgars the largest chess database in the world to study outside of—maybe—the Soviet Union's secret archives.

When she was seventeen, Susan became the first woman to qualify for the men's world championship, although the world chess federation did not allow her to participate. (A rule that would soon be changed, thanks to her accomplishments.) Two years later, in 1988, when Sofia was fourteen and Judit twelve, the girls comprised three of the four Hungarian team members for the women's Chess Olympiad. They won, and beat the Soviet Union, which had won eleven of the twelve Olympiads since the event began. The Polgar sisters became "national treasures," as Susan put it. The following year, communism fell, and the girls could compete all over the world. In January 1991, at the age of twenty-one, Susan became the first woman to achieve grandmaster status through tournament play against men. In December, Judit, at fifteen years and five months, became the youngest grandmaster ever, male or female. When Susan was asked on television if she wanted to win the world championship in the men's or women's category, she cleverly responded that she wanted to win the "absolute category."

None of the sisters ultimately reached Laszlo's highest goal of becoming the overall world champion, but all were outstanding. In 1996, Susan participated in the women's world championship, and won. Sofia peaked at the rank of international master, a level down from grandmaster. Judit went furthest, climbing up to eighth in the overall world ranking in 2004.

Laszlo's experiment had worked. It worked so well that in the early 1990s he suggested that if his early specialization approach were applied to a thousand children, humanity could tackle problems like cancer and AIDS. After all, chess was just an arbitrary medium for his universal point. Like the Tiger Woods story, the Polgar story entered an endless pop culture loop in articles, books, TV shows, and talks as an example of the life-hacking power of an early start. An online course called "Bring Up Genius!" advertises lessons in the Polgar method to "build up your own Genius Life Plan." The bestseller *Talent Is Overrated* used the Polgar sisters and Tiger Woods as proof that a head start in deliberate practice is the key to success in "virtually any activity that matters to you."

The powerful lesson is that anything in the world can be conquered in the same way. It relies on one very important, and very unspoken, assumption: that chess and golf are representative examples of all the activities that matter to you.

Just how much of the world, and how many of the things humans want to learn and do, are really like chess and golf?

Psychologist Gary Klein is a pioneer of the "naturalistic decision making" (NDM) model of expertise; NDM researchers observe expert performers in their natural course of work to learn how they make high-stakes decisions under time pressure. Klein has shown that experts in an array of fields are remarkably similar to chess masters in that they instinctively recognize familiar patterns.

When I asked Garry Kasparov, perhaps the greatest chess player in history, to explain his decision process for a move, he told me, "I see a move, a combination, almost instantly," based on patterns he has seen before. Kasparov said he would bet that grandmasters usually make the move that springs to mind in the first few seconds of thought. Klein studied firefighting commanders and estimated that around 80 percent of their decisions are also made instinctively and in seconds. After years of firefighting, they recognize repeating patterns in the behavior of flames and of burning buildings on the verge of collapse. When he studied nonwartime naval commanders who were trying to avoid disasters, like mistaking a commercial flight for an enemy and shooting it down, he saw that they very quickly discerned potential threats. Ninety-five percent of the time, the commanders recognized a common pattern and chose a common course of action that was the first to come to mind.

One of Klein's colleagues, psychologist Daniel Kahneman, studied human decision making from the "heuristics and biases" model of human judgment. His findings could hardly have been more different from Klein's. When Kahneman probed the judgments of highly trained experts, he often found that experience had not helped at all. Even worse, it frequently bred confidence but not skill.

