LEE

or

The Delusions of Artificial Intelligence

Benjamin Labatut, 2023

Our earthly existence, since it in itself has a very doubtful meaning, can only be a means towards a goal of another existence. The idea that everything in the world has a meaning is, after all, precisely analogous to the principle that everything has a cause, on which the whole of science rests.

KURT GÖDEL, LETTER TO HIS MOTHER

Who of us would not be glad to lift the veil behind which the future lies hidden; to cast a glance at the next advances of our science and at the secrets of its development during future centuries?

DAVID HILBERT

Fryer Bungey (and) Fryer Bacon . . . with great study and paines so framed a head of brasse, that in the inward parts therof there was all things like as in a natural man's head: this being done, they were as farre from perfectione of the worke as they were before . . . that at the last they concluded to raise a spirit, and to know of him that which they could not attaine to by their owne studies.

ROBERT GREENE, *THE HONORABLE HISTORIE OF FRIER BACON AND FRIER BUNGAY*, 1589

Prologue

The legendary Emperor Yao invented the game of Go to enlighten his son, Danzhu.

Yao, born of the goddess Yao-Mu, one of the five mythical sage-kings of China, begat Danzhu with his most beloved concubine, San Yi, who birthed a vicious little boy. Danzhu prized cruelty above all the ten thousand things; when he was just a child, and the rays of the sun shone through the Green Yang Brightness side of the Hall of Light, he would rip off the wings of the birds at the Easter Palace, gouge out their eyes with a sharp stick, and watch them flail helplessly on the floor, dancing to the music of the bells that he would fasten with strings carefully wrapped around their talons. He was generally opposed to the order of the world and delighted in contravening the strict rules laid down by his father to guarantee peace in the four quarters of a kingdom so vast as to be likened to infinity. In spring, he would hunt pregnant mares; in summer he would trap and hobble young fawns so they would

grow crippled and disfigured, becoming easy prey for wolves—the only animals the young prince felt any love for, since they were as cruel and heartless as he. Fall was his favorite season; when the harvest began, he would cover his body in rotten leaves, splash mud on the white walls of the Comprehensive Pattern side of the Palace of Light, and wait for the executions to begin: criminals were rounded up, along with the depraved, the infirm, and the demented, and the boy would shiver with delight watching them be interrogated, tortured, punished, and then slain. His pleasure would reach fever pitch during blackest winter, when the sun was in the Tail; then he would kidnap young boys and girls, lure them into the Dark Hall side of the Northern Palace with promises of food and gold, and then rape and strangle them, leaving their broken bodies out in the cold, for the snow to bury and the wolves to gnaw on.

He was a beast that could not learn to read, write, paint, or play the lute, but he had a supernatural ability to win at games of all kinds, be they of chance or mental or physical skill, because he was sly and cunning as a fox, and could skin a cat with his eyes closed. The emperor's mother, Yao-Mu, told her son that the boy was not truly human, but a fallen star, and like all things that plummet from heaven, he was a harbinger of death, a message from the Jade Emperor himself, a plague visited upon mankind lest we believe ourselves to be above the gods. The boy was driven by an all-consuming rage, and lusted after the peace that only the void can bring. He was a death-bringer, a destroyer, bound to nothing save his own gravity, falling further and further into himself. Yao-Mu also revealed to the emperor the true meaning of the strange characters that the child bore on his forehead, marks that no amount of water could wash away: *Heaven bestows a hundred grains upon mankind. Man*

offers not a single good deed to recompense heaven. KILL, KILL, KILL, KILL, KILL, KILL, KILL!

The emperor was a bastion of moral perfection. According to the Bamboo Annals, he lived as though he were a simple farmer, and during his reign his brilliance pervaded the four quarters, shining in the hearts of all men. Throughout his lifetime, the sun and moon were as resplendent as jewels and the five planets hung like a string of pearls in the heavens. Phoenixes nested in the palace courtyard, crystalline springs flowed down from the hills and ran along the countryside carpeted with pearl grass, and rice crops were abundant and plentiful; in the capital city of Pingyang, two unicorns, those rare and wondrous omens of peace and prosperity, were seen locking horns beneath the purple blossoms of the wisteria, but fled on the very day that Danzhu was born, and had yet to return, for the boy began to organize hunting parties from the day he could hold a bow in his tiny hands, hunts that would last for weeks, as he had sworn never to rest until he had slain at least one specimen of every living creature, dragons and unicorns notwithstanding.

With the help of his mother, emperor Yao prayed to the Four Celestial Kings, the nine suns, the Blessed Queen of the West, and to Pangu himself, the first living being of this universe, to beg their permission to divide the entire cosmos into a grid of 19 rows and 19 columns, creating a board with 361 intersections, on which to play a game against his demonic child. He summoned Danzhu and explained the rules of this game, the most important of games: all the players had to do was to place stones, either black or white, on the intersecting lines of the grid, in order to conquer as much space as possible and encircle their opponent's stones. The player who garnered the most territory in this way

would be the victor. He placed the board in the boy's hands and told him that, when he felt good and ready, they would play a tournament, one that all gods, demons, heavenly and earthly creatures would witness. The emperor would use white stones made from clamshells, the child, black slate.

Whoever won would rule the world.

The Strong Stone

Lee Sedol, the Strong Stone, 9 dan master of Go, the most creative player of his generation and the only human being who has ever defeated an advanced artificial intelligence system in tournament settings, lost his voice when he turned thirteen.

In 1996, five years after moving to Seoul from the tiny island of Bigeumdo, located at the remote western edge of the South Korean peninsula, and six months after becoming a professional Go player, a strange affliction attacked his lungs. It inflamed his bronchial tubes and paralyzed his vocal cords, leaving him not only mute, which was to be expected, but also strangely incapable of reading and understanding certain words. The root cause of his temporary aphasia was never established, but he bore the consequences of that episode forever onward, since the disease (if indeed it was a disease and not merely the outward sign of a profound inner turmoil) left his bronchial nerves permanently paralyzed, so that to this day he speaks in an odd, shrill, wheezy, almost

toylike voice, as if somewhere inside him there remains a small, scared little boy, screaming to get out. "My parents were living in Bigeumdo Island and I was boarding with my older brother in Seoul, but he was in the army, so there was no one who cared for me. I didn't even have a chance to go through a proper medical checkup when I got sick," he recalled at a time when he was already considered a living legend, during one of the few interviews he ever granted, for he was so ashamed and traumatized by his abnormal voice that he was loath to speak in public for much of his career, and would even refuse to participate in the award ceremonies of the tournaments he won. While he later became one of the greatest Go masters of the modern era, back in the midnineties, he was still a thirteen-year-old child prodigy under an enormous amount of pressure: he trained twelve hours a day, Monday through Sunday, in the Go Academy founded by Kweon Kab-yong, a renowned teacher who coached many of Korea's best players. Kweon immediately recognized the boy's talent after seeing him win the 12th National Children's Go Competition, hosted by the Haitai Confectionery and Foods Company, in 1991. Lee was only eight at the time, and the youngest player to ever win that tournament, a contest during which he already displayed his signature style: wild, violent, and unpredictable. Master Kweon had coached thousands of young aspiring Go players throughout his career, but he sensed that there was something different about that boy, with his big ears, catlike eyes, and fuzz of a mustache peppered over his upper lip, capable of beating international professionals four times older than he was, and eventually he invited him to live in his own home. "I remember his round face and dark brown eyes. Since he came from an island, he was shy and tried to

draw attention away from himself. But he was unlike all the other children. His eyes shone with a different light," Kweon recalls.

Lee Sedol had learned Go from his father, a passionate amateur player who taught his five children the game even before they could read or write. Lee was the youngest of them all, but shot past his siblings, and neither they nor his father could win a single match against him after he turned five. Under Master Kweon, Lee would train incessantly, but he could not make friends; his classmates, who were in awe of what he could do with the black and white stones on the wooden board, would laugh and poke fun at how extremely naïve he could be, teasing him incessantly and nicknaming him the Bigeumdo Boy, for he was so rural that when he arrived in Seoul with only a bundle of clothes and a stuffed-toy backpack, he asked them, without a trace of irony, what kind of trees pizza grew on. While Lee was the only pupil living in the master's home, he would follow almost the same training ritual as the others: wake up at dawn to study the six thousand problems contained in the manual of his dojo, passed down in unbroken tradition for over two and a half thousand years; play several lightning games till lunch; and then sit down in silence to learn by heart entire matches played by the ancient masters. Among them was Lee's favorite, the "blood-vomiting game" of 1835, between Japan's reigning champion, Honinbo Jowa, known as the "latter sage," and the youthful contender Akaboshi Intetsu, who had challenged him to a three-day tournament that ended with the youngling on his knees, coughing up blood onto the board, after dominating the first hundred moves of the final game, when the old man was said to have played three successive stones in a style that had never been seen before, moves so strange and outlandish

that some members of the audience later swore that they had seen a ghostly presence standing behind the master's back, like a second shadow, and that it was this phantom, and not the man himself, who had laid down the black stones. Those three moves resulted in a comeback so sudden and overwhelming that the young challenger not only lost the game, he lost his life, one week later, having drowned in his own blood. Lee Sedol's main strength, the one that made him stand out against all other players, was his ability to create daring, almost unthinkable moves that would, to the untrained eye, seem totally chaotic, rash, misjudged, and even foolish, but that, as the game progressed, slowly revealed their unique logic, a skill he developed by spending as much time as he could practicing his capacity of "reading" the empty board, peering into the future so as to see all the branching paths of possibility that arose from the simplest positions.

"I want my style of Go to be something different, something new, my own thing, something that no one has ever thought of before," Lee explained, when his international renown and his status as a hero in Korea gave him enough confidence to begin speaking in public. By then, his talent was widely recognized, even if many of his old classmates, and the professionals who grew up competing against him on the Go circuit, agreed that he had not been an exceptionally aggressive player until his father died, when he was fifteen, and Lee began to develop the particular flair that would become his trademark and earn him the moniker Strong Stone. "His style of Go changed after his father passed away," said his friend Kim Ji-yeong, a Go player and TV anchor, "it became more dogged and powerful, angrier, impulsive, less predictable. It was like playing against a wild animal, or someone who did not even know the most basic rules of the game, and yet managed

to leave you completely broken and humiliated. I have never played anyone like Lee Sedol, not when I was growing up, or since then." While Lee remained shy and introverted, he was never modest. He became the youngest player ever to reach the highest level of the game—9 dan. His flashes of virtuosity, his habit of taunting and mocking his rivals before a match, with mean-spirited barbs aimed at undermining their confidence ("I don't even know that player's name, so how should I know his style?"), his recurring boasts ("I have no confidence in this game. No confidence in losing, that is"), and his almost uncontrollable bravado earned him as many fans as detractors. "I am the best, I have never been overshadowed by anyone," he said when asked who the greatest player in the world was. "When it comes to playing skills, I am behind no one. I want to remain a living legend. I want to be the first person people associate with Go. I want my games to endure, to be studied and contemplated as works of art." Risk defined his gameplay: while most top professionals avoid it at all costs and shy away from complicated and chaotic fights, Lee would seek them out from the very beginning, and flourish under the rarefied conditions that only he seemed to be able to take advantage of, jumping into battles without forethought, forcing his opponents into all-or-nothing scenarios that should have ended in utter disaster for him, but from which he escaped with such speed and effortless grace that his rivals would often quit from sheer exasperation. Although he would train assiduously, he relied on his creative talent above all things: "I do not think, I play. Go is not a game or a sport, it is an art form. In games like chess or shogi, you start with all the pieces on the board, but in Go, you begin with an empty one, you start with nothing, and then add black and white so that between the two players you create a work of art. So everything,

all the infinite complexity of Go, arises from nothing." While his mercurial character made him one of the most feared players in the entire world, it also often betrayed him, as he would become angry during a match, or his patience would fail in the endgame, so much so that he even abandoned an important tournament when it had just begun, not because he wasn't going to win (both the judges and his opponent thought that Lee was ahead) but because he felt bored by the way the match would invariably play out. While this level of disrespect toward an opponent was not common for him, he was well-known for shunning traditional expectations of what it meant to be a top-level player. Nor did he strictly adhere to the image of the wise oriental sage; during his only appearance on prime-time national television, he confessed to a crowd of unbelieving admirers, and an even more dumbfounded presenter, that he was a massive fan of soap operas such as *Goblin* and *Touch Your Heart*, which he would watch in one sitting, at twice the regular speed. When they asked him what he liked to do in his downtime, he said that he spent entire days listening to the all-female K-pop band Oh My Girl, whose songs "Remember Me" and "Secret Garden" Lee would hum to himself over and over, to the utter exasperation of his wife, Kim Hyun-jin, whom he married when he was twenty-four, and the great embarrassment of his beloved young daughter, Lee Hye-rim, the one thing that Lee prized as high as the game of Go itself. His millions of admirers could hardly believe that incredible moves such as the "broken ladder," which Lee used against Hong Chang-sik in 2003, contravening centuries of received wisdom that said, very clearly, that such a formation, in which one player chases the other across the board, was a rookie mistake that spelled certain death for whoever used it, were conceived and thought up while listening to the bubblegum tunes

of six teenage girls bopping around the stage in miniskirts. For Lee Sedol, however, that was nothing out of the ordinary—Go was like breathing to him, a process that he could not stop: "I always think about Go. There is a Go board in my head. When I come up with new strategies, I place stones on the board in my head, even when I drink, watch dramas, or play billiards." When he was asked if he regretted missing out on life by dedicating every waking moment to a game, or if he felt unprepared to face the challenges that would come at the end of his career, as he had no formal education to speak of, and had not even finished primary school, he replied that Go was, first and foremost, a way of understanding the world, as its endless complexity mirrored the inner workings of the mind, while its stratagems, puzzles, and seemingly unfathomable intricacies made it the only human creation to rival the beauty, chaos, and order of our universe: "If someone was somehow capable of fully understanding Go, and by that I mean not just the positions of the stones and the way they relate to one another but the hidden, almost imperceptible patterns that lie beneath its ever-changing formations, I believe it would be the same as peering into the mind of God." Understanding of the deepest nature was paramount to Lee, something that went far beyond winning or losing: he never stepped away from a game before he had comprehended every single move. "One time, he and I drank together until two in the morning, but after that he invited me back to his house, falling down drunk, to go over a game he had just won, and replayed every stone, white and black, because even though he had won the match, he said there was one move—made by himself!—that he didn't quite understand," said Kim Ji-yeong.

