

IN THE PLEX

HOW GOOGLE THINKS, WORKS,
AND SHAPES OUR LIVES

STEVEN LEVY

AUTHOR OF *HACKERS*



ew companies in history have ever been as successful and as admired as Google, the company that has transformed the Internet and become an indispensable part of our lives. How has Google done it? Veteran technology reporter Steven Levy was granted unprecedented access to the company, and in this revelatory book he takes readers inside Google headquarters—the Googleplex—to show how Google works.

While they were still students at Stanford, Google cofounders Larry Page and Sergey Brin revolutionized Internet search. They followed this brilliant innovation with another, as two of Google's earliest employees found a way to do what no one else had: make billions of dollars from Internet advertising. With this cash cow (until Google's IPO nobody other than Google management had any idea how lucrative the company's ad business was), Google was able to expand dramatically and take on other transformative projects: more efficient data centers, open-source cell phones, free Internet video (YouTube), cloud computing, digitizing books, and much more.

The key to Google's success in all these businesses, Levy reveals, is its engineering mind-set and adoption of such Internet values as speed, openness, experimentation, and risk taking. After its unapologetically elitist approach to hiring, Google pampers its engineers—free food and dry cleaning, on-site doctors and masseuses—and gives them all the resources they need to succeed. Even today, with a workforce of more than 23,000, Larry Page signs off on every hire.

But has Google lost its innovative edge? It stumbled badly in China—Levy discloses what went wrong and how Brin disagreed with his peers on the China strategy—and now with its newest initiative,



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IN THE

PLEX

How Google Thinks, Works, and Shapes Our Lives

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In memory of Philip Klass (1920–2010)

PROLOGUE

SEARCHING FOR GOOGLE

[“Have you heard of Google?”](#)

It was a blazing hot July day in 2007, in the rural Indian village of Ragihalli, located thirty miles outside Bangalore. Twenty-two people from a company based in Mountain View, California, had driven in SUVs and vans up an unpaved road to this enclave of seventy threadbare huts with cement floors, surrounded by fields occasionally trampled by unwelcome elephants. Though electricity had come to Ragihalli some years earlier, there was not a single personal computer in the community. The visit had begun awkwardly, as the outsiders piled out of the cars and faced the entire population of the village, about two hundred people, who had turned out to welcome them. It was as if these well-dressed Westerners had dropped in from another planet, which in a sense they had. Young schoolchildren were pushed forward, and they performed a song. The visitors in turn, gave the children notebooks and candy. There was an uncomfortable silence, broken when Marissa Mayer, the delegation’s leader, a woman of thirty-two, said, “Let’s interact with them.” The group fanned out and began to engage the villagers in awkward conversation.

That is how Alex Vogenthaler came to ask a spindly young man with a wide smile whether he had heard of Google, Vogenthaler’s employer. It was a question that he would never have had to ask in his home country: virtually everyone in the United States and everywhere in the wired world knew Google. Its uncannily effective Internet search product had changed the way people accessed information, changed the way they *thought* about information. Its 2004 IPO had established it as an economic giant. And its founders themselves were the perfect examples of superbrained engineering mentality that represented the future of business in the Internet age.

The villager admitted that, no, he had never heard of this Google. “What is it?” he asked. Vogenthaler tried to explain in the simplest terms that Google was a company that operated on the Internet. People used it to search for information. You would ask it a question, and it would immediately give you the answer from huge repositories of information it had gathered on the World Wide Web.

The man listened patiently but clearly was more familiar with rice fields than search fields.

Then the villager held up a cell phone. “Is this you what mean?” he seemed to ask.

The little connectivity meter on the phone display had four bars. There are significant swaths of the United States of America where one can barely pull in a signal—or gets no bars at all. But here in rural India, the signal was strong.

Google, it turns out, was on the verge of a multimillion-dollar mobile effort to make smart phones into information prostheses, adjuncts to the human brain that would allow people to get information to a vast swath of all the world’s knowledge instantly. This man might not know Google yet, but the company would soon be in Ragihalli. And then he *would* know Google.

I witnessed this exchange in 2007 as an observer on the annual trip of Google associate product managers, a select group pegged as the company’s future leaders. We began our journey in San Francisco and touched down in Tokyo, Beijing, Bangalore, and Tel Aviv before returning home sixteen days later.