Kahneman included himself in that critique. He first began to doubt the link between experience and expertise in 1955, as a young lieutenant in the psychology unit of the Israel Defense Forces. One of his duties was to assess officer candidates through tests adapted from the British army. In one exercise, teams of eight had to get themselves and a length of telephone pole over a six-foot wall without letting the pole touch the ground, and without any of the soldiers or the pole touching the wall.* The difference in individuals' performances were so stark, with clear leaders, followers, braggarts, and wimps naturally emerging under the stress of the task, that Kahneman and his fellow evaluators grew confident they could analyze the candidates' leadership qualities and identify how they would perform in officer training and in combat. They were completely mistaken. Every few months, they had a "statistics day" where they got feedback on how accurate their predictions had been. Every time, they learned they had done barely better than blind guessing. Every time, they gained experience and gave confident judgments. And every time, they did not improve. Kahneman marveled at the "complete lack of connection between the statistical information and the compelling experience of insight." Around that same time, an influential book on expert judgment was published that Kahneman told me impressed him "enormously." It was a wide-ranging review of research that rocked psychology because it showed experience simply did not create skill in a wide range of real-world scenarios, from college administrators assessing student potential to psychiatrists predicting patient performance to human resources professionals deciding who will succeed in job training. In those domains, which involved human behavior and where patterns did not clearly repeat, repetition did not cause learning. Chess, golf, and firefighting are exceptions, not the rule.

The difference between what Klein and Kahneman documented in experienced professionals comprised a profound conundrum: Do specialists get better with experience, or not?

In 2009, Kahneman and Klein took the unusual step of coauthoring a paper in which they laid out their views and sought common ground. And they found it. Whether or not experience inevitably led to expertise, they agreed, depended entirely on the domain in question. Narrow experience made for better chess and poker players and firefighters, but not for better predictors of financial or political trends, or of how employees or patients would perform. The domains Klein studied, in which instinctive pattern recognition worked powerfully, are what psychologist Robin Hogarth termed "kind" learning environments. Patterns repeat over and over, and feedback is extremely accurate and usually very rapid. In golf or chess, a ball or piece is moved according to rules and within defined boundaries, a consequence is quickly apparent, and similar challenges occur repeatedly. Drive a golf ball, and it either goes too far or not far enough; it slices, hooks, or flies straight. The player observes what happened, attempts to correct the error, tries again, and repeats for years. That is the very definition of deliberate practice, the type identified with both the ten-thousand-hours rule and the rush to early specialization in technical training. The learning environment is kind because a learner improves simply by engaging in the activity and trying to do better. Kahneman was focused on the flip side of kind learning environments; Hogarth called them "wicked."

In wicked domains, the rules of the game are often unclear or incomplete, there may or may not be repetitive patterns and they may not be obvious, and feedback is often delayed, inaccurate, or both.

In the most devilishly wicked learning environments, experience will reinforce the exact wrong lessons. Hogarth noted a famous New York City physician renowned for his skill as a diagnostician. The man's particular specialty was typhoid fever, and he examined patients for it by feeling around their tongues with his hands. Again and again, his testing yielded a positive diagnosis before the patient displayed a single symptom. And over and over, his diagnosis turned out to be correct. As another physician later pointed out, "He was a more productive carrier, using only his hands, than Typhoid Mary." Repetitive success, it turned out, taught him the worst possible lesson. Few learning environments are that wicked, but it doesn't take much to throw experienced pros off course. Expert firefighters, when faced with a new situation, like a fire in a skyscraper, can find themselves suddenly deprived of the intuition formed in years of house fires, and prone to poor decisions. With a change of the status quo, chess masters too can find that the skill they took years to build is suddenly obsolete.

In a 1997 showdown billed as the final battle for supremacy between natural and artificial intelligence, IBM supercomputer Deep Blue defeated Garry Kasparov. Deep Blue evaluated two hundred million positions per second. That is a tiny fraction of possible chess positions—the number of possible game sequences is more than atoms in the observable universe—but plenty enough to beat the best human. According to Kasparov, "Today the free chess app on your mobile phone is stronger than me." He is not being rhetorical.

"Anything we can do, and we know how to do it, machines will do it better," he said at a recent lecture. "If we can codify it, and pass it to computers, they will do it better." Still, losing to Deep Blue gave him an idea. In playing computers, he recognized what artificial intelligence scholars call Moravec's paradox: machines and humans frequently have opposite strengths and weaknesses.

There is a saying that "chess is 99 percent tactics." Tactics are short combinations of moves that players use to get an immediate advantage on the board. When players study all those patterns, they are mastering tactics. Bigger-picture planning in chess—how to manage the little battles to win the war—is called strategy. As Susan Polgar has written, "you can get a lot further by being very good in tactics"—that is, knowing a lot of patterns—"and have only a basic understanding of strategy."