By the time he turned thirty-three, Lee Sedol had won the second-highest number of international titles in Go history and was widely

considered a virtuoso of the highest caliber. He had racked up eighteen international titles and thirty-two national championships and won over a thousand individual games, completely dominating the global circuit for the better part of a decade. Worshipped in South Korea, he became one of the highest-earning athletes in the country. "Lee Sedol is a genius of the century. When I look back now, I am proud of him. And I am proud of myself too," said his mentor, Master Kweon.

And then, at the peak of his career, in early 2016, Lee Sedol was challenged to a five-game matchup against the artificial intelligence system AlphaGo.

Brainchild

AlphaGo was the brainchild of Demis Hassabis, a wunderkind from North London who was four years old when he saw his father, a Greek Cypriot singer-songwriter and toy store owner, playing chess against his uncle, and asked if they could teach him how to move the pieces on the board. Two weeks later, neither of them could beat the boy.

Hassabis won his first tournament a year after that, even though he was so tiny that he had to stack a couple of chairs on top of each other and sit on a telephone directory just to see past the edge of the table. When he turned six, he won the London Under 8 championship, and three years later he was England's junior team captain, at a time when English chess was second only to the Soviet Union's. By his early teens he was a chess master, and in 1989 he became the second-highest-rated player for his age in the entire world, but while he continued touring the professional circuit for a number of years, and remained a top-level

competitor, neither his trainers nor his parents could have suspected that he had already decided to abandon his dreams of becoming the next Garry Kasparov to dedicate his considerable intellect to something that, at least to his mind, was far more important, so important, in fact, that it has the potential to change the course of humanity, a pivotal choice that he made after suffering a life-changing epiphany brought on by his most humiliating defeat.

Demis had just turned thirteen. He was a kind, exceptionally thoughtful boy with very large eyes and a wide smile that was perhaps too big for his face, which, coupled with his somewhat maniacal and apparently indefatigable energy, led his meanest classmates to compare him to Mr. Toad from *The Wind in the Willows*. However, it wasn't his oversized features so much as his outsized brain that made a lasting impression on everyone he met, one of his grammar school teachers writing that "the boy has a mind the size of a planet" on one of his end-of-term evaluations. Hassabis had taught himself to code on a Commodore Amiga that he had bought with his chess earnings, a luxury that his parents could never have afforded, since they were always struggling for money, constantly moving around, working odd jobs, starting small businesses that failed within a year, or buying and selling old, run-down houses in North London. During the first ten years of his life, Demis had lived in as many different homes, dragged from one school to the next, never able to find his place in the world or to develop close friendships. He filled that emptiness with a profound love of books, movies, and computer games, some of which he hacked to give himself infinite lives, while others he programmed himself and then tested out against his kid brother. When he was just eleven, he created his first artificial intelligence agent; while very limited it could play the game Reversi—

an extremely simplified version of Go—and Demis was astounded when his digital creation managed to beat his younger sibling five times in a row. Yes, his kid brother was just five at the time, and not the worthiest opponent, but what truly fascinated Demis was the fact that in creating his little AI he seemed to have externalized a small part of his own mind, as the program—which was so full of bugs that it kept crashing and overheating the computer it ran on—appeared to be endowed with the vestiges of a personality of sorts, if not exactly with a life of its own, something that arose less from the fact that it could play the game by deciding its own moves than because of its many flaws and quirks, the incomprehensible mistakes it made, and its tendency to stall, as if it were lost in deepest thought, when its logic circuits became entangled in strange loops that Demis, try as he might, could not unravel or fully exorcise.

Computers would take up much of Hassabis's life, but his first years were consumed by chess, and an almost uncontrollable desire to become not just a good player but the best who had ever lived, so he was truly delighted when, a couple of days after his thirteenth birthday, he received an invitation to fly to Liechtenstein and participate in a major international tournament, a more prestigious one than any he had played up to then.

Young Demis dispatched his first set of rivals with ease before being paired against the Danish champion, a middle-aged veteran who corralled and dominated him over a grueling eight hours that led to a highly unusual endgame: Hassabis had nothing but his king and queen, while his much more experienced opponent still retained a rook, a knight, and a bishop. The Dane bullied him for another four hours, with Hassabis straining his capacities to the limit while he feverishly

tried to avoid a series of deadly attacks, knowing that all his opponent needed was a single misstep on his part. He saw the chairs and tables emptying around him. All the other players filed out the door, accompanied by their parents and friends, until the massive hall, in which hundreds of men and women had been silently battling, was so empty that he could hear his own hurried breath echoing against the walls. The Dane finally cornered Hassabis's king, placing himself one move away from checkmate. Covered in sweat and utterly exhausted, Demis extended his hand across the board and resigned, but as he got up to leave, his rival burst out laughing. The boy had been fooled: he was so tired after defending himself for the entire game that he'd failed to see that all he had needed to do was to sacrifice his own queen for the match to end in a stalemate, a draw that would surely have felt like a victory to him after putting up such a long fight while trying to outmaneuver forces much stronger than his own. His forty-year-old opponent showed no grace in victory, jeering and cackling with his girlfriend, pounding his fists against the table while he showed her the way he had defeated the English upstart, clearly relieved at not having lost to a schoolboy. Hassabis had to do his best to keep from crying. He felt as if he were about to vomit and stormed out the door, pushing his parents aside, and did not stop running until he was lost in the middle of a field, with grass up to his knees.

Weak from lack of food, dizzy and light-headed, he fixated on that final move, his mind racing over and over through all the ways he could have avoided losing, with the Danish bastard's laughter resounding in his ears. Queen, sacrifice, stalemate, queen, stalemate, sacrifice, voices in the distance calling his name, a herd of cows, church bells, sacrifice,

a whole year wasted, stalemate, crows cawing under white pine, wet turds, bastard, threw it out, a strong musty smell, a poisonous species, shepherd is a wolf. Why had he lost like that? He knew that he was better than the Dane. The truth is that a part of his mind had been somewhere else. Even though he had trained for months, and awaited the tournament eagerly, he was, ever more so, eaten up by another, increasingly deeper obsession than chess, a fundamental question that would sometimes wake him up in the middle of the night and rob him of his sleep, leaving him there, sitting in darkness, reading science fiction sagas under his sheets with a small flashlight in his hand, wrecked by insomnia. While his sister and his brother slept soundly in their beds, Demis couldn't help but think about thinking. No matter what else he was doing, whether it was washing the dishes at home, doing his homework, or putting together broken toys from his father's store in Finchley Central subway station, he would think about his own thinking. What lay at the root of his strange intelligence? Why could he learn so fast? Why did numbers come so easily to him? And how did his brain come up with the moves and strategies that he could play on the chessboard? His parents were both normal, well, not really normal, they were bohemians and strange in their own ways, but when it came to mathematics, practically illiterate. His father dreamed of being a songwriter, and styled himself after his idol, Bob Dylan, while his mother, who was Chinese Singaporean, worked behind the counter at a John Lewis department store, selling high-end furniture that she herself could never afford. His younger brother and his sister were pretty ordinary too. He was the only odd one in his family, a freak of nature, one in millions. He had never really suffered from his exceptionality; he could behave and act

like any normal boy, but try as he might, he could not understand what it was about his brain that made him enjoy what most others considered boring, if not downright painful. But what truly bothered him was not his own remarkable mind, but all the minds that surrounded him, however limited in comparison. Why had evolution built us this way? Why were we burdened by consciousness, when we could have remained blissfully ignorant like all other life-forms on this planet, living and dying with such an Edenic lack of awareness that pain and pleasure were only ever felt in the present, and did not, like our pains and glories, stretch out from one day to the next, linking us all together in an endless chain of suffering? He had read enough books to know that in thousands of years of civilization, we had not moved an inch closer to understanding any of this. Consciousness remained an unsolvable puzzle, a dilemma that pointed toward the limits beyond which mankind may never tread. Demis could have accepted it were it not for the fact that, while it was true that mankind had managed to survive thus far without any semblance of true understanding, the future was now bleak, dark, and getting darker, as science—the crown jewel of our species—was so rapidly progressing that it would soon drive us off the edge, into a world for which we were woefully unprepared. It did not take a genius to realize that scientific breakthroughs were transforming every aspect of our lives, while leaving the most fundamental questions unanswered. Soon we would reach a breaking point. Our monkey brains had taken us as far as they could. Something radically new was needed. A different type of mind, one that could see past us, far beyond the shadows cast by our own eyes. There was no longer any time to waste playing childish, zero-sum games. Was that really a proper use of his brain-

power? Demis heard his parents calling him and started heading back, with a newly formed life goal already taking shape inside his head. He no longer wished to be the world chess champion. He wanted more, much more: he wanted to create a new mind, a smarter, faster, stranger one than any we had known. AGI: artificial general intelligence. The true son of man.

From then on, Hassabis worked tirelessly toward his singular goal, carefully following a twenty-year plan he sketched out for himself: He finished his A levels at fifteen and applied to Cambridge to study computer science. He won a place, but they told him that he was still too young to be admitted, and had to wait for a year. Instead of lazing about, he entered a competition that he saw in *Amiga Power* magazine, and landed a job in a prestigious computer game company, where he created the multimillion-selling video game *Theme Park*, making enough money to pay for his entire university career. After graduating at the head of his Cambridge class, he founded Elixir, his own gaming company, where he tried to simulate an entire country, populated by over a million individual agents whose aim was to overthrow a ruthless dictator by any means necessary. The game, too far ahead of its time, took five years to develop and was a complete failure, since it required computing powers far beyond what was available back then, but Hassabis was undeterred and soon found employment in another company, where he headed the design of a simulation that allowed users to play the role of an all-powerful deity lording over an island populated by warring tribes. After he had mastered programming and computer science, he moved on to the next phase of his plan: he enrolled as a PhD candidate in cognitive neuroscience at University College London, where

he became obsessed by two of John von Neumann's unfinished manuscripts—*Computing Machines and the Brain: On the Mechanisms of Thought* and *Theory of Self-Reproducing Automata*—and discovered a hitherto unknown connection between memory and imagination, listed by the journal *Science* as one of the top ten breakthroughs of 2007. Hassabis's investigation demonstrated that the faculties of memory and imagination share a common mechanism, rooted in the hippocampus. "My work was investigating imagination as a process. I wanted to know how we, as human beings, visualize the future, and then see what future computers will be able to conjure," he said after publishing his research. With a PhD under his arm, he moved on to computational neuroscience, working as a visiting researcher at MIT and Harvard, and somehow still had enough brainpower left over to win the Mind Sports Olympiad five times in a row, a contest that pits some of the smartest people in the world against each other in an Olympics-style decathlon that includes, among other games, chess, shogi, backgammon, poker, draughts, and bridge. By 2010, he felt he had acquired enough knowledge and experience in the necessary fields to put the central aspect of his plan into action: along with two of his closest friends from college, Shane Legg and Mustafa Suleyman, he founded DeepMind, a start-up whose stated goal was "to solve artificial general intelligence, and then use that to solve everything else."