My participation on the trip had been a consequence of a long relationship with Google. In late 1998, I’d heard buzz about a smarter search engine and tried it out. Google was miles better than anything I’d used before. When I heard a bit about the site’s method of extracting such good results—it relied on sort of a web-based democracy—I became even more intrigued. This is how I put it in the February 22, 1999, issue of *Newsweek*: [“Google, the Net’s hottest search engine](#), draws on feedback from the web itself to deliver more relevant results to customer queries.”

Later that year, I arranged with Google’s newly hired director of corporate communications, Cindy McCaffrey, to visit its Mountain View headquarters. One day in October I drove to 2400 Bayshore Parkway, where Google had just moved from its previous location above a Palo Alto bicycle shop. I’d visited a lot of start-ups and wasn’t really surprised by the genial chaos—a vast room, with cubicles yet unfilled and a cluster of exercise balls. However, I hadn’t expected that instead of being attired in traditional T-shirts and jeans, the employees were decked out in costumes. I had come on Halloween.

“Steven, meet Larry Page and Sergey Brin,” said Cindy, introducing me to the two young men who had founded the company as Stanford graduate students. Larry was dressed as a Viking, with a long-haired fur vest and a hat with long antlers protruding. Sergey was in a cow suit. In his chest was a rubber slab from which protruded huge, wart-specked teats. They greeted me cheerfully and we all retreated to a conference room where the Viking and the cow explained the miraculous powers of Google’s PageRank technology.

That was the first of many interviews I would conduct at Google. Over the next few years, the company became a focus of my technology reporting at *Newsweek*. Google grew from the small start-up I had visited to a behemoth of more than 20,000 employees. Every day, billions of people used its search engine, and Google’s remarkable ability to deliver relevant results in milliseconds changed the way the world got information. The people who clicked on its ads made Google wildly profitable and turned its founders into billionaires—and triggered an outpouring among traditional beneficiaries of ad dollars.

Google also became known for its irreverent culture and its data-driven approach to business decision making; management experts rhapsodized about its unconventional methods. As the years went by, Google began to interpret its mission—to gather and make accessible as useful the world’s information—in the broadest possible sense. The company created a series of web-based applications. It announced its intention to scan all the world’s books. It became involved in satellite imagery, mobile phones, energy generation, photo storage. Clearly, Google was one of the most important contributors to the revolution of computers and technology that marked a turning point in civilization. I knew I wanted to write a book about the company but wasn’t sure how.

Then in early July 2007, I was asked to join the associate product managers on their trip. It was an unprecedented invitation from a company that usually limits contact between journalists and its employees. The APM program, I learned, was a highly valued initiative. To quote the pitch of the participants made in 2006 to recent and upcoming college graduates: “We invest more into our APMs than any other company has ever invested into young employees.... [We envision a world](#) where everyone is awed by the fact that Google’s executives, the best CEOs in the Silicon Valley, and the most respected leaders of global non-profits all came through the Google APM program.” Eric Schmidt, Google’s CEO, told me, “One of these people will probably be our CEO one day—we just don’t know which one.”

The eighteen APMs on the trip worked all over Google: in search, advertising, applications, and even stealth projects such as Google’s attempt to capture the rights to include magazines in its index. Mayer’s team, along with the APMs themselves, had designed the agenda of the trip. Every activity had an underlying purpose to increase the participants’ understanding of a technology or business issue, or make them more

the parlance of the company) “Googley.” In Tokyo, for instance, they engaged in a scavenger hunt in the city’s legendary Akihabara electronics district. Teams of APMs were each given \$50 to buy the weirdest gadgets they could find. Ducking into backstreets with stalls full of electronic parts and gizmos, they wound up with a cornucopia: USB-powered ashtrays shaped like football helmets that suck up smoke; a plate-sized disk that simulated the phases of the moon; a breathalyzer you could install in your car; and a stubby wand that, when waved back and forth, spelled out words in LED lights. In Bangalore, there was a different shopping hunt—an excursion to the market area where the winner of the competition would be the one who haggled best. (Good training for making bulk purchases of computers or even buying an Internet start-up.) Another Tokyo high point was the 5 AM trip to the Tsukiji fish market. It wasn’t the fresh sushi that fascinated the APMs but the mechanics of the fish auction, in some ways similar to the way Google works its AdWords program.