Thanks to their calculation power, computers are tactically flawless compared to humans. Grandmasters predict the near future, but computers do it better. What if, Kasparov wondered, computer tactical prowess were combined with human big-picture, strategic thinking?

In 1998, he helped organize the first "advanced chess" tournament, in which each human player, including Kasparov himself, paired with a computer. Years of pattern study were obviated. The machine partner could handle tactics so the human could focus on strategy. It was like Tiger Woods facing off in a golf video game against the best gamers. His years of repetition would be neutralized, and the contest would shift to one of strategy rather than tactical execution. In chess, it changed the pecking order instantly. “Human creativity was even more paramount under these conditions, not less,” according to Kasparov. Kasparov settled for a 3–3 draw with a player he had trounced four games to zero just a month earlier in a traditional match. “My advantage in calculating tactics had been nullified by the machine.” The primary benefit of years of experience with specialized training was outsourced, and in a contest where humans focused on strategy, he suddenly had peers.

A few years later, the first “freestyle chess” tournament was held. Teams could be made up of multiple humans and computers. The lifetime-of-specialized-practice advantage that had been diluted in advanced chess was obliterated in freestyle. A duo of amateur players with three normal computers not only destroyed Hydra, the best chess supercomputer, they also crushed teams of grandmasters using computers. Kasparov concluded that the humans on the winning team were the best at “coaching” multiple computers on what to examine, and then synthesizing that information for an overall strategy. Human/Computer combo teams—known as “centaurs”—were playing the highest level of chess ever seen. If Deep Blue’s victory over Kasparov signaled the transfer of chess power from humans to computers, the victory of centaurs over Hydra symbolized something more interesting still: humans empowered to do what they do best without the prerequisite of years of specialized pattern recognition.

In 2014, an Abu Dhabi–based chess site put up $20,000 in prize money for freestyle players to compete in a tournament that also included games in which chess programs played without human intervention. The winning team comprised four people and several computers. The captain and primary decision maker was Anson Williams, a British engineer with no official chess rating. His teammate, Nelson Hernandez, told me, "What people don't understand is that freestyle involves an integrated set of skills that in some cases have nothing to do with playing chess." In traditional chess, Williams was probably at the level of a decent amateur. But he was well versed in computers and adept at integrating streaming information for strategy decisions. As a teenager, he had been outstanding at the video game *Command & Conquer,* known as a "real time strategy" game because players move simultaneously. In freestyle chess, he had to consider advice from teammates and various chess programs and then very quickly direct the computers to examine particular possibilities in more depth. He was like an executive with a team of mega-grandmaster tactical advisers, deciding whose advice to probe more deeply and ultimately whose to heed. He played each game cautiously, expecting a draw, but trying to set up situations that could lull an opponent into a mistake.

In the end, Kasparov did figure out a way to beat the computer: by outsourcing tactics, the part of human expertise that is most easily replaced, the part that he and the Polgar prodigies spent years honing.

In 2007, National Geographic TV gave Susan Polgar a test. They sat her at a sidewalk table in the middle of a leafy block of Manhattan's Greenwich Village, in front of a cleared chessboard. New Yorkers in jeans and fall jackets went about their jaywalking business as a white truck bearing a large diagram of a chessboard with twenty-eight pieces in midgame play took a left turn onto Thompson Street, past the deli, and past Susan Polgar. She glanced at the diagram as the truck drove by, and then perfectly re-created it on the board in front of her. The show was reprising a series of famous chess experiments that pulled back the curtain on kind-learning-environment skills.

The first took place in the 1940s, when Dutch chess master and psychologist Adriaan de Groot flashed midgame chessboards in front of players of different ability levels, and then asked them to re-create the boards as well as they could. A grandmaster repeatedly re-created the entire board after seeing it for only three seconds. A master-level player managed that half as often as the grandmaster. A lesser, city champion player and an average club player were never able to re-create the board accurately. Just like Susan Polgar, grandmasters seemed to have photographic memories.