During the first couple of years, funders would not touch DeepMind with a stick. Artificial intelligence was still in what specialists called its "dark age": after the initial enthusiasm that it generated when John von Neumann and Alan Turing first spoke of its possibilities, back in the 1950s, and the subsequent uptick among the scientific community when the IBM computer Deep Blue defeated the world's reigning chess

champion, Garry Kasparov, practically all interest had fizzled out. While computational capacity, cellular technology, and networks had increased in power by leaps and bounds, there seemed to be no way to even begin to make computers behave intelligently. Worse, DeepMind was not like other start-ups: it did not offer a product; it did not want to build up a user base, serve up ads, or mine data; it was a pure research company with a radically ambitious goal and no short-term returns to offer to potential financers. No investor would even speak to Hassabis till he somehow managed to land one of the biggest venture capitalists of them all, Peter Thiel, cofounder of PayPal and Facebook's first outside investor. Hassabis studied him for weeks, and then approached him in a crowded room in California; having found out that Thiel was a chess enthusiast, he asked him, point-blank, if he knew why the game was so utterly fascinating. Thiel perked up and focused on the short, bespectacled young man who was balancing nervously back and forth, and Hassabis quickly told him, knowing that he had no more than a couple of seconds to retain the billionaire's attention, that it was due to the exquisite balance of the bishop and knight across the set of all positions: their vastly different mobility created a dynamic asymmetric tension that had profound consequences throughout the game. With Thiel seduced, money started pouring in: Elon Musk from Tesla and Jaan Tallinn from Skype invested heavily enough to prod Google into making a bid to buy Hassabis's company in 2014, for over $625 million, pumping the company with money while leaving creative control in the hands of its founders.

After the acquisition, the biggest payout to that date for a British science-based start-up, everyone wondered what the DeepMind people would do to make good on their promise of solving artificial general

intelligence. They had not even begun hiring their full team when already wild rumors about the rise of the AI apocalypse were flying around the internet. Everyone wondered where they would start. Would they train an artificial intelligence to diagnose cancer? Would they focus on nuclear fusion? Would they try to create a hitherto unimaginable means of communication? The arguments raged among specialists, each one casting bets on where gold was more likely to be struck, but Hassabis didn't have a doubt in his mind: They would begin with a game, the most complex and profound one that humankind has ever conceived.

The game of Go.

AlphaGo

In 1997 computers became superior to human beings at chess. That year, grandmaster Garry Kasparov, the number one player in the world, was challenged by IBM to face Deep Blue, a chess-playing supercomputer, a challenge that the Russian virtuoso accepted without hesitation, as he had already beaten an earlier version of the same program a little over thirteen months before, in Philadelphia, and felt absolutely confident that computers were still decades away from anything resembling human-level chess play. The rematch was set up in New York, during the month of May, with massive billboards advertising the tournament on the city streets and a huge global audience anxious to see the contest between man and machine. Kasparov had never lost a single match during his entire trailblazing career. For over two decades he had reigned supreme, widely considered the best player of all time; he did not simply win, he crushed his opponents, with a

flamboyant, creative, and highly aggressive style of play, so it came as a titanic shock when the IBM computer dealt him not only his first-ever defeat, but one that Kasparov suffered without the slightest trace of dignity. After the tournament, he experienced a profound mental breakdown, and was utterly incapable of playing for an entire year. However, what broke his mind and threw him into the deepest crisis of his adult life was not the loss in itself, but rather two particular moves that occurred during his second game against Deep Blue.

Kasparov had won the first game, but now, in the second, with hundreds of photographers and cameras fixed on him with unblinking intensity, he was on the defensive, clearly dominated by the computer. It was performing much better than anyone had expected, so the grandmaster decided to set a trap that he knew most if not all chess-playing programs would fall for, as it offered a clearly advantageous position that would seem utterly irresistible to a hard, logic-driven reasoning system such as he imagined the computer employed. But Deep Blue refused to take the bait. Instead, it made a brilliant play, leaving Kasparov to wonder if he was really facing an artificial intelligence or battling against an unseen human player, hidden behind the scenes like the Wizard of Oz, a grandmaster such as himself who could spot and avoid the snare that he had so carefully laid out, and counterattack with such style. His suspicions boiled over when Deep Blue made a shocking mistake just a couple of moves later. Kasparov couldn't understand. How could the same program play like a grandmaster and a two-bit amateur during the same game? While the audience waited eagerly for the Russian champion to make a decisive comeback after the computer's blunder, Kasparov couldn't stop doubting himself and his opponent. Had IBM brought in someone to advise them? That first

move had been a stroke of genius, something that perhaps only a handful of players in the entire world could have thought up. It reminded him of Anatoly Karpov, his greatest foe. Was he behind the curtain? Was Karpov in league with IBM? Or had they brought in an entire team, a legion of grandmasters sick and tired of his supremacy, paid by that computer company's limitless pockets, bent solely on destroying him? But if that was the case, how to explain the second move, the blunder? Or had that also been on purpose, intended to throw off his suspicions, not an error in the least but a ruse, a daring gambit to hide the multiple heads of the hydra and veil the true nature of his enemy? While the clock ticked, Kasparov was unable to get out of his head and back into the game. He kept wringing his hair, rubbing his hands all over his face, and then, as the endgame neared, he simply got up and stormed off the stage, forfeiting, even though almost anyone could see that in just a couple of moves he would have been able to force a stalemate. Kasparov ended up losing or tying the remaining four games and gave up his crown. In the months that followed, he became completely despondent and increasingly paranoid, claiming that there must have been "a human mind inside the machine," and demanding that IBM give him access to the hardware and software. He insisted on seeing the machine's logs—he wanted to be able to peer into its inner workings so as to understand how the program had reached its decisions. He also wanted to see what other games Deep Blue had played. It was only fair, he argued; after all, IBM had access to thousands of his own games, and limitless computing power to analyze his strategies, openings, and preferred moves, while Kasparov had been blind in both eyes, as he had never witnessed a single match played by the computer, nor could he peer at his rival's face in search of truth. The tech giant refused,

however, and even went as far as dismantling the computer entirely and scrapping the project. The Russian champion took a year off to recover, incapable of accepting what had happened to him, but he came back stronger than ever and kept on winning as before. He quit chess altogether in 2005, still ranked as the world's best player, still at the top of his game, and still obsessed with Deep Blue's incomprehensible behavior. Years had to pass before one of the IBM programmers involved in that project confessed that the flagrant mistake that Deep Blue had made during that fatal second game, which had caused Kasparov's nervous collapse, had been due to a bug in the software: unable to calculate an optimal move, the computer had simply chosen one at random.

While it is now generally accepted among the chess-playing community that the 1997 version of Deep Blue was considerably weaker than Kasparov, and that the Russian was defeated by his own inner demons, its contemporary successors, such as Fritz, Komodo, and Stockfish, have evolved far beyond our human capabilities, becoming wellnigh unbeatable. All these programs play chess in a manner that is very different from us. They don't rely on creativity or imagination, but select the best moves through sheer number-crunching and raw computing power; while the average professional player can see some ten to fifteen moves ahead, these algorithms are capable of computing two hundred million positions per second, some fifty billion in just over four minutes. This approach, in which the computer runs through every single possibility arising from each move, is called, appropriately, brute force. While a human player uses memory, experience, high-level abstract reasoning, pattern recognition, and intuition to cast his or her mind over the board, a chess engine does not really understand the

game at all, it simply uses its power to calculate and then makes a decision following a complex set of hand-crafted rules laid down by its programmers. Each time its opponent places a piece on a black or white square, the computer constructs a search tree consisting of every possible future arising from that particular configuration of the board; the tree keeps on growing and branching out till it reaches the end of the game, and the computer simply selects between its many limbs the outcomes that it considers most advantageous. With each new move comes a different tree, as the game changes and evolves constantly, but with enough power, the computer can look so far into the future as to remain a step, if not several thousand steps, ahead of any human opponent.

The game of Go, however, is very different.

Its vast complexity makes brute-force search unviable. While in a game of chess you have about 20 possibilities for each individual move, in Go you have over 200. If an average chess match ends after some 40-odd moves, a single game of Go requires more than 200. After the first two moves in chess, there are 400 possible interchanges; in Go there are close to 130,000. The board itself is much larger in the oriental game—19 by 19 squares—with its western counterpart limited to a universe of just 8 by 8. Due to all of the above, the combinatorial space—the size of the tree that a computer would have to generate to see all possible game configurations arising from each move—is simply gargantuan. Also, while the total number of possible chess games is somewhere close to 10^{123}, which is a one followed by a hundred and twenty-three zeros, the number of all possible Go games is almost unimaginably larger: over 10^{700} potential games. The number of legal board positions—the unique configurations of stones that can arise from one

player facing off against another—is so large that it was not clearly established until 2016:

208,168,199,381,979,984,699,478,633,344,862,770,
286,522,453,884,530,548,425,639,456,820,927,419,
612,738,015,378,525,648,451,698,519,643,907,259,
916,015,628,128,546,089,888,314,427,129,715,319,
317,557,736,620,397,247,064,840,935

If one were to consider all theoretically possible games—including ones that would never take place in the real world, since they include completely irrational, fanciful matches—the total number defies comprehension: it exceeds a googolplex, $10^{(10^{\wedge}100)}$, a figure so large that it is physically impossible to write down in full decimal form because doing so would require more space than is available in the known universe.

But that is not where Go's complexity ends.

In Go, all pieces have the same value; there are no castles or pawns, no knights or rooks, no kings or queens, simply black and white stones of the same exact worth. While you can easily program a chess-playing computer to distinguish what the intrinsic value of the queen is in relation to a knight, a bishop, or a pawn, in Go the weight of each stone has to do with its position on the board, and its relationship with every other stone, as well as with the intervening spaces on the grid. Telling a good move from a bad one is highly subjective; professionals feel out positions, they use their intuition and instinct to decide where to place the next stone. They train for years to be able to oversee the entire board, to detect rising and falling patterns, and to distinguish configurations of stones that are common to almost all Go games, groupings that beginners have to master before they can even sit at the board. These formations or clusters have highly evocative names such as "eyes," "ladders," and "bamboo joints." Go players speak of groups of stones as "alive," "dead," or "unsettled." There are stones that cut, stones that kill, and stones that commit suicide. Players must be able to read the board, peering into the future with their mind's eye to determine if a group of stones will live or die. They must know how to form a harmonious position by alternating high and low attacks. They must distinguish between the thickness and lightness of their formations to decide if they need to be reinforced, or can withstand enemy attacks; they must learn to invade, to counter, and to capture; they must weigh the *aji*, the potential of each individual stone, tread the fine line of *korigatachi* to avoid being completely surrounded, and learn when to take the initiative—*sente*—or play on the defensive, *gote*; they must decide when to fight head-on and bite down on a position or to gambit and steal away to some other corner of the board, exacting *tenuki*. They must distinguish between real and false eyes. They must learn to play at the Star point, the Origin of Heaven, and at the Large, High, and Small eyes. They must develop their *kiai*, an aggressive fighting spirit that lets you control the flow of play, without giving in to irrational greed. They must learn to monkey jump, to peep, to pincer, to shoulder hit. They must learn to play *kikashi*, a forcing move that enlivens through sacrifice. All of that, and much more, must be achieved with the simple laying down of successive stones, to maximize the boundaries of your territory while minimizing your opponent's.

Played continuously for over three thousand years, Go is humanity's

oldest and most studied game. Schools in China, Japan, and Korea have amassed a truly astounding body of wisdom that has been passed down through generations, encoded in a series of swift proverbs that all players know by heart, warnings for avoiding common pitfalls or amateurish mistakes, while trying to whittle down the seemingly endless possibilities that the board offers.

Don't make empty triangles.

Don't peep at a cutting point.

Don't peep at both sides of a bamboo joint.

Even a moron connects against a peep.

Play fast, lose fast.

Don't play 1, 2, 3—just play 3.

If you don't understand ladders then don't play Go.

If you have lost all four corners then you have lost.

If you have secured all four corners then you have lost.

In the corner six stones live but four stones die.

Never try to cut bamboo joints.

Strange things happen at the 1-2 points.

Strike at the waist of the knight's move.

Learn the eye-stealing tesuji.

The weak carpenter's square is dead.

Your enemy's key point is your own key point.

Greed cannot prevail!

There is death in the hane.

