DEEP THINKING

where machine intelligence ends and human creativity begins

GARRY KASPAROV

WITH MIG GREENGARD

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FOR MY CHILDREN, POLINA, VADIM, AIDA, AND NICKOLAS.

Challenge yourselves and you will challenge the world.

INTRODUCTION

IT WAS A PLEASANT DAY in Hamburg on June 6, 1985, but chess players rarely get to enjoy the weather. I was inside a cramped auditorium, pacing around inside a circle of tables upon which rested thirty-two chessboards. Across from me at every board was an opponent, who moved promptly when I arrived at the board in what is known as a simultaneous exhibition. "Simuls," as they are known, have been a staple of chess for centuries, a way for amateurs to challenge a champion, but this one was unique. Each of my opponents, all thirty-two of them, was a computer.

I walked from one machine to the next, making my moves over a period of more than five hours. The four leading chess computer manufacturers had sent their top models, including eight bearing the "Kasparov" brand name from the electronics firm Saitek. One of the organizers warned me that playing against machines was different because they would never get tired or resign in dejection the way a human opponent would; they would play to the bitter end. But I relished this interesting new challenge—and the media attention it attracted. I was twenty-two years old, and by the end of the year I would become the youngest world chess champion in history. I was fearless, and, in this case, my confidence was fully justified.

It illustrates the state of computer chess at the time that it didn't come as much of a surprise, at least not in the chess world, when I achieved a perfect 32–0 score, winning every game, although there was one uncomfortable moment. At one point I realized that I was drifting into trouble in a game against one of the Kasparov models. If this machine scored a win or even a draw against me, people might suggest that I had thrown the game to get publicity for the company, so I had to intensify my efforts.

Eventually I found a way to trick the machine with a sacrifice it should have refused and secure my clean sweep. From the human perspective, or at least from my perspective as the human in this equation, these were the good old days of human versus machine chess. But this golden age would be brutally short.

Twelve years later I was in New York City fighting for my chess life against just one machine, a $10 million IBM supercomputer nicknamed "Deep Blue." This battle, actually a rematch, became the most famous human-machine competition in history. *Newsweek*'s cover called it "The Brain's Last Stand" and a flurry of books compared it to Orville Wright's first flight and the moon landing. Hyperbole, of course, but not out of place at all in the history of our love-hate relationship with so-called intelligent machines.

Jump forward another twenty years to today, to 2017, and you can download any number of free chess apps for your phone that rival any human Grandmaster. You can easily imagine a robot in my place in Hamburg, circling inside the tables and defeating thirty-two of the world's best human players at the same time. The tables have turned, as they always do in our eternal race with our own technology.

Ironically, if a machine did perform a chess simul against a room full of human professional players, it would have more trouble moving from board to board and physically moving the pieces than it would have calculating the moves. Despite centuries of science fiction about automatons that look and move like people, and for all the physical labor today done by robots, it's fair to say that we have advanced further in duplicating human thought than human movement.

In what artificial intelligence and robotics experts call Moravec's paradox, in chess, as in so many things, what machines are good at is where humans are weak, and vice versa. In 1988, the roboticist Hans Moravec wrote, "It is comparatively easy to make computers exhibit adult level performance on intelligence tests or playing checkers, and difficult or impossible to give them the skills of a one-year-old when it comes to perception and mobility." I wasn't aware of these theories at the time, and in 1988 it was safe to include checkers but not yet chess, but ten years later it was

obviously the case in chess as well. Grandmasters excelled at recognizing patterns and strategic planning, both weaknesses in chess machines that, however, could calculate in seconds tactical complications that would take even the strongest humans days of study to work out.

This disparity gave me an idea for an experiment after my matches with Deep Blue attracted so much attention. You could also call it "if you can't beat 'em, join 'em," but I was eager to continue the computer chess experiment even if IBM was not. I wondered, what if instead of human versus machine we played as partners? My brainchild saw the light of day in a match in 1998 in León, Spain, and we called it Advanced Chess. Each player had a PC at hand running the chess software of his choice during the game. The idea was to create the highest level of chess ever played, a synthesis of the best of man and machine. It didn't quite go according to plan, as we'll see later, but the fascinating results of these "centaur" competitions convinced me that chess still had a lot to offer the worlds of human cognition and artificial intelligence.

In this belief I was hardly a pioneer; a chess-playing machine has been a holy grail since long before it was possible to make one. I just happened to be the human holding the grail when it was finally in science's grasp. I could run away from this new challenge or I could embrace it, which was really no choice at all. How could I resist? It was a chance to promote chess to a general audience beyond that reached even by Bobby Fischer's Cold War–era match against Boris Spassky and my own title duels with Anatoly Karpov. It had the potential to attract a new set of deep-pocketed sponsors to chess, especially tech companies. For example, Intel sponsored a Grand Prix cycle in the mid-1990s as well as my world championship match with Viswanathan Anand in 1995, played at the top of the World Trade Center. And then there was the irresistible curiosity I felt. Could these machines really play chess at the world championship level? Could they really think?

Humans have dreamed of intelligent machines since long before the technology to attempt one was conceived. In the late eighteenth century, a chess-playing mechanical automaton called the "Turk" was a wonder of the age. A carved wooden figure

moved the pieces and, most remarkably, played a very strong game. Before it was destroyed in a fire in 1854, the Turk toured Europe and the Americas to great acclaim, claiming among its victims the famous chess aficionados Napoleon Bonaparte and Benjamin Franklin.

Of course it was a hoax; there was a human inside the cabinet under the table, hidden by an ingenious set of sliding panels and machinery. In another irony, today chess tournaments are plagued by cheaters who access super-strong computer programs to defeat their human opponents. Players have been caught using sophisticated signaling methods with accomplices, Bluetooth headsets in hats or electrical devices in shoes, and simply using a smartphone in the restroom.