After Susan succeeded in her first test, National Geographic TV turned the truck around to show the other side, which had a diagram with pieces placed at random. When Susan saw that side, even though there were fewer pieces, she could barely re-create anything at all.

That test reenacted an experiment from 1973, in which two Carnegie Mellon University psychologists, William G. Chase and soon-to-be Nobel laureate Herbert A. Simon, repeated the De Groot exercise, but added a wrinkle. This time, the chess players were also given boards with the pieces in an arrangement that would never actually occur in a game. Suddenly, the experts performed just like the lesser players. The grandmasters never had photographic memories after all. Through repetitive study of game patterns, they had learned to do what Chase and Simon called "chunking." Rather than struggling to remember the location of every individual pawn, bishop, and rook, the brains of elite players grouped pieces into a smaller number of meaningful chunks based on familiar patterns. Those patterns allow expert players to immediately assess the situation based on experience, which is why Garry Kasparov told me that grandmasters usually know their savants are briefly shown pictures and asked to reproduce them, they do much better with images of real-life objects than with more abstract depictions.

It took Treffert decades to realize he had been wrong, and that savants have more in common with prodigies like the Polgar sisters than he thought. They do not merely regurgitate. Their brilliance, just like the Polgar brilliance, relies on repetitive structures, which is precisely what made the Polgars' skill so easy to automate.

With the advances made by the AlphaZero chess program (owned by an AI arm of Google's parent company), perhaps even the top centaurs would be vanquished in a freestyle tournament. Unlike previous chess programs, which used brute processing force to calculate an enormous number of possible moves and rate them according to criteria set by programmers, AlphaZero actually taught itself to play. It needed only the rules, and then to play itself a gargantuan number of times, keeping track of what tends to work and what doesn't, and using that to improve. In short order, it beat the best chess programs. It did the same with the game of Go, which has many more possible positions. But the centaur lesson remains: the more a task shifts to an open world of big-picture strategy, the more humans have to add.

AlphaZero programmers touted their impressive feat by declaring that their creation had gone from "tabula rasa" (blank slate) to master on its own. But starting with a game is anything but a blank slate. The program is still operating in a constrained, rule-bound world. Even in video games that are less bound by tactical patterns, computers have faced a greater challenge.

The latest video game challenge for artificial intelligence is *StarCraft,* a franchise of real-time strategy games in which fictional species go to war for supremacy in some distant reach of the Milky

Way. It requires much more complex decision making than chess. There are battles to manage, infrastructure to plan, spying to do, geography to explore, and resources to collect, all of which inform one another. Computers struggled to win at *StarCraft*, Julian Togelius, an NYU professor who studies gaming AI, told me in 2017. Even when they did beat humans in individual games, human players adjusted with "long-term adaptive strategy" and started winning. "There are so many layers of thinking," he said. "We humans sort of suck at all of them individually, but we have some kind of very approximate idea about each of them and can combine them and be somewhat adaptive. That seems to be what the trick is."

In 2019, in a limited version of *StarCraft*, AI beat a pro for the first time. (The pro adapted and earned a win after a string of losses.) But the game's strategic complexity provides a lesson: the bigger the picture, the more unique the potential human contribution. Our greatest strength is the exact opposite of narrow specialization. It is the ability to integrate broadly. According to Gary Marcus, a psychology and neural science professor who sold his machine learning company to Uber, "In narrow enough worlds, humans may not have much to contribute much longer. In more open-ended games, I think they certainly will. Not just games, in open ended real-world problems we're still crushing the machines."

The progress of AI in the closed and orderly world of chess, with instant feedback and bottomless data, has been exponential. In the rule-bound but messier world of driving, AI has made tremendous progress, but challenges remain. In a truly open-world problem devoid of rigid rules and reams of perfect historical data, AI has been disastrous. IBM's Watson destroyed at *Jeopardy!* and was subsequently pitched as a revolution in cancer care, where it flopped so spectacularly that several AI experts told me they worried its reputation would taint AI research in health-related fields. As one oncologist put it, “The difference between winning at *Jeopardy!* and curing all cancer is that we know the answer to *Jeopardy!* questions.” With cancer, we’re still working on posing the right questions in the first place.