For centuries, Go was considered an art form more than a game. In China, it was one of the four disciplines that any nobleman had to master. Top players throughout the ages have never depended on calculation to decide their moves, but on sensibilities that border on the artistic, or the mystical. The game was considered to be too profound, too complex and labyrinthine, to ever yield to a computational approach. And then, in 2016, Hassabis and his team at DeepMind shocked the entire Go-playing world, and stunned their peers in the AI community, when they published an article in *Nature* showing that they had managed to build an artificial intelligence agent that not only played Go but had actually beaten the reigning European champion, Fan Hui. It was the first time a program had ever defeated a professional Go player, and hundreds of computer scientists started poring over the details of the paper, and the games DeepMind published online, scrutinizing every move to see if that holy grail of artificial intelligence had really been achieved, so far ahead of its time. Before DeepMind's paper, there had been a strong general agreement that artificial intelligence would need at least another decade before it could even begin to compete against human beings in Go. And yet, somehow, Hassabis and his team had done it. Their program, AlphaGo, had pummeled Fan Hui, winning all five games they played against each other. It was a stunning achievement that caused an immediate blowback: Go fans from around the world mocked and ridiculed Fan Hui, saying that he may be the champion in Europe, but he was only a 5 dan professional, and nowhere close to the

world's top players, the 9 dans, who mostly lived in Japan, China, and South Korea. They picked apart the games, pointing out every single mistake that Fan Hui had made, and declared that he was not a worthy adversary, and that the whole exercise was flawed. To the people at DeepMind, it quickly became clear that their agent needed a much better opponent.

And there was no one better than Lee Sedol.

A Sharp, Sudden Invasion

Lee Sedol picked up a black stone from his bowl and placed it on the upper right-hand corner of the board.

Outside the players' room, on the sixth floor of Seoul's new Four Seasons Hotel, over two hundred journalists from all around the world watched the viewing screens, sitting alongside expert commentators who were eagerly waiting to analyze every move for the more than 100,000 people who had tuned in to the official YouTube feed of the game and a television audience of sixty million watching the seven networks from Japan, China, and South Korea that would live-broadcast the entire match. Lee Sedol was sitting in the game room—a spare accommodation with nothing but a table, two black leather chairs, some cameras, and the three judges presiding over the match from an elevated platform at the back—safely isolated from the bustle outside after walking down the marble corridors of the five-star hotel, lit by enormous golden chandeliers. Across from him, on the other side of the board, sat Aja Huang, a senior programmer from DeepMind charged

with playing the moves that the AlphaGo artificial intelligence agent would select, after seeing them appear on a small computer terminal to his left; a couple of years later, after all five games had been played, after Lee Sedol had shocked the world by announcing his sudden retirement in his hollowed-out, breathless voice, Lee could not help but poke fun at Huang's uncanny stillness, which he maintained throughout the entire match, which lasted five days. "Aja Huang. Just thinking about him makes me laugh. He is truly a remarkable man. He is just a human being, right? AlphaGo is the AI. But I almost thought that he was the artificial one. Because it's not just that he had a poker face, he was like a puppet. He never once went to the bathroom, never left his seat, not once. And he would take these tiny sips of water, really tiny sips of water, which looked incredibly quaint and weird. I didn't know if it was water, because he just wet his lips, like a robot, or an animal at a waterhole. And his movements were really slow, completely deliberate, with great patience and precision. And he never made eye contact with me. Not once! I kept looking at him and thinking, *Who is he really?* It was like playing Go with a robot, an automaton, a heartless, unfeeling zombie, or a complete simpleton, a fool. Later I found out that he wasn't allowed to go to the bathroom. The people at DeepMind would not let him. He also wasn't allowed to emote or show feelings of any kind, so as not to give anything away. But even so, if you see that in a person, if someone behaves like that in front of you, you feel very uncomfortable. More than uncomfortable! I wanted to scream at him, or get up, walk over, and pinch him, just to see if he was real," Lee recalled during a prime-time television show interview, casting his mind back to the very first day of that fateful match, and the very first move made by the computer, which took an unreasonably long amount of time.

Opening moves in Go tend to be very quick. The board is empty, there are no stones at all, just the endless grid, bursting with possibilities. Commonly, a player will stake out a territory near the upper corner, and his rival will place his stone on the opposing side. There is not much to think about, it is usually just a matter of seconds, but in the Four Seasons Hotel, after Lee Sedol had laid down his opening—a slightly unconventional one meant to get away from the computer's knowledge base—the clock began to tick and Aja Huang stared at his computer screen, then at Lee's black slate stone lying there on the board, its flattened surface shining under the glaring studio lights, and then turned back to his screen, where all he could see were the lines of the grid and a tiny spinning ball that indicated that AlphaGo was still calculating to reach a decision. Five, ten, fifteen, twenty seconds went by and the anxious South Korean commentators began to make jokes about AlphaGo, while inside DeepMind's control room, situated two floors down from the game room, all twenty technicians, including Demis Hassabis and his colleague David Silver, the head researcher of the AlphaGo project, began to panic. Had the program stalled? Had it crashed? What the hell could be taking so long! Were they going to shit the bed in the first move of the game?

When almost thirty seconds had passed, Lee started making faces. Surely this had all been a mistake, a monumental waste of his valuable time. He had studied the games that AlphaGo had played against Fan Hui, the European champion, and had seen nothing special in either of them. Compared to him, Fan Hui was not even an amateur. If they had faced off against each other, it would have been as if a child (and not a particularly gifted one) had played against Go Seigen, the legendary Japanese master. Lee had also been unimpressed by AlphaGo. Yes, it

could play the game, even with a certain flair that was uncommon in computer programs, but it was still nowhere near his level. Google, DeepMind's parent company, had put forward a million-dollar prize for the winner of the match, and many people who analyzed the Fan Hui–AlphaGo matches had said that it was like giving that money away to Lee. In South Korea, professional Go players joked that they were envious, that surely it was the easiest money a top-level player could ever make. Everyone was convinced that the human would win.

Lee shot mocking looks at the camera and at Aja Huang, who was sweating in his seat as he tried to stay calm during that long pregnant pause at the start, thinking, perhaps, of what Lee had said during the inaugural press conference, held in the glitzy sixth-floor ballroom that had been repurposed to house the enormous number of national and foreign correspondents who occupied every square inch of that place: "There is a beauty to the game of Go, and I don't think machines understand that beauty. I believe human intuition is too advanced for AI to have caught up yet, so I am not worried about if I will win or not. What worries me is if I will win five to zero, or four to one." After more than a minute had gone by, a white circle appeared on Huang's computer screen. The programmer picked up a stone from the bowl in front of him and set it down neatly, with a smart click, at the opposite side of the board, at the same height as Lee Sedol's stone, where almost every human player would have done so.

What followed were several plays in quick succession, and after some twenty-odd moves, nobody seemed impressed by AlphaGo's performance. Some commentators were even repulsed after a particularly uninspired white stone laid down by Aja Huang. "This program really

needs a good teacher who will knock it about the head and bestow some wisdom after playing such a bad move. Everybody just knows that this move isn't good at all . . . These first white moves are obviously not optimal and look like beginner's mistakes," quipped the Chinese 5 dan professional player Guo Juan during her live commentary, shaking her head in clear disapproval. Throughout the entire opening of the game, Lee Sedol was unmistakably in the lead, but then, two hours in, Huang placed white stone 102 on the tenth line, at the middle of the board, two squares from the left edge of the grid, and everything changed.

It was a sharp, sudden invasion into Lee's territory. With a single stone, AlphaGo created several complicated positions, setting off fights across the entire board. It was exactly the type of viciously aggressive move that Lee Sedol had become famous for, and the Bigeumdo Boy could hardly believe what he was seeing. His jaw dropped and hung open for a cartoonish twenty seconds during which he remained bolt upright, with both arms dangling at his sides as if he had lost all muscle control. Completely flabbergasted, he began rocking back and forth in his chair, looking like an emaciated Playmobil toy, with his loose-fitting suit and bowl haircut. Slowly, he started to smile and leaned back, bringing the palm of his hand to the nape of his neck, where he scratched three circular moles he had there, set in a skewed triangle pattern and that look for all the world exactly like tiny ceramic Go stones. He would exhibit that same nervous tic many times during the course of the match, but on that first occasion he quickly removed his hand from his neck and then leaned forward over the board while a host of emotions washed over his face: shock, disbelief, and puzzlement, eventually leading to fear, then amusement, then something akin to sheer joy. How could a

computer have played such a bold move? he would ask one of his friends after the match was done. In that moment he simply couldn't understand what he was looking at. This was a wholly different level of play. It was nothing like the AlphaGo that had beaten the European champion. But how on earth could the algorithm have improved so much in so little time? Those games had taken place only five months before. Lee thought about his next move for over ten minutes, frowning, crossing and uncrossing his feet, squinting his eyes, cupping his face in his hands, shaking his head now and again in sheer disbelief, and then becoming absolutely still, eyes fixed on the board, before placing his stone right next to the one that AlphaGo had played, knowing full well that the tide had turned, as an entire swath of territory that had been squarely in his hands was now completely destroyed. Eighty moves after that, Lee Sedol picked up a white stone—not the black ones he was using—and laid it down in the middle of the board, resigning in the politest way possible.

A Thing of Beauty, Not of This World

When future historians look back at our time and try to pin down the first glimmer of a true artificial intelligence, they may well find it in a single move during the second game between Lee Sedol and AlphaGo, played on the tenth of March 2016: move 37.

It was unlike anything a computer had ever done before. It was also different from anything that a human being had ever been known to consider. It was something new, a complete break from tradition, a radical departure from thousands of years of accumulated wisdom. The people who saw it, whether live at the Four Seasons Hotel in Seoul or transmitted via the internet, unwittingly caught a glimpse of a future that is rushing wildly toward us, for now perhaps still distant, but already affecting our present in myriad ways. It is a future that inspires hope and horror: some believe we should welcome it with open arms, while many others are convinced that we should do everything in our power to ensure that this mad dream remains safely beyond our grasp,

forever inaccessible, even if its first echoes have already rung out from a slate stone laid down on a wooden board by a human hand following the instructions of an intelligence that may one day rival our own.

AlphaGo's victory during the first game against Lee Sedol stunned the world, but many players and commentators were unimpressed. Lee, they said, had made several childish mistakes and had not played to his usual standard. The machine had performed better than anyone had expected, but it had not made any truly earth-shattering moves. It was impressive, yes, but uninspired. Like its chess-playing forebears, AlphaGo was clearly efficient and powerful, but there was no beauty to its game, even if its aggressiveness and fighting spirit surprised both Lee and the Go community at large. While almost no one had the same unwavering confidence in the South Korean champion as before the first game, everybody was still betting on him to take the match, and some went as far as saying that the victory achieved by the DeepMind program had been nothing but a one-time fluke, an anomaly that Lee would surely redress during the encounters to come.

The South Korean master, however, did not feel that way.

The first game had shaken him to his core. He could not understand the incredible leap forward that the algorithm had achieved in such a short span of time. It had taken him more than two decades to develop his unique skills, and AlphaGo had beaten him, when just four months before, during its match against Fan Hui, it had played like a middling professional, someone Lee could have annihilated without strain. During the first game, Lee had followed his signature style, but now he was scared. If he lost the second game, it meant that he would have to win the remaining three in a row to avoid defeat. In the press conference at

the end of their first encounter, he dialed back his bravado: "I didn't think that AlphaGo would play the game in such a perfect manner. But I have won many world championships and losing one game will not affect my playing in the future. I think it's fifty-fifty now," he said while his mentor, Kweon Kab-yong, nibbled his fingernails and paced nervously among the members of the media. On the eve of the second game, there were twice as many reporters, and Lee could feel the enormous pressure of having to represent the whole of humanity bearing down upon him. Clearly worn out from the physical and mental strain of the previous day's game, he walked out of his room wearing a loose-fitting black suit and a light blue shirt that seemed two sizes too big for him and made him look like a skinny high school student. He would only appear more frail as the tournament progressed—he lost almost eighteen pounds during preparation and play. On his way to the pre-game photo shoot he smiled at the people who cheered him on—*Go, Lee Sedol! Go fight, Lee!*—surrounded by five guards who waved the crowds aside. While he waited for the lift he kept glancing at his watch, an expensive, heavy-looking model that dwarfed his scrawny wrist and hung there like the shackle of an unseen chain, weighing on his arm. As the cameras flashed around him, he seemed to be a world away, lost deep within himself; he would close his eyes as if in prayer, then suddenly frown and pinch the bridge of his nose, as though he were suffering a splitting migraine. His young daughter ran up and hugged him before he entered the game room, burying her face in the pit of his arm. Lee knelt down and she snuggled against him, but it was hard to tell if it was her father who was consoling her, or if she was trying to give him what little strength she could. When it was time to begin, Lee's wife, Kim

Hyun-jin, came and gently pried them apart, so that Lee could enter the game room alone and focus solely on the board. It was his time to play white.