The first real chess program actually predates the invention of the computer and was written by no less a luminary than Alan Turing, the British genius who cracked the Nazi Enigma code. In 1952, he processed a chess algorithm on slips of paper, playing the role of CPU himself, and this "paper machine" played a competent game. This connection went beyond Turing's personal interest in chess. Chess had a long-standing reputation as a unique nexus of the human intellect, and building a machine that could beat the world champion would mean building a truly intelligent machine.

Turing's name is forever attached to a thought experiment later made real, the "Turing test." The essence is whether or not a computer can fool a human into thinking it is human and if yes, it is said to have passed the Turing test. Even before I faced Deep Blue, computers were beginning to pass what we can call the "chess Turing test." They still played poorly and often made distinctively inhuman moves, but there were complete games between computers that wouldn't have looked out of place in any strong human tournament. As became clearer as the machines grew stronger every year, however, this taught us more about the limitations of chess than about artificial intelligence.

You cannot call the globally celebrated culmination of a forty-five-year-long quest an anticlimax, but it turned out that making a great chess-playing computer was not the same as making a thinking machine on par with the human mind, as Turing and others had dreamed. Deep Blue was intelligent the way your

programmable alarm clock is intelligent. Not that losing to a $10 million alarm clock made me feel any better.

The AI crowd, too, was pleased with the result and the attention but dismayed by the fact that Deep Blue was hardly what their predecessors had imagined decades earlier when they dreamed of creating a machine to defeat the world chess champion. Instead of a computer that thought and played chess like a human, with human creativity and intuition, they got one that played like a machine, systematically evaluating up to 200 million possible moves on the chess board per second and winning with brute number-crunching force. This isn't to diminish the achievement in any way. It was a human achievement, after all, so while a human lost the match, humans also won.

After the unbearable tension of the match, exacerbated by IBM's questionable behavior and my suspicious human mind, I was in no mood to be a gracious loser. Not that I've ever been a good loser, I hasten to add. I believe accepting losses too easily is incompatible with being a great champion—certainly this was the case with me. I do believe in fighting a fair fight, however, and this is where I felt IBM had shortchanged me as well as the watching world.

Reexamining every aspect of that infamous match with Deep Blue for the first time in twenty years has been difficult, I admit. For two decades I have succeeded almost completely in avoiding and deflecting discussion about my Deep Blue matches beyond what was publicly known. There are many books about Deep Blue, but this is the first one that has all the facts and the only one that has my side of the story. Painful memories aside, it has also been a revealing and rewarding experience. My great teacher Mikhail Botvinnik, the sixth world champion, taught me always to seek the truth in the heart of every position. It has been fulfilling to finally find the truth at the heart of Deep Blue.

MY CAREER and my investigations into human-machine cognition did not end with Deep Blue, however; nor does this book. In fact, in both cases it's just the beginning. Competing head to head against a computer the way I did isn't the norm, although it was symbolic of how we are in a strange competition both with

and against our own creations in more ways every day. My Advanced Chess experiment flourished online, where teams of humans and computers working together competed with remarkable results. Smarter computers are one key to success, but doing a smarter job of humans and machines working together turns out to be far more important.

These investigations led to visits to places like Google, Facebook, and Palantir, companies for whom algorithms are lifeblood. There have also been some more surprising invitations, including one from the headquarters of the world's largest hedge fund, where algorithms make or lose billions of dollars every day. There I met one of the creators of Watson, the *Jeopardy*-playing computer that could be called IBM's successor to Deep Blue. Another trip was to participate in a debate in front of an executive banking audience in Australia on what impact AI was likely to have on jobs in their industry. Their interests are quite different, but they all want to be on the cutting edge of the machine intelligence revolution, or at least to not be cut by it.

I've been speaking to business audiences for many years, usually on subjects like strategy and how to improve the decision-making process. But in recent years, I'm receiving more and more requests to talk about artificial intelligence and what I call the human-machine relationship. Along with sharing my thoughts, these appearances have given me the opportunity to listen closely to the interests of the business world regarding intelligent machines. Much of this book is dedicated to addressing these concerns and separating inevitable facts from conjecture and hyperbole.

In 2013, I was honored to become a senior visiting fellow at the Oxford Martin School, where I get to spend time with a constellation of brilliant expert minds. At Oxford, artificial intelligence is as much an area of philosophy as technology, and I enjoy trying to cross these streams. Their wonderfully named Future of Humanity Institute is the perfect place to collaborate on where the human-machine relationship is headed. My goal is to take some of the sophisticated, often arcane, expert research, predictions, and opinions and to serve as your translator and guide to their practical implications while adding my own insights and

questions along the way.

I have spent most of my life thinking about how humans think and have found this to be an excellent basis for relating how machines think, and how they do not. In turn, this insight helps inform us as to what our machines can and cannot do ... yet.

THE NINETEENTH-CENTURY African American folk legend of John Henry pits the "steel-driving man" in a race against a new invention, a steam-powered hammer, bashing a tunnel through a mountain of rock. It was my blessing and my curse to be the John Henry of chess and artificial intelligence, as chess computers went from laughably weak to nearly unbeatable during my twenty years as the world's top chess player.

As we will see, this is a pattern that has repeated over and over for centuries. People scoffed at every feeble attempt to substitute clumsy, fragile machines for the power of horses and oxen. We laughed at the idea that stiff wood and metal could replicate the soaring grace of the birds. Eventually we have had to concede that there is no physical labor that couldn't be replicated, or mechanically surpassed.

It is also now widely accepted that this inexorable advance is something to celebrate, not fear, although it is usually two steps forward and one step back in this regard. With every new encroachment of machines, the voices of panic and doubt are heard, and they are only getting louder today. This is partly due to the differences in what, and who, is being replaced. The horses and oxen couldn't write letters to the editor when cars and tractors came along. Unskilled laborers also lacked much of a voice, and were often considered lucky to be freed from their backbreaking toil.