In China, Google’s top executive there, Kai-Fu Lee, talked of balancing Google’s freewheeling style with government rules—and censorship. But during interviews with Chinese consumers, the APMs were discouraged to hear the perception of the company among locals: “Baidu [Google’s local competitor] knows more [about China] than Google,” said one young man to his APM interlocutors.

At every office the APMs visited, they attended meetings with local Googlers, first learning about projects under way and then explaining to residents what was going on at Mountain View headquarters. I began to get an insider’s sense of Google’s product processes—and how serving its users was akin to a crusade. An interesting moment occurred in Bangalore when Mayer was taking questions from local engineers at a presentation of an overview of upcoming products. One of them asked, “We’ve heard the road map for products, what’s the road map for revenue?” She almost bit his head off. “That’s *not* the way to think,” she said. “We are focused on our *users*. If we make them happy, we will have revenues.”

The most fascinating part of the trip was the time spent with the young Googlers. They were generally from elite colleges, with SAT scores approaching or achieving perfection. Carefully culled from thousands of people who would have killed for the job, their personalities and abilities were a reflection of Google’s own character. During a bus ride to the Great Wall of China, one of the APMs charted the group demographics and found that almost all had parents who were professionals and more than half had parents who taught at a university—which put them in the company of Google’s founders. They all grew up with the Internet and considered its principles to be as natural as the laws of gravity. They were among the brightest and most ambitious of a generation that was better equipped to handle the disruptive technology wave than their elders were. Their minds hummed like tuning forks in resonance with the company’s values of speed, flexibility, and a deep respect for data.

Yet even while immersed in an optimism bubble with these young people, I could see the strains that came with Google’s abrupt growth from a feisty start-up to a market-dominating giant with more than 20,000 employees. The APMs had spent a year navigating the folkways of a complicated corporation, albeit a determinedly different one—and now they were almost senior employees. What’s more, I was stunned when a poll of my fellow travelers revealed that not a single one of them saw him- or herself working for Google in five years. Marissa Mayer took this news calmly, claiming that such ambition was why they had been hired in the first place. “This is the gene that Larry and Sergey look for,” she told me. “Even if they leave, it’s still good for us. They’re going to take the Google DNA with them.”

After covering the company for almost a decade, I thought I knew it pretty well, but the rare view of the company I got in those two weeks made me see it in a different, wider light. Still, there were considerable mysteries. Google was a company built on the values of its founders, who harbored ambitions to build a powerful corporation that would impact the entire world, at the same time loathing the bureaucracy and commitment that running such a company would entail. Google professed a sense of moral purity—as exemplified by its informal motto, “Don’t be evil”—but seemed to have a blind spot regarding the consequences of its own technology on privacy and property rights. A bedrock principle of Google was serving its users—but a goal was building a giant artificial intelligence learning machine that would bring uncertain consequences to the way all of us live. From the very beginning, its founders said that they wanted to change the world. But who were they, and what did they envision this new world order to be?

After the trip I realized that the best way to answer these questions was to report as much as possible from inside Google. Just as I’d had a rare glimpse into its inner workings during that summer of 2007, I would try to immerse myself more deeply into its engineering, its corporate life, and its culture, to report how it really operated, how it developed its products, and how it was managing its growth and public exposure. I would do this from an outsider with an insider’s view.

To do this, of course, I’d need cooperation. Fortunately, based on our long relationship, Google’s executives, including “LSE”—Larry Page, Sergey Brin, and Eric Schmidt—agreed to let me in. During the next two years—a critical time when Google’s halo lost some of its glow even as the company grew more powerful—I interviewed hundreds of current and former Googlers and attended a variety of meetings in the company. These included product development meetings, “interface reviews,” search launch meetings, privacy council sessions, weekly TGIF all-hands gatherings, and the gatherings of the high command known as Google Product Strategy (GPS) meetings, where projects and initiatives were approved or rejected. I also ate a lot of meals at Andale, the burrito joint in Google’s Building 43.

What I discovered was a company exulting in creative disorganization, even if the creativity was not always as substantial as hoped. Google had massive goals, and the entire company channeled its values from the founders. Its mission was collecting and organizing all the world’s information—and that’s only the beginning. From the very start, its founders saw Google as a vehicle to realize the dream of artificial intelligence augmenting humanity. To realize their dreams, Page and Brin had to build a huge company. At the same time, they attempted to maintain as much as possible the nimble, irreverent, answer-to-no-one freedom of a small start-up. In the two years I researched this book, the clash between those goals reached a peak, as David had become a Goliath.