He used a wholly different approach, playing an uncharacteristically cautious opening. His first couple of stones avoided any violence as he sought to establish a firm base. He pondered every move with enormous care, having by then realized that his sudden changes of pace, so useful for throwing off his human opponents, were pointless against an unthinking, unfeeling machine. As was his custom, he drank coffee throughout the game, his staff refilling his cup as soon as it was empty. He was also well-known for smoking, and the organizers had set up a particular arrangement for him to be able to smoke outside the hotel, even during the game, in an open-air terrace on the upper floors, where he could pace and think by himself while enjoying a full view of Seoul's Gwanghwamun district, with its wall of towering skyscrapers and the great green mountains beyond. The stones began to build up on the board, at a turtle's pace: after AlphaGo played black 13, Lee sank deep into thought and then declined to attack a group of stones that were beginning to amass on the lower right corner, biding his time and splitting territory on the opposite side. The commentators immediately noticed his unwillingness to engage AlphaGo and criticized his attitude: "Lee seems very tense. My guess is that he didn't sleep last night," said one of the South Korean reporters as the game plodded along, adding that Lee was being overly cautious, as every now and then AlphaGo would play amateurish, or even nonsensical-looking, moves that Lee seemed to be unwilling, or unable, to capitalize on. "Those last two moves make me doubt AlphaGo's ability," said a Chinese commentator after one particularly slack move by the computer. "But we have to stay

alert," he added. "AlphaGo is hard to understand." At black 15, the DeepMind computer played a "peep," a forcing move that any Go teacher would deride as crude and uninspired, but which Lee Sedol failed to respond to, continuing to proceed with the greatest caution. His previous experience had clearly left him shell-shocked and overly wary, an attitude that led several of his fans to begin to complain on the YouTube feed, writing that Lee was betraying his essence and forgoing the playing style that had made him a legend. Even his mentor, Master Kweon, had to admit that his star pupil was in trouble, saying to a reporter, "Lee Sedol is playing in a completely different style from his usual one," while also reflecting that the Strong Stone was at the center of global attention during a truly historic moment, and that while his nickname may have implied it, Lee was not made of stone. It was easy enough for outsiders to criticize Lee Sedol's attitude, but the truth is that no one really knew what was going on inside AlphaGo's strange algorithm, or what it was truly capable of. Had that last move—black 15—really been so crude and amateurish? Even the programmers at DeepMind were completely in the dark: AlphaGo made its own decisions, fully unsupervised; they simply watched it play. Demis Hassabis had explained as much ahead of the match: "Although we have programmed this machine, we have no idea what moves it will come up with. They are an emergent phenomenon from its training. We just create the data sets and the training algorithms. But the moves AlphaGo then comes up with are out of our hands, and they are much better than the ones we could come up with. The program is rather autonomous in its nature." The following fifteen moves were all pretty standard: when AlphaGo's black stones connected at 21, Lee nodded as if to reaffirm his choice to avoid conflict and play on the left side of the

board. By move 30, the game remained balanced, with AlphaGo's inner evaluation function setting its odds of winning at 48 percent. The machine prevented Lee from invading a corner and extended its forces on the third line with a short fight developing and then simmering down again. AlphaGo enclosed a corner; Lee hesitated briefly and then approached his opponent's stones from below. Both sides played normally, without any upsets or excitements, until Lee placed white stone 36.

Aja Huang looked at his monitor, picked up a black stone, and placed it below and to the left of a solitary piece that Lee had just laid out near the middle of the board. It was a "shoulder hit" on the fifth line, a type of move meant to decrease the potential of your enemy's territory, but it was unlike anything seen before in competitive play. Move 37 went against everything that Go players hold to be true. You simply do not shoulder hit on the fifth line. It was so outrageous and counterintuitive that when Aja Huang played there, the commentators, the audience, and even the judges thought he had put the stone down by mistake. Because no human being would ever dare to play like that. It is not simply considered a bad move, it has been reviled and derided by the great masters and the thousands of volumes on Go written during more than three thousand years of continuous play. But you don't have to be a grandmaster or a great sage to realize that you should never shoulder hit on the fifth line—even children and beginners know not to play there, as most times it actually helps your opponent gain ground! It looks bad and it is counterproductive, but more importantly, it *feels* bad to players, as it is almost completely impossible to estimate its future consequences across the board. But AlphaGo did not care about any of that, and Aja Huang, who was a competent Go player himself, sat there

after placing the stone, trying to hide the fact that he was as flabbergasted as everyone else by the algorithm's choice, and even felt ashamed of having been made to play there. Very few people were able to see its potential. All the professional commentators criticized it immediately. It wasn't like the other "slack" moves that AlphaGo would choose now and then, those uninspired stones that did little to increase its advantage and that seemed not to affect the game at all; this was altogether different, and many saw it as the computer's first all-out blunder, the concrete evidence that no matter how powerful computers became, they would never really understand the game as we humans did. The only one who immediately recognized it as something other was Fan Hui, the Chinese-born European Go champion, recently defeated by AlphaGo.

Fan Hui was the person who had the most experience playing against AlphaGo, and he was in awe of what the program could do. After he lost his five games against the machine, DeepMind had hired him as a consultant to the project. In the four months leading up to the match in Seoul, he had played against several versions of the algorithm, advising Hassabis, Silver, and the rest of the team and helping them make it much, much stronger, so strong, in fact, that he had become convinced that AlphaGo was capable of exhibiting one of the hallmarks of human intelligence: true creativity. Fan Hui had flown to Seoul for the match and was serving as one of its three judges, sitting on an elevated table that looked straight down on Lee, Huang, and the board. His intimate knowledge of the program helped him recognize move 37 for what it really was: a stroke of genius. "Black 37 casts an invisible net across the board. The shoulder hit creates potential all across the

center. All the stones placed before worked together, they connected like a network, linking everywhere," he would write months later in his in-depth analysis of the game, but in the moment when he saw it for the first time, all he could do was to jot down a quick note in his logbook, after recovering from the initial shock of disbelief: "*Here?!* This goes beyond my understanding. It's not a human move. I've never seen a human play this move." After the game was done—though some people, including Lee Sedol, would argue that the game was done there and then—Fan Hui could not put his thoughts fully into words, and just kept repeating, "Beautiful, beautiful, so beautiful!" when others approached him to ask his opinion about that soon-to-be-famous move. Most onlookers remained as flummoxed as he was at first: "A totally unthinkable move," said a Korean commentator. "I don't even know if it's good or bad at this point," quipped Michael Redmond, the only western player to have ever achieved 9 dan status. Redmond was analyzing the game for DeepMind's live YouTube feed, but he did not know how to answer the questions that his counterpart, the head of the American Go Association, directed at him. He chuckled nervously and admitted that he also thought it was a mistake, but not on AlphaGo's part; he actually believed that it was the algorithm's human aide—Aja Huang—surely he must have read the monitor incorrectly before placing the stone on the board. A few people gradually began to appreciate what the machine had done: Demis Hassabis got up from the game room and ran upstairs to where the DeepMind team had set up their control room, anxious to know how AlphaGo's monitoring systems had evaluated that bizarre play. When he got there, he found David Silver just as excited as he was, already rooting around inside the algorithm, trying somehow to understand what had just happened, and waiting

anxiously to see how Lee Sedol would react when he returned to the game room—as, due to one of those strange coincidences that seem to suggest that there is a hidden and slightly mischievous intelligence behind this world, the man who would have to react to one of the most uncanny moves played by anyone in centuries was the last one to see it.

Lee Sedol had just left his seat for a ten-minute cigarette break when Aja Huang placed the shoulder hit. When he came back downstairs, escorted by two smartly dressed guards, and settled himself in his chair, he scrunched up his nose and scowled in disgust with his mouth agape, as if he had just stepped in shit. After a moment had passed, he leaned forward while a huge beatific smile started slowly spreading across his face, as if he had finally seen what he himself had spent his entire life looking for: a thing of beauty, not of this world. Lee was known to be an incredibly impulsive player, one who would normally spend no more than a minute thinking before making a decision, but on that occasion he exhausted over twelve minutes of his allotted time pondering AlphaGo's seemingly absurd invention, blinking repeatedly, pinching the skin between his thumb and forefinger, with his head tilted slightly to one side, much as a dog does when it is puzzled by something it has never seen before. His thoughts were almost written on his face. "At the beginning of the game I thought it was making a lot of mistakes. It was still in charge but I was making a comeback. But it kept making more and more mistakes and I thought, 'There is a chance of winning.' I thought, 'This machine is still imperfect.' But then it made this move. In a real game, it's unthinkable, because there were many black stones, it was almost completely surrounded. You can't just drop one in there. But it made that move, move 37, and I knew that I didn't have a chance. Later I realized that the reason that it had given up spaces, given me

some room in other parts of the board, is because it already had that move in mind. It was letting me win. It tricked me. With that move, I was finished, it had already won." That is how Lee would recall that game a year later, after announcing his retirement, but during the game he gave no indication of capitulating without a fight, and continued staring at the board while his clock slowly ran down, picking at his lower lip with his finely manicured nails and long, delicate fingers. "I thought AlphaGo was based on probability calculation and it was merely a machine. But when I saw this move it changed my mind. Surely AlphaGo is creative. This move made me think about Go in a new light. What does creativity mean in Go? It was not just a good, or great, or a powerful move. It was meaningful," he would say to the documentary crew who interviewed him after the match was done. Lee fought the machine for another three hours, playing long past the point where he would normally have resigned, and he continued to fight while commentators began the slow, difficult process of tallying the score, unable to accept what was already inevitable, or perhaps reticent to walk away from a game that he knew was bound to go down in history. By move 99, Lee no longer had any chance of winning, but the algorithm never went for the kill, and instead continued nibbling away at Lee's territory, bit by bit, stone by stone. Lee Sedol held on, hoping for a miracle, or perhaps expecting that the machine would somehow make a mistake, or go back to the erratic play that it had exhibited in the beginning, but the program only got stronger as the stones covered the board, and by white 211, Lee finally gave up.

The press swarmed the postgame conference room while Lee Sedol took the stage next to Hassabis looking like a broken man. A sense of sadness and melancholy permeated the entire floor, as fans, commentators, and other players could hardly believe that their national hero had been defeated, not once, but twice. Lee had been outplayed and outsmarted, dominated and kicked about like an amateur. Many agreed that if in the first game Lee had been caught off guard, during the second he had been powerless. With his frail ventriloquist dummy voice strangled by emotion, Lee apologized deeply for his loss: "Yesterday I was surprised, but today I am quite speechless. It was a very clear loss. From the very beginning there was not a moment in time when I felt that I was leading. It played a near-perfect game," he confessed as the camera flashes blinded him. Though he was deeply self-effacing and looked humbled and shocked, he made clear that he would not go down without a fight: "I may have lost the second game, but the match is not over. There is still a third game left to play."

One of the Ten Thousand Things

Lee had a day off before the third game and he spent all that time holed up in his room with four other top Go professionals, touching on every single stone of the previous matches, to try to understand how a group of computer scientists with next to no background in Go had been able to create a system capable of wiping away centuries of tradition with a single move. How had the people at DeepMind managed to program an algorithm to play like that? he marveled. The truth was that they hadn't.

Move 37 was not a part of AlphaGo's memory, nor had it come out of any sort of preprogrammed rule or general guideline manually encoded into its silicon brain. It was created by the program itself, with no human input, but what made it all the more impressive was the fact that AlphaGo knew—at least as far as a nonsentient being can be said to "know" anything—that it was a move that not even a Go master would consider. With DeepMind just one game away from victory, and media attention already at a frenzy, Demis Hassabis had to do the rounds to try to explain how such a thing was even possible. The system, he told reporters, was not hand crafted, nor had it been given a comprehensive set of rules to follow, as IBM had done with DeepBlue, its chess-playing engine, two decades before. AlphaGo was based on self-play and reinforcement learning, which meant that, in essence, it had taught itself how to play.

But first, it had to learn how to imitate human beings.

Hassabis and his team had believed that the only way to beat a top professional was to try to replicate the highly creative and somewhat mysterious ways in which human beings approach Go. To do so, they fed 150,000 games from a database of top amateur players into an artificial neural network—a complex mathematical model that mimics the web of neurons in our brains, and that is composed of several layers of algorithms connected to each other, each one designed to recognize a specific set of patterns and features; working together, they create a vast model with millions of parameters that affect each other, and that can be ever so slightly adjusted, to change the overall behavior of the network. AlphaGo's first neural network analyzed those many thousands of games and learned, little by little, to mimic, copy, and predict the moves that an amateur would play in any given situation. This first human-based data set amounts to AlphaGo's "common sense," as it equates, very roughly, to the knowledge that a beginner would derive from books and the lessons he or she would learn directly from his teachers. The people at DeepMind called this the *Policy Network*. Using it, AlphaGo could play a half-decent game, at the same level as a human amateur, but it was still a long way away from a true professional. To reach that level, it needed to develop that specific skill that great players have of seeing the entire board and achieving an intuitive grasp

of how the game will play out from a particular position, that essentially human capacity to "read the board," one that young players must spend years developing, and that Lee Sedol had attained after countless hours of staring unblinkingly at the empty grid, playing out each move and its countermoves in his mind's eye. AlphaGo needed a way of estimating the value of each board position, to get a much broader understanding of the game, a way to tell—moment by moment—if it was inching to victory or staggering toward defeat. But to do that, it would have to face itself.