So it went over the decades of the twentieth century, with countless jobs lost or transformed by automation. Entire professions disappeared with little time to mourn them. The elevator operators' union was seventeen thousand strong in 1920, although its ability to paralyze cities with strikes like the one its members staged in New York in September 1945 surely cost them more than a few mourners when automatic push-button elevators began to replace them in the 1950s. According to the Associated

Press, "Thousands struggled up stairways that seemed endless, including the Empire State Building, tallest structure in the world."

Good riddance, you might imagine. But the worries about operatorless elevators were quite similar to the concerns we hear today about driverless cars. In fact, I learned something surprising when I was invited to speak to the Otis Elevator Company in Connecticut in 2006. The technology for automatic elevators had existed since 1900, but people were too uncomfortable to ride in one without an operator. It took the 1945 strike and a huge industry PR push to change people's minds, a process that is already repeating with driverless cars. The cycle of automation, fear, and eventual acceptance goes on.

Of course, what an observer calls freedom and disruption, a worker calls unemployment. The educated classes in the developed world have long had the luxury of lecturing their blue-collar brethren about the glories of the automated future. Service personnel have been on the block for decades—their friendly faces, human voices, and quick fingers replaced by ATMs, photocopiers, phone trees, and self-checkout lines. Airports have iPads instead of food servers. No sooner did massive call centers spring up around India than automated help-desk algorithms begin replacing them.

It is far easier to tell millions of newly redundant workers to "retrain for the information age" or to "join the creative entrepreneurial economy" than to be one of them or to actually do it. And who can say how quickly all that new training will also become worthless? What professions today can be called "computer proof"? Today another set of tables has turned, or rather, desks. The machines have finally come for the white collared, the college graduates, the decision makers. And it's about time.

JOHN HENRY won his race against the machine only to die on the spot, "his hammer in his hand." I was spared such a fate myself, and humans are still playing chess, in fact more today than ever before. The doomsayers who said no one would want to play a game that could be dominated by a computer have been proven wrong. This seems obvious, considering how we also still play far

simpler games like tic-tac-toe and checkers, but doomsaying has always been a popular pastime when it comes to new technology.

I remain an optimist if only because I've never found much advantage in the alternatives. Artificial intelligence is on a path toward transforming every part of our lives in a way not seen since the creation of the Internet, perhaps even since we harnessed electricity. There are potential dangers with any powerful new technology and I won't shy away from discussing them. Eminent individuals from Stephen Hawking to Elon Musk have expressed their fear of AI as a potential existential threat to mankind. The experts are less prone to alarming statements, but they are quite worried too. If you program a machine, you know what it's capable of. If the machine is programming itself, who knows what it might do?

The airports with their self-check-in kiosks and restaurants full of iPads are staffed by thousands of human workers (most using machines) in the long security lines. Is it because they can do things no machine can do? Or, like operating an elevator and driving a car, is it because at first we don't trust machines to do a job where lives are at risk? Elevators became much safer as soon as the human operators were replaced. The human-hating Skynet from the *Terminator* movies could hardly do a better job of killing people than we do killing ourselves with cars. Human error is responsible for over 50 percent of plane crashes, although overall air travel is getting safer as it becomes more automated.

In other words, fail-safes are required, but so is courage. When I sat across from Deep Blue twenty years ago I sensed something new, something unsettling. Perhaps you will experience a similar feeling the first time you ride in a driverless car, or the first time your new computer boss issues an order at work. We must face these fears in order to get the most out of our technology and to get the most out of ourselves.

Many of the most promising jobs today didn't even exist twenty years ago, a trend that will continue and accelerate. Mobile app designer, 3D print engineer, drone pilot, social media manager, genetic counselor—to name just a few of the careers that have appeared in recent years. And while experts will always be in demand, more intelligent machines are continually lowering the

bar to creating with new technology. This means less training and retraining for those whose jobs are taken by robots, a virtuous cycle of freeing us from routine work and empowering us to use new technology productively.

Machines that replace physical labor have allowed us to focus more on what makes us human: our minds. Intelligent machines will continue that process, taking over the more menial aspects of cognition and elevating our mental lives toward creativity, curiosity, beauty, and joy. These are what truly make us human, not any particular activity or skill like swinging a hammer—or even playing chess.

CHAPTER 1

THE BRAIN GAME

CHESS IS OLD ENOUGH for its origins to be less than entirely clear. Most histories place the origins of the chess precursor game chaturanga in India sometime before the sixth century. From there chess moved to Persia and into the Arab and Muslim world, where it followed the well-trod path into southern Europe via Moorish Spain. By the time of the late Middle Ages, it was a standard presence in the courts of Europe and appears regularly in manuscripts from the period.

The modern game we know today appeared in Europe at the end of the fifteenth century, when the ranges of the queen and bishop were extended, making the game far more dynamic. Older and regional variants still existed, and there were a few minor rule standardizations, but for the most part, games played by the eighteenth century were identical to those played today. This rich history includes thousands of games from great masters of centuries past, with each move, each brilliancy and each blunder, perfectly preserved in chess notation as if trapped in amber.

The games are what matter most to serious players, but history and physical relics also play a role in the game's status. The twelfth-century Lewis chessmen, carved from walrus tusks; illuminated Persian illustrations from 1500 of players accompany Rumi's poetry; the third book ever printed in English was *Game and Playe of the Chesse*, which came from the press of William Caxton himself in 1474; Napoleon Bonaparte's personal chess set. You start to see why chess fans resent it being called just a game.

This global heritage is what makes chess unique as a cultural artifact, but the fact of its longevity and popularity doesn't explain

it. The number of people who play chess regularly is impossible to know exactly, of course, but some of the more extensive surveys with modern sampling methods put the figure in the hundreds of millions. The game is popular on every continent, with regional concentrations from its traditional popularity in the former Soviet and Soviet Bloc countries and from its recent boom in India, which is due largely to the successes of former world champion Viswanathan Anand.