My inside perspective also provided me the keys to unlock more of the secrets of Google’s two “black boxes”—its search engine and its advertising model—than had previously been disclosed. Google search is part of our lives, and its ad system is the most important commercial product of the Internet age. In this book, for the first time, readers can learn the full story of their development, evolution, and inner workings. Understanding those groundbreaking products helps us understand Google and its employees because their operation embodies both the company’s values and its technological philosophy. More important, understanding them helps us understand our own world—and tomorrow’s.

The science fiction writer William Gibson once said that the future is already here—just not evenly distributed. At Google, the future is already under way. To understand this pioneering company and its people is to grasp our technological destiny. And so here is Google: how it works, what it thinks, why it’s changing, how it will continue to change us. And how it hopes to maintain its soul.

PART ONE

THE WORLD ACCORDING TO GOOGLE

Biography of a Search Engine

“It was science fiction more than computer science.”

On February 18, 2010, Judge Denny Chin of the New York Southern District federal court took stock of the packed gallery in Courtroom 23B. It was going to be a long day. He was presiding over a hearing that would provide only a gloss to hundreds of submissions he had already received on this case. “[There is just too much](#) to digest,” he said. He shook his head, preparing himself to hear the arguments of twenty-seven representatives of various interest groups or corporations, as well as presentations by some of the lawyers for various parties, lawyers who filled every place in the long tables before him.

The case was *The Authors Guild, Inc., Association of American Publishers, et al. v. Google Inc.* It was a lawsuit tentatively resolved by a class settlement agreement in which an authors’ group and a publishers’ association set conditions for a technology company to scan and sell books. Judge Chin’s decision would involve important issues affecting the future of digital works, and some of the speakers before the court engaged on those issues. But many of the objectors—and most who addressed the court were objectors to the settlement—focused on a young company headquartered on a sprawling campus in Mountain View, California. That company was Google. The speakers seemed to distrust it, fear it, even despise it.

“[A major threat](#) to ... freedom of expression and participation in cultural diversity”

“[An unjustified monopoly](#)”

“[Eviscerates privacy protections](#)”

“[Concealment and misdirection](#)”

“[Price fixing](#) ... a massive market distortion ... preying on the desperate”

“May well be a per se violation of the antitrust laws”

(That last statement held special weight, as it came from the U.S. deputy assistant attorney general.)

But the federal government was only one of Google’s surprising opponents. Some of the others were supporters of the public interest in monitoring the privacy rights and pocketbooks of citizens. Others were advocates of free speech. There was even an objector representing the folk singer Arlo Guthrie.

The irony was that Google itself explicitly embraced the lofty values and high moral standards that it was being attacked for flouting. Google’s founders had consistently stated that their goal was to make the world better, specifically by enabling humanity’s access to information. Google had created an astonishing tool that took advantage of the interconnected nature of the burgeoning World Wide Web, a tool that empowered people to locate even obscure information within seconds. This search engine transformed the way people worked, entertained themselves, and learned. Google made historic profits from that product by creating a new form of advertising—nonintrusive and even useful. It hired the sharpest minds in the world and encouraged them to take on challenges that pushed the boundaries of innovation. Its focus on engineering talent to accomplish difficult goals was a national inspiration. It even warned its shareholders that the company would sometimes pursue business practices that served humanity even at the expense of lower profits. It accomplished all those achievements with a puckish irreverence that captivated the public and made heroes of its employees.

But that didn’t matter to the objectors in Judge Chin’s courtroom. Those people were Google’s natural allies, and they thought that Google was no longer ... good. The mistrust and fear in the courtroom were reflected globally by governments upset by Google’s privacy policies and businesses worried that Google’s disruptive practices would target them next. Everywhere Google’s executives turned, they were faced with protests and lawsuits.

The course of events was baffling to Google’s two founders, Larry Page and Sergey Brin. Of all Google’s projects, the one at issue in the hearing—Google’s Book Search project—was perhaps the most idealistic. It was an audacious attempt to digitize every book ever printed, so that anyone in the world could locate the information within. Google would not give away the full contents of the books, so when users discovered them, they would have reason to buy them. Authors would have new markets; readers would have instant access to knowledge. After being sued by publishers and authors, Google made a deal with them that would make it even easier to access the books and to buy them on the spot. Even libraries would get a free terminal to connect to the entire corpus of the world’s books. To Google, it was a boon to civilization.