In 2009, a report in the esteemed journal *Nature* announced that Google Flu Trends could use search query patterns to predict the winter spread of flu more rapidly than and just as accurately as the Centers for Disease Control and Prevention. But Google Flu Trends soon got shakier, and in the winter of 2013 it predicted more than double the prevalence of flu that actually occurred in the United States. Today, Google Flu Trends is no longer publishing estimates, and just has a holding page saying that “it is still early days” for this kind of forecasting. Tellingly, Marcus gave me this analogy for the current limits of expert machines: “AI systems are like savants.” They need stable structures and narrow worlds.

When we know the rules and answers, and they don’t change over time—chess, golf, playing classical music—an argument can be made for savant-like hyperspecialized practice from day one. But those are poor models of most things humans want to learn.

When narrow specialization is combined with an unkind domain, the human tendency to rely on experience of familiar patterns can backfire horribly—like the expert firefighters who suddenly make poor choices when faced with a fire in an unfamiliar structure. Chris Argyris, who helped create the Yale School of Management, noted the danger of treating the wicked world as if it is kind. He studied high-powered consultants from top business schools for fifteen years, and saw that they did really well on business school problems that were well defined and quickly assessed. But they employed what Argyris called single-loop learning, the kind that favors the first familiar solution that comes to mind. Whenever those solutions went wrong, the consultant usually got defensive. Argyris found their “brittle personalities” particularly surprising given that “the essence of their job is to teach others how to do things differently."

Psychologist Barry Schwartz demonstrated a similar, learned inflexibility among experienced practitioners when he gave college students a logic puzzle that involved hitting switches to turn light bulbs on and off in sequence, and that they could play over and over. It could be solved in seventy different ways, with a tiny money reward for each success. The students were not given any rules, and so had to proceed by trial and error.* If a student found a solution, they repeated it over and over to get more money, even if they had no idea why it worked. Later on, new students were added, and all were now asked to discover the general rule of all solutions. Incredibly, every student who was brand-new to the puzzle discovered the rule for all seventy solutions, while only one of the students who had been getting rewarded for a single solution did. The subtitle of Schwartz's paper: "How Not to Teach People to Discover Rules"—that is, by providing rewards for repetitive short-term success with a narrow range of solutions.

All this is bad news for some of the business world's favorite successful-learning analogies—the Polgars, Tiger, and to some degree analogies based in any sport or game. Compared to golf, a sport like tennis is much more dynamic, with players adjusting to opponents every second, to surfaces, and sometimes to their own teammates. (Federer was a 2008 Olympic gold medalist in doubles.) But tennis is still very much on the kind end of the spectrum compared to, say, a hospital emergency room, where doctors and nurses do not automatically find out what happens to a patient after their encounter. They have to find ways to learn beyond practice, and to assimilate lessons that might even contradict their direct experience.

The world is not golf, and most of it isn't even tennis. As Robin Hogarth put it, much of the world is "Martian tennis." You can see the players on a court with balls and rackets, but nobody has shared the rules. It is up to you to derive them, and they are subject to change without notice.

We have been using the wrong stories. Tiger's story and the Polgar story give the false impression that human skill is always developed in an extremely kind learning environment. If that were the case, specialization that is both narrow and technical and that begins as soon as possible would usually work. But it doesn't even work in most sports.

If the amount of early, specialized practice in a narrow area were the key to innovative performance, savants would dominate every domain they touched, and child prodigies would always go on to adult eminence. As psychologist Ellen Winner, one of the foremost authorities on gifted children, noted, no savant has ever been known to become a "Big-C creator," who changed their field.