My personal and entirely unscientific survey method is based on how often I am recognized in public when I travel, which I do most of the year. In the United States, where I now live in New York City, I can pass in anonymity for days at a time before being recognized, often by someone from Eastern Europe. For better or worse, chess champions can safely walk the streets of America without worrying about autograph hounds and paparazzi. Meanwhile, I was so mobbed by chess fans at my hotel during a lecture trip to New Delhi that the hotel had to have security escort me through, so I can't even imagine what it's like there for their national idol Anand.

The Soviet heyday, when chess champions were met by cheering crowds at train stations and airports, survives today only in chess-mad Armenia, where the national team has brought home gold medals at an astounding rate for a country with a population of only 3 million people. And despite my own half-Armenian heritage, there is no genetic explanation necessary for this success. When a society emphasizes something, by custom or by mandate, results will follow, whether it's a state religion, a traditional art form, or chess.

Does the "why chess?" question find an answer in anything intrinsic to the game itself? Is there something uniquely attractive to chess's blend of strategic and tactical elements, its balance of preparation, inspiration, and determination? To be honest, I don't think so. It's true that the game has had the benefit of centuries of evolution, adapting to its surroundings like one of Darwin's finches. For example, the romantic Renaissance players made the game far more lively, accelerating the game just as the world of ideas accelerated around it. And who is to say that the eight-by-eight chessboard isn't somehow more pleasing or accessible to the

human mind than the nine-by-nine shogi board or the fathomless nineteen-by-nineteen grid of Go stones? It's a diverting thought, but we don't really have to look much further than how the increasingly interconnected world of the Enlightenment led to the standardization of everything from spelling to beer recipes to chess rules. Had a ten-by-ten board been in vogue around 1750 that's probably what we'd be playing with today.

THE ABILITY to play chess well has always had a special mystique as a representation of intelligence, a statement that applies equally to both human and machine players. As a young chess star and world champion I personally experienced this mystique and its side effects more than just about anyone. For every truth around elite chess players—we do have good memories and concentration skills—there are at least a dozen misconceptions, both positive and negative.

Connections between chess skill and general intelligence are weak at best. There is no more truth to the thought that all chess players are geniuses than in saying that all geniuses play chess. In fact, one of the things that makes chess so interesting is that it's still unclear exactly what separates good chess players from great ones. Recently, sophisticated brain scans have started to illuminate which functions of the brain strong players rely on most, although psychologists have analyzed the matter extensively for decades with batteries of tests.

The results of all these investigations have so far confirmed the ineffable nature of human chess. The start of the game, called the opening phase, is mostly a matter of study and recall for professionals. We select openings from our personal mental library according to our preferences and preparation for our opponent. Move generation seems to involve more visuospatial brain activity than the sort of calculation that goes into solving math problems. That is, we literally visualize the moves and positions, although not in a pictorial way, as many early researchers assumed. The stronger the player, the more they demonstrate superior pattern recognition and doing the sort of "packaging" of information for recall that experts call "chunking."

Then comes understanding and assessing what we see in our

mind's eye, the evaluation aspect. Different players of equal strength often have very different opinions of a given position and recommend entirely different moves and strategies. There is ample room here for disparate styles, creativity, brilliancy, and, of course, terrible mistakes. All this visualization and evaluation must be verified by calculation, the "I go here, he goes there, I go there" mechanics that novices rely on—and that many assume incorrectly to be what chess is all about.

Finally, the executive process must decide on a course of action, and it must decide *when* to decide. Time is limited in a serious game of chess, so how much of it do you use on a given move? Ten seconds or thirty minutes? Your clock is ticking and your heart is racing!

All these things are happening at once during every second of a chess game, which can last for six or seven stressful hours at the competitive level. Unlike machines, we also have to cope with emotional and physical responses during every moment, everything from worry and excitement about the position to tiredness, hunger, and the limitless distractions about everyday life that constantly float through our consciousness.

A character of Goethe's called chess a "touchstone of the intellect," while Soviet encyclopedias defined chess as an art, a science, and a sport. Marcel Duchamp, himself a strong player, said that "I have come to the personal conclusion that while all artists are not chess players, all chess players are artists." Brain scans will continue to better define exactly what goes on in the human brain during a chess game, and may even come to some conclusions about what makes one person a naturally superior player. But I remain confident that we will continue to enjoy chess, and to revere it, as long as we enjoy art, science, and competition.

Thanks to the Internet's matchless ability to spread myths and rumors, I've found myself bombarded with all sorts of misinformation about my own intellect. Spurious lists of "highest IQs in history" might find me between Albert Einstein and Stephen Hawking, both of whom have probably taken as many proper IQ tests as I have: zero. In 1987, the German news magazine *Der Spiegel* sent a small group of experts to a hotel in Baku to administer a battery of tests to measure my brainpower in different ways, some

specially designed to test my memory and pattern recognition abilities.

I have no idea how closely these approximated a formal IQ test, nor do I much care. The chess tests proved I was very good at chess, the memory tests that I had a very good memory, neither of which was much of a revelation. My weakness, they told me, was "figural thinking," apparently proven after I blanked out for a while when tasked with filling in some dots with pencil lines. I have no idea what was, or wasn't, going through my mind at the time, but I have always had difficulty motivating myself to perform tasks I cannot see the point of, a tendency I now see reflected in my daughter Aida when it's time to do her homework.

When *Der Spiegel* asked me what I thought separated me, the world champion, from other strong chess players, I answered, "The willingness to take on new challenges," the same answer I would give today. The willingness to keep trying new things—different methods, uncomfortable tasks—when you are already an expert at something is what separates good from great. Focusing on your strengths is required for peak performance, but improving your weaknesses has the potential for the greatest gains. This is true for athletes, executives, and entire companies. Leaving your comfort zone involves risk, however, and when you are already doing well the temptation to stick with the status quo can be overwhelming, leading to stagnation.