AlphaGo took the Policy Network it had created based on the amateur games, and played against itself, many millions of times. Learning from its mistakes through trial and error, it became better and better, stronger and stronger, no longer trying to mimic and play like a human being, but focused only on besting itself. Throughout millions of games it made billions of tiny adjustments to its mathematical model, improving for reasons that no human being could ever really understand, as the inner functioning of an artificial neural network is almost completely opaque to us, for we cannot keep track of or tally the countless effects that arise from the almost innumerable tweaks that the algorithm makes to its inner parameters while slowly building toward its desired outcome. "Initially it was terrible," Hassabis explained, "flailing around wildly on the board like a child, or an extremely clumsy and untalented human newcomer, as it had no inner representation of what the game was about, something that, to us, comes naturally, almost instinctively; but occasionally it would do clever things, totally by accident, and then it learned to recognize good patterns of play, and strengthen those patterns. Its networks worked together, reinforcing behavior that increased its possibility of winning, gradually improving its abilities." After that

second training process was complete, the new, sturdier version of AlphaGo played another thirty million games against its improved self, creating a data set that allowed it to train a second neural network, which DeepMind named the *Value Network*: this one would analyze any given configuration of stones on the board and look ahead toward the end of the game, to estimate if it was winning or not, and by how much. This went far beyond what even the smartest and best-trained human beings are capable of, as this second neural network could put a numerical value on something that we can only grasp at by vague feelings and nebulous intuition. Those two neural networks allowed the DeepMind program to whittle down Go's infinite complexity and reach a hitherto unimaginable level of play. It did not need to waste its vast computing powers searching through the endless possibilities that branch out from every single stone, since it could use the common sense of its Policy Network to consider only the best possible moves and prune the branches of its Monte Carlo search tree that it did not consider optimal; its Value Network, meanwhile, saved it from having to internally play out the entirety of each match to come to a conclusion about whether a particular move would bring it closer to winning or losing. The combination of those two systems—honed and perfected during millions and millions of games of self-play—is what allowed AlphaGo to range far beyond human knowledge and come up with radical strategies and counterintuitive moves like the one that it had flaunted during the second game against Lee Sedol. They also allowed it to have a precise estimate of how unlikely that particular move would seem to its human opponent.

When Hassabis and David Silver looked at how AlphaGo's internal systems had evaluated move 37, they saw that it had assigned it a probability value of one in ten thousand; this meant that, according to its

understanding of how we play the game, only one in ten thousand human Go players would ever consider putting a stone down in that particular part of the board, at that particular time. And yet, that was exactly the move that AlphaGo had chosen, and that was the level of cunning and ingenuity that Lee Sedol would have to reach if he was to overcome the machine and win the tournament.

The third game began at one p.m. on March 12. Lee Sedol took black and suffered from the very beginning.

Sitting atop the judges' podium and overlooking the board, Fan Hui could see Lee's hand tremble slightly as he placed his third stone down on the lower right corner of the grid. He had read that the Korean superstar suffered from insomnia, and knew, from his own experience in international tournaments, that one needed inner peace and a calm heart to play at the highest level; Lee Sedol looked so haggard and weak that Fan Hui half expected him to faint and fall headfirst onto the board, or keel over and die like Akaboshi Intetsu during the "blood-vomiting game." Before the match, Fan Hui had looked at the commentaries online: there was no one who still believed that Lee could win. Even his fans had turned against him, mercilessly criticizing his mistakes and even questioning his character, resolve, and *kiai*, his "fighting spirit." Fan Hui was perhaps the only man alive who could fully understand what Lee Sedol was going through. He had been crushed during his matchup with the machine, and knew full well just how uncanny it felt to play against a merciless, unfeeling opponent. AlphaGo did not hesitate and it never thought twice. It was immune to weariness. It knew no self-doubt. It cared not for style or beauty, and it did not waste time with any of the elaborate mind games that all professional players bait each other with. It simply did not care about what

others thought or felt; all it cared about was winning. To AlphaGo, it made no difference if it won by only a single point. That explained the "lazy" moves it would play now and again, moves that seemed subpar and uninspired to everyone, till a South Korean commentator pointed out that they were based on pure calculation: each one of those lazy stones made a tiny, almost imperceptible gain toward the final goal, and their true value would only be realized when they all came together in the endgame. Fan Hui was already aware of this, as he looked at Lee Sedol trying to battle the artificial intelligence, squirming in his seat as if he were being subjected to a novel form of torture, and he wished that he could somehow help or warn him, for he knew that there was something deeply distressing about playing against AlphaGo: it could induce a sense of despair, a strange feeling of being pulled down into a void, slowly but irrevocably. "It is like a black hole," Fan Hui would later write, "sucking you in, little by little. No matter how you try to break away, you will discover that your efforts count for nothing. AlphaGo creeps up on you like a fatal yet undiagnosed disease. By the time you feel the first hint of pain, you are already dead." Lee had perhaps already realized this after his two previous defeats, for as soon as he saw an opportunity to attack, he seized it.

Before the computer's advantage became overwhelming, Lee Sedol attempted to tear into AlphaGo's territory with a sudden and unexpected attack, but he had not taken the time to build up a proper foundation, and his ambush was rash and ill-timed. "Showed his fangs too early," wrote Fan Hui in his notes, as he watched AlphaGo counter with a two-space jump that was so inspired, it became apparent to Fan that the system that Lee Sedol was facing had advanced far beyond the machine that he had played against himself, so far that it seemed to be

looking down from the heavens, not only comprehending the entire board but somehow peering inside Lee's mind, anticipating every single move he made. Clearly infuriated, Lee slapped down his next stone, his face reddening as AlphaGo tore apart the Elephant's Eye formation that he had so painstakingly set up. He began losing his temper, rocking back and forth like a drunkard, glancing at the clock over and over. When he made a particularly gruesome mistake, he slapped himself on the cheek and then rested his hand on the edge of his bowl, dipping his fingers among the black slate stones as if he were physically unable to pick one up. He needed to regain his calm, but he continued attacking aggressively, without making any headway, like a boxer punching himself out. By move 48, AlphaGo's systems indicated that its probability of winning had soared to 72 percent. The game was essentially decided already, but Lee hunkered down nonetheless, and tried to dismantle the AI's Dragon formation at the bottom of the grid, to no avail. When Lee finally acknowledged that he could no longer win by playing smart, he resorted to his signature "zombie" style, a mad thrashing all over the board, a desperate, last-ditch attempt of a man who already knows that he is dead, but wishes to catch his opponent off guard with wild, unpredictable attacks. It was a foolish, almost nonsensical strategy that had let him win back many a lost game in the past but stood no chance against an opponent that could not be bullied, threatened, or confused, and AlphaGo continued to adapt to Lee's now seemingly insane moves, and secured an enormous stretch of territory on the top of the board. Its Value Network estimated that its chances of winning had already surpassed 87 percent: white was alive all over the board, while black was way behind on points. There seemed to be nowhere left to play, but in that last moment Lee found a small crack in white's fortifications,

and enough breathing room to cut AlphaGo's group on the right side. A human player would never allow an opponent to live there, especially so far into the game, but AlphaGo, heaping insult on injury, did not even bother to respond; in a final show of incontestable dominance, it let him live there, in the corner, and simply played elsewhere, adding another point to its score, while reaching a 98 percent likelihood of winning. The game continued for another twenty-eight moves that were excruciating to watch. Lee Sedol fussed and twitched around in his seat, biting his nails, sighing, and murmuring to himself, as commentators derided his unwillingness to accept the inevitable. "There's no point in playing out the endgame if you know you're going to lose, right?" asked the president of the American Go Association. "I don't know how to describe the situation . . . If I were black, I would resign. We should admit that we are facing the strongest existence in Go's history," said a Chinese commentator.

AlphaGo had won the game, and with it the tournament.

God's Touch

Even though Lee Sedol had already lost, and wanted nothing more than to leave the Four Seasons Hotel, go back home with his wife and daughter, and lie down to lick his wounds, the rules of the tournament stipulated that all five games had to take place, regardless of the results. That meant that he still had to face AlphaGo two more times, and the thought that he might not win a single game was almost more than he could stand, an unbearable disgrace, a loss of honor from which he would never recover. The DeepMind team had already shamed him—albeit unwittingly—by sending a bottle of expensive champagne to his room at the end of the third game. It had been meant as a gesture of respect, for they had been informed that it was his ten-year wedding anniversary, but the timing simply could not have been more disrespectful. Lee had suffered from that lack of gracefulness (so characteristic of westerners) by himself, but if he lost the two upcoming matches against AlphaGo, in front of a global audience of millions of people, there was no way he could ever sit down in front of a Go board again. Such a public humiliation would surely break what little remained of his formerly indomitable spirit. It seemed wholly unlikely that he could claw his way back and defeat the computer. During the press conference after AlphaGo's third straight win, Lee Sedol's voice cracked, and he was barely able to expel the air from his lungs as he apologized: "I think I disappointed too many of you this time. I want to beg your forgiveness for being so powerless. I've never felt this much pressure, this much weight. I think I was too weak to overcome it," he confessed before the cameras. At the end of the conference, he smiled bashfully as he received shouts of praise and support from fellow Go players, who urged him to recover his confidence and play like himself during the final games, but he was now far too weary, and haunted by the very real possibility of losing five to zero—the same score he had boasted that he would win by. With the match already decided, there were fewer journalists to deal with as he made his way to the game room, but there was no way for him to hide just how scared and nervous he really was. He slumped down in his chair and took his place at the board, looking thinner and more childlike than ever, and bowed deeply to Aja Huang as the DeepMind programmer glanced at his computer screen waiting for AlphaGo's first move.

AlphaGo played black and took control of the game immediately. By move 28, the commentators were already criticizing Lee's reactions as sluggish and overly cautious. He was taking too long to think, his clock winding down faster than in any of the previous encounters. AlphaGo, meanwhile, seemed to be brimming with confidence, as it was playing far more aggressively than before, looking for fights from the very beginning. That was exactly the type of game that Lee had always preferred, and when AlphaGo delivered a vicious shoulder hit, he cracked

a smile, as if he were playing against a brash, mischievous child, or a younger, wilder version of himself. Was he beginning to enjoy the game at last? It seemed highly unlikely. The computer had already taken control of the entire board and was attempting to completely overwhelm him. What was even more shocking to everyone watching was Lee's total lack of response: as meek as a snow-white lamb, he allowed AlphaGo to barricade the middle of the board and seal his tiny group of stones on the left side, leaving him almost no space at all to maneuver. It seemed as if he had already given up. Only a single commentator, one of his old classmates from his days in Master Kweon's academy, who was analyzing the game for the South Korean audience, stood up for him: she was absolutely convinced that Lee was playing possum, and that he would somehow find a way to live inside that minuscule area, even if the computer's black stones now seemed to have almost complete control over the entire grid. As the game plodded along, Lee fell into a state of absolute concentration: he was no longer fidgeting or fussing with his hair; he looked focused and determined, eyes fixed on the board like a tiger stalking its prey, his body the very image of stillness. He took longer and longer before each move, cocking his head to one side, as if listening to a far-off rumble that only he could hear. By move 54, Lee's clock had just 51 minutes left, while AlphaGo's had 1 hour and 28 minutes of available time. The game inched forward, and just like before, it looked as if Lee was already on the verge of defeat; reporters began to crowd outside the playing room as the rumor that the fourth game would be the shortest of them all began to spread online. Nevertheless, Lee did not react, and played slowly, cautiously, avoiding direct confrontation, giving up almost the entire board to his opponent. "Is he not afraid to die?" Fan Hui wrote in his notes, de-

spairing at Lee's stubborn refusal to engage with the computer. Fan was so close to him physically that he could almost hear Lee's thoughts and feel what he was waiting for, and soon he fell into the same trancelike state that had mesmerized the Korean grandmaster. By move 69, Lee was down to just 34 minutes, while his opponent still had over 1 hour and 18 minutes left. AlphaGo continued to pound Lee with its attacks, swallowing a large group on the left side, while Lee's fans despaired as they watched him waste an entire ten minutes before placing his next stone on the board. AlphaGo answered immediately, blocking off the center. There appeared to be nothing left for Lee to do; in the DeepMind control center, Demis Hassabis saw that AlphaGo's estimation of its probability of winning had climbed to over 70 percent. He watched a set of monitors that featured the Chinese, Japanese, and Korean commentators already calling the game for AlphaGo, as not a single one of them could see a way out of the rock-solid fortress that the computer had built. Lee remained motionless. When his clock had run down to just eleven minutes, he placed his palm flat over the edges of his bowl, then quickly picked up a stone between his index and middle fingers, and smacked it down right in the center of AlphaGo's territory.