There are domains beyond chess in which massive amounts of narrow practice make for grandmaster-like intuition. Like golfers, surgeons improve with repetition of the same procedure. Accountants and bridge and poker players develop accurate intuition through repetitive experience. Kahneman pointed to those domains' "robust statistical regularities." But when the rules are altered just slightly, it makes experts appear to have traded flexibility for narrow skill. In research in the game of bridge where the order of play was altered, experts had a more difficult time adapting to new rules than did nonexperts. When experienced accountants were asked in a study to use a new tax law for deductions that replaced a previous one, they did worse than novices. Erik Dane, a Rice University professor who studies organizational behavior, calls this phenomenon "cognitive entrenchment." His suggestions for avoiding it are about the polar opposite of the strict version of the ten-thousand-hours school of thought: vary challenges within a domain drastically, and, as a entrenchment. They employed what Hogarth called a "circuit breaker." They drew on outside experiences and analogies to interrupt their inclination toward a previous solution that may no longer work. Their skill was in *avoiding* the same old patterns. In the wicked world, with ill-defined challenges and few rigid rules, range can be a life hack.

Pretending the world is like golf and chess is comforting. It makes for a tidy kind-world message, and some very compelling books. The rest of this one will begin where those end—in a place where the popular sport is Martian tennis, with a view into how the modern world became so wicked in the first place.

CHAPTER 2

How the Wicked World Was Made

THE TOWN OF DUNEDIN sits at the base of a hilly peninsula that juts off of New Zealand's South Island into the South Pacific. The peninsula is famous for yellow-eyed penguins, and Dunedin boasts, demurely, the world's steepest residential street. It also features the University of Otago, the oldest university in New Zealand, and home to James Flynn, a professor of political studies who changed how psychologists think about thinking.

He started in 1981, intrigued by a thirty-year-old paper that reported IQ test scores of American soldiers in World Wars I and II. The World War II soldiers had performed better, by a lot. A World War I soldier who scored smack in the middle of his peers—the 50th percentile—would have made only the 22nd percentile compared to soldiers in World War II. Flynn wondered if perhaps civilians had experienced a similar improvement. "I thought, if IQ gains had occurred anywhere," he told me, "maybe they had occurred everywhere." If he was right, psychologists had been missing something big right before their eyes.

Flynn wrote to researchers in other countries asking for data, and on a dull November Saturday in 1984, he found a letter in his university mailbox. It was from a Dutch researcher, and it contained years of raw data from IQ tests given to young men in the Netherlands. The data were from a test known as Raven's

Progressive Matrices, designed to gauge the test taker's ability to make sense of complexity. Each question of the test shows a set of abstract designs with one design missing. The test taker must try to fill in the missing design to complete a pattern. Raven's was conceived to be the epitome of a "culturally reduced" test; performance should be unaffected by material learned in life, inside or outside of school. Should Martians alight on Earth, Raven's should be the test capable of determining how bright they are. And yet Flynn could immediately see that young Dutchmen had made enormous gains from one generation to the next.

Flynn found more clues in test reference manuals. IQ tests are all standardized so that the average score is always 100 points. (They are graded based on a curve, with 100 in the middle.) Flynn noticed that the tests had to be restandardized from time to time to keep the average at 100, because test takers were giving more correct answers than they had in the past. In the twelve months after he received the Dutch letter, Flynn collected data from fourteen countries. Every single one showed huge gains for both children and adults. "Our advantage over our ancestors," as he put it, is "from the cradle to the grave."

Flynn had asked the right question. Score gains *had* occurred everywhere. Other academics had stumbled upon pieces of the same data earlier, but none had investigated whether it was part of a global pattern, even those who were having to tweak the test scoring system to keep the average at 100. "As an outsider," Flynn told me, "things strike me as surprising that I think people trained in psychometrics just accepted."

The Flynn effect—the increase in correct IQ test answers with each new generation in the twentieth century—has now been documented in more than thirty countries. The gains are startling: three points every ten years. To put that in perspective, if an adult who scored average today were compared to adults a century ago, she would be in the 98th percentile.

When Flynn published his revelation in 1987, it hit the community of researchers who study cognitive ability like a firebomb. The American Psychological Association convened an entire meeting on the issue, and psychologists invested in the immutable nature of IQ test scores offered an array of explanations to usher the effect away, from more education and better nutrition —which presumably contributed—to test-taking experience, but none fit the unusual pattern of score improvements. On tests that gauged material picked up in school or with independent reading or study—general knowledge, arithmetic, vocabulary—scores hardly budged. Meanwhile, performance on more abstract tasks that are never formally taught, like the Raven's matrices, or "similarities" tests, which require a description of how two things are alike, skyrocketed.