AS FLATTERING AS all the "genius" mythmaking might sound, it's really more a case of flattery of chess itself. It is a perpetuation of hundreds of years of praise of chess masters as virtuosos and prodigies. In 1782, the great French player François-André Danican Philidor played two games simultaneously while blindfolded and was acclaimed as an intellect without parallel. As one contemporary newspaper account described it, "a phenomenon in the history of man and so should be hoarded among the best samples of human memory, till memory shall be no more." Flattering, but as good as Philidor was for his era, playing two games without sight of the board is easily in range of any competent player with a little practice. And while there have been various claims to the world record for simultaneous blindfold play,

the modern official record is forty-six, set by a German player of average master strength.

Regardless of the origins, there is no doubt that chess is an enduring symbol of intellectual prowess and strategic thinking, as well as an overly popular metaphor for everything from politics to war to every kind of sport and even to romantic entanglements. Perhaps chess players should receive a commission every time a football coach is said to be "playing a chess game out there" or when routine political maneuvering is called "three-dimensional chess."

Pop culture has long been obsessed with chess as an indicator of brilliance and strategy. Hollywood tough guys Humphrey Bogart and John Wayne were both chess aficionados and played on the set with and without the cameras rolling. My favorite James Bond film, *From Russia with Love*, contains no small amount of chess. Early on, one of Bond's associates warns him, "These Russians are great chess players. When they wish to execute a plot, they execute it brilliantly. The game is planned minutely; the gambits of the enemy are provided for."

The end of the Cold War and the passing of the era of Russians as the bad guys in every movie didn't put an end to pop culture's affinity for an ancient board game. Many of today's top franchises highlight chess scenes. The *X-Men* movies put Professor X and Magneto across a glass board and set. *Harry Potter* has its Wizard's Chess, whose animated pieces are reminiscent of the game between C-3PO and Chewbacca in *Star Wars*. Even heartthrob vampires play chess, as seen in the Twilight movie *Breaking Dawn*.

Chess-playing machines have also figured prominently in fiction. In Stanley Kubrick's 1968 film, *2001*, the computer HAL 9000 easily defeats the character Frank Poole, foreshadowing that the machine will eventually murder him. Kubrick loved chess, so the game in his movie, like the one at the start of *From Russia with Love*, was based on a historical tournament game. Arthur C. Clarke's *2001* novel doesn't include a game, but it does mention that HAL could easily beat any of the humans on the ship if it played at full strength, but since that would be bad for morale it had been programmed to only win 50 percent of the time. Clarke adds, "His human partners pretended not to know this."

Advertisers are paid to exploit the power of symbols and again we see chess routinely deployed as a winning metaphor. Chess imagery in ads for banks, consultancies, and insurance companies seems obvious enough, but what about in commercials for Honda trucks, billboards for BMW cars, and online ads for dating websites? When you consider that only an estimated 15 percent of the US population plays chess, its cultural prominence is extraordinary.

It is also paradoxically at odds with the negative stereotypes of chess players as socially stunted, as if our brains developed processing power at the expense of emotional intelligence. It is true that chess can be a refuge for quiet people who prefer the company of their own thoughts, and obviously it doesn't require teamwork or social skills to excel. And even in the tech-obsessed twenty-first century, where Silicon Valley is Shangri-la and where it has become conventional wisdom that the geeks and nerds are the big winners, a particularly American strain of anti-intellectualism still bubbles up regularly.

Much of this fetishizing of chess and its practitioners, pro and con, stems from a simple lack of familiarity with the game. Relatively few Westerners play chess at all and fewer play to a level beyond knowing the rules. I've noticed that games without a chance factor—rolled dice, shuffled cards—are often considered hard, more like work than relaxing fun. Along with having no luck element, chess is a 100 percent information game; both sides know everything about the position all the time. There are no excuses in chess, no guesses, nothing out of the players' control.

Because of these factors, chess mercilessly punishes disparities in skill level, making it less friendly to newcomers who often don't have opponents of similar level at hand. After all, nobody likes to lose every time, as HAL's programmers realized. Poker and backgammon are games of skill, but their luck element is strong enough for every player to credibly dream about an upset in any given match. Not so with chess.

Chess-playing software on PCs and mobile devices and the Internet has mitigated this problem by providing a ready supply of opponents of all levels with 24/7 availability, although this also puts chess into direct competition with the never-ending supply of

new online games and diversions. It also poses an interesting chess Turing test since you have no way to be sure whether you are playing against a computer or a human when you play online. Most people are far more engaged when playing against other humans and find facing computer opponents a sterile experience even when the machine has been dumbed down to a competitive level.

While chess programs today are so strong it's hard to tell the difference between their games and those of elite human Grandmasters, it has proved difficult to create convincingly weak chess machines. They tend to alternate between strong play and grotesque blunders during the same game. It's more than a little ironic that after half a century of trying to build the strongest chess entity on Earth, the programmers today are more concerned about making them play worse. Unfortunately, Arthur C. Clarke did not provide any guidance on how HAL arrived at its programmed mediocrity.

As a side note, it's a little curious that we take such joy and pride in winning a game due to a lucky roll or hand, is it not? I suppose it is human nature to revel in good fortune and beating the odds, merited or not, and everyone loves an underdog. Still, the phrase "it's better to be lucky than good" must be one of the most ridiculous homilies ever uttered. In nearly any competitive endeavor, you have to be damned good before luck can be of any use to you at all.

WAS VERY INTERESTED in improving chess's image in the West even before I became world champion in 1985, and I did my best to speak out against the negative stereotypes of chess and chess players. I was also aware of the power of my own example in this regard, and in interviews and press conferences made a conscious effort to present myself as a well-rounded human being with interests beyond the sixty-four squares. This wasn't hard, since I was very much interested in history and politics, among other things, but as often as not, the articles about me in the mainstream press still fixated on angles that made me and other Grandmasters sound abnormal instead of like normal people with a particular talent.