"The hand of God! That is a divine move!" shouted one of Lee Sedol's historic rivals, Gu Li, jumping up from his seat in the Chinese webcast. Like a bolt of lightning, Lee's 78th stone tore AlphaGo's position apart, striking at the heart of the board with a wedge move unlike anything anyone had seen before. People went wild with excitement. Even if they could not fully grasp the significance of what they had just seen, or begin to compute the consequences of Lee's incredibly daring gambit, everyone recognized that it was an unthinkable move, a move no one would have considered. "That would be so cool if it works," said

Chris Garlock, an American commentator, completely stunned. "That is such an exciting move. It's going to change the whole game," said his colleague at the DeepMind YouTube feed, Michael Redmond, agog at the potential that Lee Sedol had managed to find inside his opponent's dominion, at a place where no other Go player in the world would have had the audacity to dive in. Not a single analyst or commentator had anticipated it, but as soon as Lee laid down his white stone, they scrambled to try to understand what had just happened, shouting over each other, applauding or critiquing the wedge move. Some openly contradicted themselves, lauding it and then decrying its failure, while a few simply stared dumbstruck, their minds reeling. There was a moment of chaos as the shock of the new move sank in, but not a single one of them was as utterly confused as AlphaGo.

The computer's response to Lee's flash of genius made no sense whatsoever: when Aja Huang played the program's next stone in an obviously disadvantageous position, everyone, including Lee Sedol, was surprised, but nobody dared to point out the obvious blunders that AlphaGo began to make from then onward, as the previous games had left them wary about critiquing what they could not understand. Lee Sedol himself hesitated before capitalizing on the clear advantages that AlphaGo was suddenly gifting him. Was this a new strategy? he wondered. Was the computer laying another trap for him? The only ones who knew that AlphaGo had lost its mind and was simply playing nonsense were the people up in DeepMind's control room.

When he saw what was happening, Demis Hassabis snuck away from the players' room as quietly as he could and ran up the stairs, storming into the control room just in time to watch the head programmers huddled in front of a screen, where AlphaGo's probability of winning had just fallen off a cliff. "Did anything strange happen before it started acting this way?" he asked them, and when everyone replied that, just a few moments before Lee Sedol played his wedge move, everything looked normal—hell, better than normal, AlphaGo had been massacring Lee—they had nothing else to do but hunker down and try to contain the sinking feeling in their stomachs, as they realized that their worst fears were now coming true: AlphaGo had become delusional.

It was not the first time that they had witnessed this type of behavior. Every now and then, in very specific board configurations, AlphaGo went mad, suddenly losing all sense of position and value, to the point where it would think that it was alive in areas in which it was very clearly dead, as if it had become blind, unable to distinguish self from other, black from white, friend from foe, life from death. They watched as Aja Huang tried not to betray his feelings before the cameras, although they knew that he understood just how far AlphaGo had fallen, and how deranged its systems had become: "I knew after move 78, after like ten or twenty moves, that AlphaGo somehow became crazy, but I didn't realize why," he would later recall. In the moment all he could do was faithfully translate what he saw on the screen to the board, even as Lee Sedol gawked at him, begging for some type of explanation. Back in the control room, David Silver, Aja Huang's counterpart as head programmer of AlphaGo, saw that the computer had searched over ninety-five moves ahead after Lee's astounding move, developing endless lines of probability branching out from each one of those possible moves: "I think that something went wrong," he said to Hassabis, who was pacing frantically from one side of the room to the other. "That's the longest it has searched during the entire game. I think it searched so deeply, that it lost itself."

"What's it doing there!" Hassabis screamed as he saw the next move that the computer was considering.

"Maybe it has a master plan . . ." joked one of the younger engineers.

"No, it doesn't. It doesn't even think it has, does it?" replied a bitter Hassabis. "It knows it's made a mistake, but it's evaluating it the other way. I mean, look! Look! Lee is confused. He's like, *What's it doing?* That's not an *I'm scared* look, that's a *What the fuck is it doing?* look."

The entire DeepMind team watched in despair as the international commentators started demanding answers. "What's going on!" cried Kim Myungwan, a Korean 9 dan professional, after AlphaGo continued to stumble blindly across the board. "This could be that it can't find a way through, like it looked far enough ahead to see that it doesn't work, and now maybe it's . . . on tilt? . . . I don't know . . ." answered one of his counterparts.

"Are you *kidding* me?" David Silver groaned as he watched one of AlphaGo's inner monitors, holding his face in both hands. "This . . . this move, literally, this next move we are going to play . . . I think they're going to laugh. I think Lee is going to laugh."

Aja Huang picked up a black stone and as soon as he laid it down, the entire audience outside the playing room burst out laughing.

"Oh, that is ridiculous!" shouted the female host of one of seven South Korean TV stations that were broadcasting the match live. "Is it a mouse mis-click from Aja Huang? No, that's the move. These are not human moves. It's inexplicable. Those are mistakes, clear mistakes. For the first time in four matches, we have seen AlphaGo make mistakes. I think Lee Sedol found a chink in its armor. He found the weakness in the system," she added as everyone watched the champion stare at the board, clearly as confused as everyone else. It took AlphaGo more than

twenty moves to recover its sanity, but by then it had completely lost control of the game.

Lee's clock had run out, and from then onward he was playing under *byoyomi*, a time constraint that forced him to make his moves in less than a minute each. Ahead for the first time, he could not afford a single mistake, and played on without betraying a smile, even as a horde of reporters who had left early when AlphaGo's lead seemed incontestable started piling back into the hotel and filling the press room to capacity in anticipation. Lee sat up straight as AlphaGo began playing a series of last-ditch attempts that no self-respecting human would consider, mainly out of a sense of dignity that the computer lacked, as they were easy enough to counter and even allowed Lee to increase his already considerable lead. They were not bad moves per se, simply pointless. When AlphaGo's internal networks indicated that its probability of winning had fallen below 20 percent, a message appeared on Aja Huang's monitor:

The result "W+Resign" was added to the game information

AlphaGo resigns.

Aja picked up a stone from his bowl, laid it down on the edge of the board, and bowed to Lee Sedol.

Professional commentators screamed, clapped, and burst out laughing from sheer delight. The onlookers inside the game room erupted into applause and several of Lee's best friends rushed forward to greet him. Outside in the hall and in the streets of South Korea, perfect strangers who had been watching the game hugged each other, while others were moved to tears—it was as if Lee Sedol had just won a victory for

our entire species. The press room lit up with excitement as cameramen and foreign journalists began to jump up and down, cheering wildly, all objectivity thrown out the door, but Lee himself remained perfectly still, moving stones around the board and analyzing alternatives as he had done at the end of all the previous games, not even smiling to himself, despite the fact that he could clearly hear the voices of many hundreds of people shouting his name, and see that the only female judge of the match was beaming down at him from her podium, with tears welling up in her eyes. "I heard people were shouting from joy when it was clear that AlphaGo had lost the game," he later said. "I think it's clear why: People felt helplessness and fear. It seemed we humans are so weak and fragile. And this victory meant we could still hold our own. As time goes on, it'll probably be very difficult to beat AI. But winning this one time . . . it felt like it was enough. One time was enough." He remained seated and did not look up from the board or smile until Demis Hassabis walked over to him and very gently tapped his hand on Lee's shoulder, nodding to convey his congratulations and respect. He stayed there, picking stones from the board, as Fan Hui descended from the judges' podium, bent down to his eye level, and gave him a massive thumbs-up before leaving him there, alone, his chin resting on his hand, while he pondered the entire game, almost as if he were afraid to stand, because to him, as to so many others, it seemed as if he had witnessed a miracle, a moment in time so precious as to never be forgotten.

When he entered the press room, the applause was so thunderous that one might have thought the massive chandeliers would suddenly crash down onto the journalists who chanted *LEE-SE-DOL! LEE-SE-DOL! LEE-SE-DOL!* at the top of their lungs. Lee made his way to the

podium as serious as he had been at the end of the game, almost indifferent, but when he finally looked up from his shoes, his expression changed in an instant, as if he had just snapped out of a trance. He began to smile, then beam as he bowed his head again and again in appreciation, while the room was flooded with cheers, hooting, and applause. At first, it was hard for him to understand, he later said. After all, he had lost the match and this new result did not change that at all. "I didn't expect it to be like that. It was unbelievable, unbelievable!" he would recall, but in that moment he could hardly contain his emotions. "Thank you very much," he said, chuckling to himself. "I've never been congratulated so much for winning one game! I couldn't be happier, after losing three in a row." He had to stop speaking as cheers erupted once again. "I wouldn't give this up for anything in the world." Completely drained after five hours of play and emotionally overwhelmed, Lee took just a couple of questions and then retired to his room amid deafening applause.

Outside the hotel, Lee's fans were running out in the streets of Seoul, chanting and celebrating their hero's victory. Even the team at DeepMind, who had lost, rather embarrassingly, were amazed at Lee's stunning ability to create something out of nothing. How could a man, however smart, defeat a computer like AlphaGo, able to calculate over two hundred million positions a second? Surely it was a feat that would go down in history, as it showed the true measure of Lee Sedol's creative genius, something that all mankind could truly celebrate. Demis Hassabis, however, could not lay his mind to rest.

He needed to understand what had gone wrong with AlphaGo, and he gathered the members of his team in the DeepMind control room.

Just like Lee Sedol had done, they went over the entire game, and quickly confirmed that it was move 78—as everyone suspected—that had thrown AlphaGo into madness. Lee would later confess that he had wanted to find a move that the computer could not anticipate, however much it calculated, but that his own thought process had not been rational at all: the move had come to him out of sheer inspiration. He had not foreseen or planned it, and when he was asked about it during the press conference, he admitted so quite frankly: "At that point in the game, it was the only move I could see. There was no other placement. It was the only option for me, so I put it there. I am quite humbled by all the praise I am getting for it." Hassabis and his team huddled around the main terminal, prodding the system to see exactly what had happened, but due to the nature of AlphaGo itself, it was exceedingly difficult to unpack the choices the program had made, and why it had let the center of the board, which had been squarely under its control for almost the entire game, crumble away like it had.

"We were winning before this," said Aja Huang as he pointed to Lee's wedge move, but nobody in the DeepMind team could really judge its true worth, as they did not have a sufficiently profound understanding of the game. Finally, David Silver had the idea of running the entire match through AlphaGo's systems, making it play Lee's moves and its own moves, to see how the Value and Policy Networks would assess "God's touch." "Would we have played it?" he asked as they fired up the computer and saw it apply its boundless computational powers to sort through the endless lines of probability. "What chance does it give that particular move?"

"Zero point zero zero zero one," a junior researcher replied.

There was silence. One in ten thousand: exactly the same probability that AlphaGo had assigned to its own groundbreaking move 37 during the second game, the one that had made the entire Go community recognize its potential. As it turned out, AlphaGo's networks agreed with Gu Li, the Chinese professional who had christened Lee's move: it truly had been divine, a touch from God's hand—only one in ten thousand human players would have considered it. That was the reason AlphaGo had been incapable of dealing with Lee's wedge move: it was too far from human experience, and past even where AlphaGo's seemingly boundless capabilities could reach.

Facing each other, Lee and the computer had managed to stray beyond the limits of Go, casting a new and terrible beauty, a logic more powerful than reason that will send ripples far and wide.

Game Over

Lee lost his final game with AlphaGo.

During the fifth encounter, there was no hand of God, no blinding flashes of inspiration that could have allowed him to defeat that unnatural, behemoth intelligence. There were more journalists than ever before, over two hundred million people following the game worldwide, and major international networks like CNN and the BBC reporting live from the Four Seasons. For the last game, Lee had requested to play black, even though that meant giving the machine a slight advantage that no one really thought he could afford. But Lee had won playing white, and he wanted to prove, perhaps only to himself, that he could also do so with black.

The press room overflowed as more journalists flew into Seoul to be firsthand witnesses of the final game between the man and the machine. Never before, in all of Go's three-thousand-year history, had such attention been paid to a single game. On the South Korean networks, the excitement was almost unimaginable; there was no other news that mattered that day.