A young person today asked to give similarities between "dusk" and "dawn" might immediately realize that both connote times of day. But they would be far more likely than their grandmothers to produce a higher-level similarity: both separate day from night. A child today who scores average on similarities would be in the 94th percentile of her grandparents' generation. When a group of Estonian researchers used national test scores to compare word understandings of schoolkids in the 1930s to those in 2006, they saw that improvement came very specifically on the most abstract words. The more abstract the word, the bigger the improvement. The kids barely bested their grandparents on words for directly observable objects or phenomena ("hen," "eating," "illness"), but they improved massively on imperceptible concepts ("law," "pledge," "citizen").

The gains around the world on Raven's Progressive Matrices—where change was least expected—were the biggest of all. "The huge Raven's gains show that today's children are far better at solving problems on the spot without a previously learned method for doing so," Flynn concluded. They are more able to extract rules and patterns where none are given. Even in countries that have recently had a *decrease* in verbal and math IQ test scores, Raven's scores went up. The cause, it seemed, was some ineffable thing in modern air. Not only that, but the mystery air additive somehow supercharged modern brains specifically for the most abstract tests. What manner of change, Flynn wondered, could be at once so large and yet so particular?

Through the late 1920s and early 1930s, remote reaches of the Soviet Union were forced through social and economic changes that would normally take generations. Individual farmers in isolated areas of what is now Uzbekistan had long survived by cultivating small gardens for food, and cotton for everything else. Nearby in the mountain pasturelands of present-day Kyrgyzstan, herders kept animals. The population was entirely illiterate, and a hierarchical social structure was enforced by strict religious rules. The socialist revolution dismantled that way of life almost overnight.

The Soviet government forced all that agricultural land to become large collective farms and began industrial development. The economy quickly became interconnected and complex. Farmers had to form collective work strategies, plan ahead for production, divvy up functions, and assess work along the way. Remote villages began communicating with distant cities. A network of schools opened in regions with 100 percent illiteracy, and adults began learning a system of matching symbols to sounds. Villagers had used numbers before, but only in practical transactions. Now they were taught the concept of a number as an abstraction that existed even without reference to counting animals or apportioning food. Some village women remained fully insisted. The bullet must be loaded in the rifle to kill the bird, and "then you have to cut the bird up with the dagger, since there's no other way to do it." These were just the introductions explaining the grouping task, not the actual questions. No amount of cajoling, explanation, or examples could get remote villagers to use reasoning based on any concept that was not a concrete part of their daily lives.

The farmers and students who had begun to join the modern world were able to practice a kind of thinking called "eduction," to work out guiding principles when given facts or materials, even in the absence of instructions, and even when they had never seen the material before. This, it turns out, is precisely what Raven's Progressive Matrices tests. Imagine presenting the villagers living in premodern circumstances with abstract designs from the Raven's test.

Some of the changes wrought by modernity and collective culture seem almost magical. Luria found that most remote villagers were not subject to the same optical illusions as citizens of the industrialized world, like the Ebbinghaus illusion. Which middle circle below looks bigger?

If you said the one on the right, you're probably a citizen of the industrialized world. The remote villagers saw, correctly, that they are the same, while the collective farmers and women in teachers' school picked the one on the right. Those findings have been repeated in other traditional societies, and scientists have suggested it may reflect the fact that premodern people are not as drawn to the holistic context—the relationship of the various circles to one another—so their perception is not changed by the presence of extra circles. To use a common metaphor, premodern people miss the forest for the trees; modern people miss the trees for the forest.