There are practical and social considerations at work, as with every stereotype, and cultural traditions change very slowly. For better or worse, chess has been broadly categorized in the West as a slow and difficult game, reserved for smart people and bookworms at best, for misanthropic nerds at worst. This image is being refuted at the grassroots level thanks to the rising popularity of scholastic chess programs. After all, how can a game easily learned and greatly enjoyed by six-year-olds be difficult or dull?

In the Soviet Union, where I was raised and where chess was officially promoted as a national pastime, chess possessed less mystique and was treated as a professional sport. Soviet chess masters and instructors were accorded respect and a decent living. Nearly every citizen learned to play, and having such a large base of players meant finding more top talents, who were given special training. The game had deep Russian roots during tsarist times and, after the 1917 revolution, was prioritized by the Bolsheviks with the goal of endowing the new proletariat society with intellectual and martial values. As early as 1920, special military exemptions were given to strong chess players so that they could play in Moscow in the first Soviet Russia championship instead of being sent to the civil war front.

Years later, Joseph Stalin, though not much of a chess player himself, continued to support and promote the game as a way of demonstrating to the world the superiority of the Soviet man and the Communist system that produced him. While I cannot agree with that conclusion, you cannot argue with the results chesswise, as the Soviet Union completely dominated world chess for decades, winning the gold medal in eighteen of the nineteen Chess Olympiads in which it participated from 1952 to 1990. The world championship was held by five different Soviets starting with the first post-WWII championship contest in 1948 until 1972, and then again from 1975 until the impending collapse of the USSR, which allowed me to proudly exchange my Soviet flag for a Russian one hastily handmade by my mother, Klara, for my 1990 world championship match with Anatoly Karpov in New York City.

My own coming of age as a serious chess player in Baku, Azerbaijan, was benefited by this renaissance of political interest

in chess in the 1970s. The Soviet leadership had been put into a panic by the avalanche of victories by American Bobby Fischer over the leading Soviet players. When Fischer took the world championship title from Boris Spassky in 1972 it became a matter of national pride to find and train players who could retake the crown. This happened sooner than expected when Fischer declined to defend his title in 1975 and it was given to Karpov by forfeit.

I was recruited into the Soviet chess machine at a very young age and given coaching and a place in the school of former world champion Mikhail Botvinnik. The "Patriarch of the Soviet Chess School," as Botvinnik was rightly called, also figures into the history of computer chess. An engineer by training, Botvinnik spent much of his retirement from chess working with a group of Soviet programmers to develop a chess program, an endeavor that resulted in nearly complete failure.

And so to me, playing chess was a completely normal thing to do both as a career and as recreation. As a young star I was allowed to travel abroad for tournaments and there I encountered for the first time the strange prejudices about chess players as eccentric geniuses or mentally unstable savants. It made no sense to me at all. I knew dozens of elite players and they were, if not "normal," whatever that means, all quite different from one another. Even selecting only from the world champions, they ranged from the mellow musicality of Vasily Smyslov to the chain-smoking and wisecracking of Mikhail Tal. Botvinnik was a stern professional from dawn to dusk in his suit and tie while Spassky had the air of a bon vivant and would occasionally show up to his games in tennis whites.

My own nemesis for five consecutive world championship matches, Karpov, was considered ice to my fire, both on and off the board. His soft-spoken demeanor and dependable character matched his quiet, boa constrictor chess style, while my exuberance and outspokenness mirrored my dynamic attacking play. The only thing all of us had in common was being very good at chess.

AS OFTEN HAPPENS, a few prominent cases from fiction and from real life helped create a lasting stereotype. The American

chess champion Paul Morphy of New Orleans was also likely the first American world champion in any discipline after crushing Europe's best players on a tour in 1857–58. Soon after his hero's welcome he left chess to make his way as a lawyer, only to struggle and later suffer mental breakdowns that many attributed, without evidence, to the strain of his chess exploits.

The next American world champion, Bobby Fischer, is more recent and his decline is better documented. Fischer wrested the world championship title away from Boris Spassky and the Soviet Union in a legendary match held in Reykjavik, Iceland, in 1972. Partially due to Fischer's outrageous behavior leading up to and during the "match of the century," the international media coverage was incredible. Each game of the Cold War showdown was shown live around the world, even on American television. I was nine years old and already a strong club player when the Fischer-Spassky match took place and I avidly followed the games. Fischer, who had crushed two other Soviet Grandmasters on his march to the title match, nonetheless had many fans in the USSR. They respected his chess, of course, but many of us quietly enjoyed his individuality and independence.

After the match ended in a convincing victory for the American the world was at his feet. Chess was on the cusp of becoming a commercially successful sport for the first time. Fischer's play, nationality, and charisma created a unique opportunity. He was a national hero whose popularity rivaled that of Muhammad Ali. (Would the secretary of state have called Ali before a fight the way Henry Kissinger called Fischer in 1972?)

With glory comes responsibility and tremendous pressure. Fischer couldn't bring himself to play again. He spent three years away from the board before the precious title he had worked his entire life for was forfeited without the push of a pawn in 1975. Astronomical amounts of money were offered to bring him back. He could have played a match against the new champion, Karpov, for an unheard of $5 million. Opportunities abounded, but Fischer's was a purely destructive force. He demolished the Soviet chess machine, but could build nothing in its place. He was the ideal challenger and a disastrous champion.

When Fischer was lured out to play a so-called championship

rematch with Spassky in Yugoslavia, then under UN sanctions, in 1992, his predictably rusty chess was accompanied by vociferous anti-Semitic and anti-American paranoia. He surfaced infrequently after that, each time causing the chess world to cringe and brace itself. Fischer's recorded rants rejoicing over the terror attacks on 9/11 could have done serious damage to the image of chess and chess players had they been more widely heard.