At first it seemed that Lee had more than a fighting chance, as the computer began playing moves that no one approved of, leading one commentator to joke that perhaps the algorithm hadn't recovered from the previous day's defeat. Hassabis fretted in front of the control room's monitors, as it looked like AlphaGo was once again short-circuiting. "Why's it playing there for!" he shouted when Aja Huang placed a stone in a position that seemed completely useless and out of place, even though the program's inner evaluation function was 91 percent certain that it was winning. "Because it's incorrect again," answered one of the technicians. During the entire game, the DeepMind team was convinced that AlphaGo was wrong in its judgments of the board, playing weird, slack moves that appeared to do nothing to further its own score, even though everyone thought they could see several options that were more solid and robust. Hassabis, Fan Hui, Aja Huang, David Silver, and the others on the DeepMind team were absolutely sure that it was going to turn out to be another huge embarrassment for them. But they were all mistaken. None of them knew Go well enough to judge AlphaGo's merit. However, others did.

"White is winning now," said Kim Ji-yeong, a top-level player commenting for the American audience, after seeing the computer make another apparently nonsensical throw-in.

"I don't know," his broadcasting partner replied, confused. "Perhaps this is what 10, or 11, dan play looks like? It looks weird, it looks ugly, it just doesn't make sense to us."

AlphaGo continued playing its strange moves to the very end, and

some analysts began to point out that there was indeed a different kind of thinking behind its decisions. Normally, a human player would judge a player's strength by the amount of territory that he or she controlled; by that simple, straightforward logic, the more territory one had, the bigger one's chances of winning were. But AlphaGo could do something that no human was capable of: it could calculate, with unerring precision, just how much it needed to win, and do no more than that. To the computer there was no difference between winning by a landslide or a hair's breadth. Why should it gobble up vast expanses of territory when it didn't need them? The match stretched out endlessly, over five hours of play that led to an excruciatingly complex endgame. Lee and AlphaGo played a total of 280 moves, almost completely covering the board in black and white stones, before Lee finally gave up and resigned. It was almost impossible to tell who had won just by looking at the board. When the experts finally tallied up the score, they found that it had been by far the closest of all five games: AlphaGo had beaten Lee by just two and a half points.

During the award ceremony, Lee Sedol looked dignified but shrunken. "I've grown through this experience," he said. "I will make something out of it with the lessons I've learned. What surprised me the most was that AlphaGo showed us that moves humans may have thought creative were actually conventional. I think this will bring a new paradigm to Go. I'm thankful for all this, I feel like I've found the reason why I play Go. I realize that it was a really good choice, learning to play this game. It's been an unforgettable experience." The packed press room had fallen into a deep and solemn silence. Demis Hassabis sat next to Lee

on the podium and could not hide his excitement, despite the fact that he was very keen not to gloat, and tried his best to respect the dignity of the fallen idol at his side. Lee was nervously fumbling with the earpiece they had given him for the simultaneous translation of the final press conference, and had to ask for help from an assistant to fit it in his ear. "I'm kind of speechless," Hassabis said. "This is the most mind-blowing experience of my life. It was an incredible game, very exciting and incredibly stressful. At the beginning it seemed that AlphaGo made quite a big mistake with a stone-killer tesuji that it played wrong, but in the end it came back and it was very, very close. We saw some incredible games of Go these past five days, and I think there are some moves, like move 37 in game two, and move 78 in game four, that will be discussed for a very long time to come. This is a once-in-a-lifetime thing. For me it's the culmination of a twenty-year dream. I would say it's the most amazing thing I have ever experienced." Lee gnawed on his lower lip and apologized once more to his fans and to the world at large for having been so powerless, so utterly helpless, convinced that it had been his own personal weakness, and not the computer's fundamental superiority, that had led to his ignominious defeat. "I don't necessarily think that AlphaGo is superior to me," he said. "I believe that there is still more that human beings can do against artificial intelligence. I feel regret, because there is more that I could have shown. Go is a game that you enjoy, whether you are an amateur or a professional. Enjoyment is the essence of Go. And AlphaGo is very strong, but it cannot know that essence. My defeat is not mankind's defeat. I think that these games clearly showed my own weaknesses, not humanity's weakness."

When Lee Sedol finally bowed to everyone present and stepped down from the stage, Demis Hassabis and David Silver stayed on to

receive, on behalf of their entire team, a certificate from South Korea's Go Association, awarding AlphaGo an honorary 9 dan ranking, the highest level a grandmaster can achieve, a title reserved for those players whose ability at the ancient game borders on the supernatural. The citation on the certificate—the first one of its kind ever produced—carried the serial number 001, and stated that it was given out *in recognition of AlphaGo's sincere efforts to master Go's Taoist foundations and reach a level close to the territory of divinity.*

Calculate, Abandon Instinct

During the months following his defeat against AlphaGo, Lee Sedol won every single tournament game that he played.

When he was asked for his secret, he replied, "Do not rely on instinct. Calculate with the utmost precision." His series of consecutive victories and his new style of play made it look like he would extend his already illustrious career for several years to come, but in November 2019, Lee shocked the world by suddenly announcing his retirement.

At first, nobody understood his decision. Famous Go players usually compete well into old age. In Japan, professionals often play tournaments until the last day of their lives, and Lee had just turned thirty-six. There was a public outcry for him to take back his decision, but he explained that he had dedicated his entire life to Go, having thought of nothing else since he was five years old, and now it was time for something new. As brave as ever, he decided not to play his farewell match against his longtime friend and rival Gu Li, or the cocky rising star of

the international circuit, Ke Jie, but against HanDol, an artificial intelligence software developed by South Korea's NHN Entertainment Corporation.

HanDol had already defeated South Korea's top five players that year, and Lee started his first game with a two-stone advantage granted to him by the organizers of the event, to level out the playing field. "Even with a two-stone advantage, I feel like I will lose the first game to HanDol," he told the press, leading everyone to think that he had lost his fighting spirit, but in what has to be one of the most uncanny of coincidences, he managed to win that first game after his 78th move threw his artificially intelligent rival into utter confusion, just like during his bout against AlphaGo. While Lee regarded his move as nothing out of the ordinary, many experts said that it had been unthinkable, and the team behind HanDol declared that they were astounded at Lee's ability to find bugs and weaknesses in what had previously seemed to be a totally flawless software architecture; they had to bear witness when HanDol began to make completely irrational moves and nonsensical throw-ins, resigning just fourteen turns later. Lee Sedol became front-page news once again: he was the only human being alive to have defeated two advanced artificial intelligence systems in a tournament setting. No other player in the world had even come close to doing so. Nevertheless, during the following game, which he played without any type of advantage, HanDol crushed him.

The tournament was held not in Seoul but in El Dorado, a five-star resort in Sinan-gun county, just thirty kilometers from Lee's home island of Bigeumdo. The posh, high-class hotel was a veritable world away from the humble home where Lee had played his first matches against

his brothers and sisters, most of whom had become professional players like him, raised under the strict tutelage of their father. His whole family showed up for the game, and many of his old classmates and teachers from elementary school took the ferry to see him; they crowded outside the lavish beachside hotel with hand-painted signs to showcase their support, eager for a chance to see the Strong Stone, the Bigeumdo Boy, with their own eyes, as they could hardly believe that the small, timid child they had seen climbing trees and fishing with the other boys had become a national hero, won tens of millions of dollars in prize money, and turned into a legendary figure in Go. They cheered throughout the first twenty minutes of the match and only quieted down when hotel officials came and told them that their racket could throw Lee off his game. Everyone wanted him to go out with a bang, to demonstrate the sort of gameplay that had made him a legend, during this, his swan song, but after five hours of grueling effort and 181 stones, Lee resigned.

"I used to have this sense of pride," he said a couple of weeks later, after losing his third game against HanDol, when he was interviewed on a popular talk show that recapped his entire career. "I thought I was the best, or at least one of the best. But then artificial intelligence put the final nail in my coffin. It is simply unbeatable. In that situation, it doesn't matter how much you try. I don't see the point. I started playing when I was five. Back then, it was all about courtesy and manners. It was more like learning an art form than a game. As I grew up, Go started to be seen as a mind game, but what I learned was an art. Go is a work of art made by two people. Now it's totally different. After the advent of AI, the concept of Go itself has changed. It is a devastating

force. AlphaGo did not beat me, it crushed me. After that, I continued playing but I had already decided to retire. With the debut of AI, I've realized that I cannot be at the top, even if I make a spectacular comeback and return to being the number one player through frantic efforts. Even if I become the best that the world has ever known, there is an entity that cannot be defeated."

EPILOGUE

The God of Go

Shortly after Lee announced his retirement, a strange player appeared on the international online Go circuit.

Under the moniker Master, it began racking up one win after another. Seemingly unbeatable, it won fifty consecutive games against the world's top Go players and when it finally lost one, DeepMind's people confessed that they were the ones behind Master, and that it was a stronger version of the artificial intelligence that had defeated Lee Sedol, explaining that the single loss Master had suffered had been due to an internet connection time-out.

Once again, DeepMind's researchers decided to pit their program against the strongest possible player, to see just how far it had advanced: they chose to challenge the Chinese prodigy Ke Jie, the world's highest-ranked player, at the Future of Go Summit in Wuzhen, China, the country where the game had originated over three thousand years before. Ke Jie was only nineteen years old and even more boastful than Lee

Sedol. He had risen to the top spectacularly and had heavily criticized Lee for the games that the South Korean had lost against AlphaGo, saying that Lee was no longer at the top of his game by the time he had faced the computer. Ke was absolutely sure that he would do better, bragging before the matchup that he would show the supremacy of Chinese Go and restore the hegemony of the human race.

Master annihilated Ke Jie, winning all three games.

The teenager cried during the final press conference, taking off his thick-rimmed glasses and wiping tears from his eyes as he tried to convey the feeling of helplessness that had overcome him during the games, saying that, as soon as he had started playing against Master, he had begun to sense something that was new, and deeply unsettling. When he was asked to explain what made Master different from AlphaGo, he could not help but lapse into the type of language that we usually reserve for conscious beings: "To me, he is a god of Go. A god that can crush all who defy him. I've never doubted myself. I have always felt I had everything under control. I thought I had a very good understanding of composition, an intimate knowledge of the board. But Master looks at all this and he is, like, 'What's all this rubbish!' He can see the whole universe of Go, I see only a tiny area around me. So please, let it explore the universe, and let me play in my own backyard. I will fish in my little pond. How much more could it improve through self-learning? Its limits are hard to fathom. I think the future belongs to AI."

With both Lee Sedol and Ke Jie defeated, Demis Hassabis and the team at DeepMind could climb no higher, at least not by playing against human opponents. While he had reached a fundamental milestone in his quest toward artificial general intelligence, Ke Jie's final question—*How much further could the program evolve through self-learning?*—continued to

gnaw away at Hassabis, even as he celebrated DeepMind's complete dominance over a game that had once been considered mankind's bastion against the machines, the pinnacle of human intuition and creativity. Just *how* far could they take their self-learning algorithm?

Hassabis and the DeepMind team made a radical departure: they stripped Master, AlphaGo's successor, of all its human knowledge—those many millions of games based on which it had first learned to play, and that formed the cornerstone of its common sense, the program's unique ability to judge the value of an individual position, to estimate its chances of winning, and to see the board as a human being would, and left only its bare bones. Their aim was to create a more powerful and much more general artificial intelligence, one that was not restricted to Go in its learning capabilities and that did not rely on human understanding and knowledge as a crutch during its first formative baby steps. They took their algorithm and wiped it clean, leaving no human data from which it could learn, depriving it of its only direct connection with mankind.

The results were terrifying.

The new program defeated the version of AlphaGo that had pushed Lee Sedol into retirement one hundred games to zero. But it was only getting started. When they applied that same algorithm to chess, it proved to be just as strong: after two hours it had played more games against itself than have been recorded throughout all of history; after four hours it had already become better than any human; after eight it could defeat Stockfish, the reigning AI chess champion. "It plays like a human on fire," said Matthew Sadler, the English grandmaster who was first exposed to it. Sadler described its style as extremely aggressive and reminiscent of the manner that Garry Kasparov used to play in, an

opinion that was later ratified by the great Russian genius himself. After conquering chess, the system took on shogi, a Japanese game that is somewhat similar to chess but with higher complexity, as pieces are not fixed, and can be swapped from one army to the other, creating multiple variations that would never occur in chess; the new algorithm mastered shogi in under twelve hours, and beat the world's strongest program—Elmo—in 90 percent of the games they played.

For all these games, it considered no human experience: it was simply given the rules and allowed to play against itself. At first, it made completely random moves, but in next to no time it had evolved into an unbeatable force. It has now become the strongest entity the world has ever known at Go, chess, and shogi.

Its name is AlphaZero.