Since Luria's voyage to the interior, scientists have replicated his work in other cultures. The Kpelle people in Liberia were subsistence rice farmers, but in the 1970s roads began snaking toward them, connecting the Kpelle to cities. Given similarities tests, teenagers who were engaged with modern institutions grouped items by abstract categories ("All of these things can keep us warm"), while the traditional teens generated groups that were comparatively arbitrary, and changed frequently even when they were asked to repeat the exact same task. Because the touched-by-modernity teens had constructed meaningful thematic groups, they also had far superior recall when asked later to recount the items. The more they had moved toward modernity, the more powerful their abstract thinking, and the less they had to rely on their concrete experience of the world as a reference point.

In Flynn's terms, we now see the world through "scientific spectacles." He means that rather than relying on our own direct experiences, we make sense of reality through classification schemes, using layers of abstract concepts to understand how pieces of information relate to one another. We have grown up in a world of classification schemes totally foreign to the remote villagers; we classify some animals as mammals, and inside of that class make more detailed connections based on the similarity of their physiology and DNA.

Words that represent concepts that were previously the domain of scholars became widely understood in a few generations. The word "percent" was almost absent from books in 1900. By 2000 it appeared about once every five thousand words. (This chapter is 5,500 words long.) Computer programmers pile layers of abstraction. (They do very well on Raven's.) In the progress bar on your computer screen that fills up to indicate a download, abstractions are legion, from the fundamental—the programming language that created it is a representation of binary code, the raw 1s and 0s the computer uses—to the psychological: the bar is a visual projection of time that provides peace of mind by estimating the progress of an immense number of underlying activities.

Lawyers might consider how results of one court case brought by an individual in Oklahoma could be relevant to a different one brought by a company in California. In order to prep, they might try out different hypothetical arguments while putting themselves in the shoes of an opposing attorney to predict how they will argue. Conceptual schemes are flexible, able to arrange information and ideas for a wide variety of uses, and to transfer knowledge between domains. Modern work demands knowledge transfer: the ability to apply knowledge to new situations and different domains. Our most fundamental thought processes have changed to accommodate increasing complexity and the need to derive new patterns rather than rely only on familiar ones. Our conceptual classification schemes provide a scaffolding for connecting knowledge, making it accessible and flexible.

Research on thousands of adults in six industrializing nations found that exposure to modern work with self-directed problem solving and nonrepetitive challenges was correlated with being "cognitively flexible." As Flynn makes sure to point out, this does not mean that brains now have more inherent potential than a generation ago, but rather that utilitarian spectacles have been swapped for spectacles through which the world is classified by concepts.* Even recently, within some very traditional or orthodox religious communities that have modernized but that still block women from engaging in modern work, the Flynn effect has proceeded more slowly for women than for men in the same community. Exposure to the modern world has made us better adapted for complexity, and that has manifested as flexibility, with profound implications for the breadth of our intellectual world.

In every cognitive direction, the minds of premodern citizens were severely constrained by the concrete world before them. With cajoling, some solved the following logic sequence: "Cotton grows well where it is hot and dry. England is cold and damp. Can cotton grow there or not?" They had direct experience growing cotton, so some of them could answer (tentatively and when pushed) for a country they had never visited. The same exact puzzle with different details stumped them: "In the Far North, where there is snow, all bears are white. Novaya Zemlya is in the Far North and there is always snow there. What colors are the bears there?" That time, no amount of pushing could get the remote villagers to answer. They would respond only with principles. "Your words can be answered only by someone who was there," one man said, even though he had never been to England but had just answered the cotton question. But even a faint taste of modern work began to change that. Given the white bear puzzle, Abdull, forty-five and barely literate but chairman of a collective farm, would not give an answer confidently, but he did exercise formal logic. "To go by your words," he said, "they should all be white."

The transition completely transformed the villagers' inner worlds. When the scientists from Moscow asked the villagers what they would like to know about them or the place they came from, the isolated farmers and herders generally could not come up with a single question. "I haven't seen what people do in other cities," one said, "so how can I ask?" Whereas those engaged in collective farming were readily curious. "Well, you just spoke about white bears," said thirty-one-year-old Akhmetzhan, a collective farmer. "I don't understand where they come from." He stopped for a moment to ponder. "And then you mentioned America. Is it governed by us or by some other power?" Nineteen-year-old Siddakh, who worked on a collective farm and had studied in a school for two years, was brimming with imaginative questions

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