Fischer died alone in Iceland in 2008, having been offered refuge by the host of his greatest triumph. I am still asked about him regularly and no, I never played him or even met him. Everyone is keen to diagnose everything from schizophrenia to Asperger's from afar, a foolish and dangerous practice to be sure. I will say only that I am certain it was not chess that drove Fischer mad, if indeed he ever was mad. Fischer's tragic downfall wasn't what happens when someone plays chess; it's what happens when a fragile mind leaves his life's work behind.

I CANNOT DENY that the many legends and metaphors around the game have benefited me and my reputation. As much as I like to be appreciated for my work in human rights, my lectures and seminars to business and academic audiences, my foundation's work in education, and my books on decision making and Russia, I recognize that "former world chess champion" is a calling card with few peers. And, as I explained in detail in that 2007 book on decision making, *How Life Imitates Chess*, my chess career shaped and informed my thinking in every way.

I was just twenty-two years old when I became world champion in 1985, the youngest champion ever. My precocity created an awkward dynamic for me and my interviewers, since few young stars in any discipline are aware of why they excel. Instead of talking mostly to the chess press about openings and endgames, suddenly I was receiving earnest questions about everything from Soviet politics to my diet and my sleep habits from *TIME, Der Spiegel,* and even *Playboy*. As hard as I tried, I'm sure my banal answers often disappointed them. There was no secret, only innate gifts, hard work, and discipline that I learned from my mother and Botvinnik.

During my professional career, there were a few moments

when I had the chance to step back and consider where chess fit in the greater arc of my life and, perhaps, in the world, but I rarely had the opportunity to dig into these matters for long. It wasn't until I retired from professional chess in 2005 that I had time to think more deeply about thinking and to see chess as a lens through which to investigate the decision-making processes that define every second of our waking lives.

The exceptions that occurred during my chess career are very much at the root of this book. My matches against computers, which spanned nearly the entire twenty years I spent as the world's top-rated player, allowed me to think about chess as something other than a competition. Battling each new generation of chess machines meant participating in a hallowed scientific quest, sitting at the nexus of human and machine cognition, and holding up the banner for mankind.

I could have spurned these invitations, as many of my Grandmaster colleagues did, but I was fascinated by the challenge and by the experiment itself. What could we learn from a strong chess machine? If a computer could play world-championship-level chess, what else could it do? Were they intelligent and what did that really mean? Could machines think, and what did the answers tell us about our own minds? Some of these questions have been answered while others are more passionately disputed than ever.

CHAPTER 2

RISE OF THE CHESS MACHINES

IN 1968, when the *2001* book and movie were created, it was not yet a foregone conclusion that computers would come to dominate humans at chess, or anything else beyond rote automation and calculation. As you might expect from the dawn of the computer age, predictions about machine potential were all over the map. Utopian dreams about the fully automated world just around the corner shared column space with dystopian nightmares of, well, pretty much the same thing.

This is a critical point to keep in mind before we criticize or praise anyone for their predictions, and before we make our own. Every disruptive new technology, any resulting change in the dynamics of society, will produce a range of positive and negative effects and side effects that shift over time, often suddenly. Consider the most discussed impact of the machine age, employment. The avalanche of factory automation, business machines, and domestic labor-saving devices that, starting in the 1950s, led to the disappearance of millions of jobs and entire professions, while skyrocketing productivity created unprecedented economic growth—and the creation of more jobs than had been lost.

Should we pity all the steel-driving John Henrys put out of work by steam engines? Or the office pool typists, assembly-line workers, and elevator operators who had to retool and retrain as technology replaced them by the thousands? Or should we consider them lucky for being able to leave behind such work, work that is tedious, or physically exhausting, or dangerous?

Our attitude matters, and not because we can stop the march

of technological progress even if we wanted to, but because our perspective on disruption affects how well prepared for it we will be. There is plenty of room between the utopian and dystopian visions of the fully automated and artificially intelligent future we are heading into at rapidly increasing speed. Each of us has a choice to make: to embrace these new challenges, or to resist them. Will we help shape the future and set the terms of our relationship with new technology or will we let others force the terms on us?

JUST AS I was fascinated by chess machines, generations of scientific luminaries have been fascinated with chess and with making machines that played chess. You might assume that the mathematicians, physicists, and engineers who formed the first wave of computer scientists and cyberneticists in the 1950s would hold little romanticism for a board game, even one they enjoyed passionately. And yet several of these eminently logical, scientific minds insisted that if a machine could be taught to play chess well, surely the secrets of human cognition would be unlocked at last.

This sort of thinking is a trap into which every generation falls when it comes to machine intelligence. We confuse performance—the ability of a machine to replicate or surpass the results of a human—with method, how those results are achieved. This fallacy has proved irresistible in the domain of higher intelligence that is unique to *Homo sapiens*.

There are actually two separate but related versions of the fallacy. The first is "the only way a machine will ever be able to do X is if it reaches a level of general intelligence close to a human's." The second, "if we can make a machine that can do X as well as a human, we will have figured out something very profound about the nature of intelligence."

This romanticizing and anthropomorphizing of machine intelligence is natural. It's logical to look at available models when building something, and what better model for intelligence than the human mind? But time and again, attempts to make machines that think like humans have failed, while machines that prioritize results over method have succeeded.

Machines don't need to do things the same way the natural

world does in order to be useful, or to surpass nature. This is obvious from millennia of physical technology and it applies to software and artificially intelligent machines as well. Airplanes don't flap their wings and helicopters don't need wings at all. The wheel doesn't exist in nature, but it has served us very well. So why should computer brains work like human brains in order to achieve results? As is so often the case in the crossroads of human and machine thinking, chess proved to be an ideal laboratory for investigating this question.

Beyond science fiction, the matter of whether a machine can be intelligent didn't really arise among technologists and the general public until the digital took over from the mechanical and analog in the 1940s and vacuum tubes gave way to semiconductors in the 1950s. It was as if ghosts could be imagined in the machines as soon as their processes could no longer be followed by the naked eye. Mechanical calculators had been around since the seventeenth century and key-driven desktop versions were produced in the thousands by the middle of the nineteenth. Programmable mechanical calculators were designed by Charles Babbage in 1834, and the first "computer" program for one was written by Ada Lovelace in 1843.

Despite the impressive sophistication of these machines, nobody seriously wondered if they were intelligent any more than they did about pocket watches or steam locomotives. Even if you had no idea how a mechanical device like a cash register performed, you could hear the wheels spinning. You could open it up and see the gears turning. As amazing it was for a machine to perform "mental" feats like logic and mathematics faster than a human could, there was little discussion of how it did it compared to how the human mind worked.

This was due partly to the relatively comprehensible nature of these early machines and partly because human cognition wasn't very well understood. We'd come a long way since the fourth century BC, when Aristotle believed the brain was a sort of cooling organ while the senses and intelligence resided in the heart, something to remember the next time you hear the phrase "learn something by heart." But it wasn't until toward the end of the nineteenth century, with the discovery of neurons, that the idea of

the brain as an electrically powered calculation device became possible. Before that, the concept of the brain was more metaphysical than physical, with Roman-era arguments about "animal spirits" and where, exactly, the soul resided.

Souls aside, it is generally agreed today that the mind is not greater than the sum of a being's physical parts and experiences. The mind goes beyond reasoning to include perception, feeling, remembering, and, perhaps most distinctively, *willing*—having and expressing wishes and desires. Brains grown in petri dishes from stem cells are interesting for experiments, but without any input or output they could never be called minds.

WHEN YOU LOOK BACK at the history of computers it seems like as soon as a machine is invented, the next step is to turn it into a chess player. For the first decades of computing, chess was always near the forefront. Along with the reputation of the game, many of the founding fathers of computation were dedicated chess players, so they were quick to see the game's potential as a challenging test bed for their programming theories and electronic inventions.

How do machines play chess? The basic formula hasn't changed since 1949, when the American mathematician and engineer Claude Shannon wrote a paper describing how it might be done. In "Programming a Computer for Playing Chess," he proposed a "computing routine or 'program'" for use on the sort of general-purpose computer Alan Turing had theorized years earlier. You can tell how early it was in the computer age that Shannon put the word "program" in quotation marks as jargon.

As with many who followed him, Shannon was slightly apologetic at proposing a chess-playing device of "perhaps no practical importance." But he saw the theoretical value of such a machine in other areas, from routing phone calls to language translation. Shannon also explained as well as anyone why chess was such an excellent test bed:

The chess machine is an ideal one to start with, since

- the problem is sharply defined both in allowed operations (the moves) and in the ultimate goal (checkmate);

- it is neither so simple as to be trivial nor too difficult for satisfactory solution;
- chess is generally considered to require "thinking" for skillful play; a solution of this problem will force us either to admit the possibility of a mechanized thinking or to further restrict our concept of "thinking";
- the discrete structure of chess fits well into the digital nature of modern computers.

Pay particular attention to point three, where Shannon bridges the gap between computer science and the metaphysical world in just thirty-five words. Since chess requires thinking, either a chess-playing machine thinks or thinking doesn't mean what we believe it to mean. I also admire his use of the word "skillful," since simply memorizing the rules and making random legal moves or regurgitating moves from memory (or a database) isn't how he defines thinking.

This insight echoes Norbert Wiener's note at the end of his seminal 1948 book, *Cybernetics*: "Whether it is possible to construct a chess-playing machine, and whether this sort of ability represents an essential difference between the potentialities of the machine and the mind."

Shannon went on to describe the various factors a chess program would need, including the rules, piece values, an evaluation function, and, most critically, the possible search methods a future chess machine could use. He described the most fundamental element of search, what we call the "minimax" algorithm, which originated in game theory and has been applied to logical decision making in many fields. Very simply put, a minimax system evaluates possibilities and sorts them from best to worst.

In games like chess, the program uses its evaluation system to rate as many variations as possible in the given position and puts a value on each position it sees. The move that returns the highest value is put at the top of its move list as the move to make. The program has to evaluate all the possible moves of both players, as deeply as time allows.

In an important contribution, Shannon outlined "Type A" and "Type B" search techniques. This is rather boring nomenclature, to be honest, and it's probably helpful to think of Type A as "brute force" and Type B as "intelligent search." Type A is an exhaustive search method that examines every possible move and variation, deeper and deeper with each pass. Type B describes a relatively efficient algorithm that works more like the way a human player thinks by focusing only on a few good moves and looking deeply at those instead of checking everything.

Think about selecting a chess move the way you choose a pastry at a bakery with a long glass case. You don't need to look at every single item in the case before you order, and even if you do, you don't need to ask what every item is and what its ingredients are. You know what type of pastries you like best, what they look like and taste like. You quickly narrow your choice down to a few favorites before taking time to decide among them.

But wait! You spy something in the corner of the case you haven't seen before and it looks quite delicious. Now you have to slow down a little, maybe ask the clerk for more information about it, and use your evaluation function to find out if it's something you'd actually enjoy. Why did it look delicious? Because it's in some way analogous to something you have had before and liked. This is also how strong human chess players start evaluating moves even before we start doing any calculation. The pattern-matching part of the brain has rung a bell to attract our attention to something interesting.

At the risk of overextending this analogy and also making you hungry, the bakery itself matters as well. If it's the same bakery you go to every day, your choice is nearly automatic, perhaps based on the time of day or what you're in the mood for. But what if it's a bakery you've never been to before, in a country you're visiting for the first time? You don't recognize anything; your intuition and experience are practically worthless. Now you have to use brute force, a Type A search, asking about each item, each ingredient, and trying samples before you decide. You may still get something you like, but it takes much more time to make a quality decision this way.

That describes a novice human chess player and, to a degree, a