Didn’t people understand?

By all metrics, the company was still thriving. Google still retained its hundreds of millions of users, hosted billions of searches every day, and had growing businesses in video and wireless devices. Its employees were still idealistic and ambitious in the best sense. But a shadow had darkened Google’s image. To many outsiders, the corporate motto that Google had taken seriously—“Don’t be evil”—had become a joke. A bludgeon to be used against it.

What had happened?

Doing good was Larry Page’s plan from the very beginning. Even as a child, he wanted to be an inventor, not simply because his mind aligned perfectly with the nexus of logic and technology (which it did) but because, he says, “I really wanted to change the world.”

Page grew up in Lansing, Michigan, where his father taught computer science at Michigan State. His parents divorced when he was eight, but he was close with both his father and mother—who had her own computer science degree. Naturally, he spoke computers as a primary language. As he later told an interviewer, “I think I was [the first kid](#) in my elementary school to turn in a word-processed document.”

Page was not a social animal—people who talked to him often wondered if there were a jigger of Asperger’s in the mix—and could communicate by simply not talking. But when he did speak, more often than not he would come out with ideas that bordered on the fantastic. Attending a [summer program in leadership](#) (motto: “A healthy disregard for the impossible”) helped move him to action. At the University of Michigan, Page became obsessed with transportation and drew up plans for an elaborate monorail system in Ann Arbor, replacing the mundane bus system with a “futuristic” commute between the dorms and the classrooms. It seemed to come as a surprise to him that a fanciful multimillion-dollar transit fantasy

from an undergraduate would not be quickly embraced and implemented. (Fifteen years after he graduated, Page would bring up the issue again at a meeting with the university's president.)

His intelligence and imagination were clear. But when you got to know him, what stood out was his ambition. It expressed itself not as a personal drive (though there was that, too) but as a general principle that everyone should think big and then make big things happen. He believed that the only true failure was not attempting the audacious. "Even if you fail at your ambitious thing, it's very hard to fail completely," he says. "That's the thing that people don't get." Page *always* thought about that. When people proposed a short-term solution, Page's instinct was to think long term. There would eventually be a joke among Googlers that Page "went to the future and came back to tell us about it."

Page earned a degree in computer science like his father did. But his destiny was in California, specifically in the Silicon Valley. In a way, Page's arrival at Stanford was a homecoming. He'd lived there briefly in 1979 when his dad had spent a sabbatical at Stanford; some faculty members still remembered him as an insatiably curious seven-year-old. In 1995, Stanford was not only the best place to pursue cutting-edge computer science but, because of the Internet boom, was also the world capital of ambition. Fortunately, Page's visions extended to the commercial: "Probably from when I was twelve, I knew I was going to start a company eventually," he'd later say. Page's brother, nine years older, was already in Silicon Valley, working for an Internet start-up.

Page chose to work in the department's Human-Computer Interaction Group. The [subject would stand Page](#) in good stead in the future with respect to product development, even though it was not in the HCI domain to figure out a new model of information retrieval. On his desk at the time permeating his conversations was Apple interface guru Donald Norman's classic tome *The Psychology of Everyday Things*, the bible of a religion whose first, and arguably only, commandment is "The user is always right." (Other Norman disciples, such as Jeff Bezos at Amazon.com, were adopting this creed on the web.) Another influential book was a biography of Nikola Tesla, the brilliant Serb scientist; though Tesla's contributions arguably matched Thomas Edison's—and his ambitions were grand enough to impress even Page—he died in obscurity. "I felt like he was a great inventor and it was a sad story," says Page. "I feel like he could've accomplished much more had he had more resources. And he had trouble commercializing the stuff he did. Probably more trouble than he should've had. I think that was a good lesson. I didn't want to just invent things, I wanted to make the world better, and in order to do that, you need to do more than just invent things."

The summer before entering Stanford, Page attended a program for accepted candidates that included a tour of San Francisco. The guide was a grad student Page's age who'd been at Stanford for two years. "[I thought he was pretty obnoxious](#)," Page later said of the guide, Sergey Brin. The content of the encounter is now relegated to legend, but their argumentative banter was almost certainly good-natured. Despite the contrast in personalities, in some ways they were twins. Both felt most comfortable in the meritocracy of academia, where brains trump everything else. Both had an innate understanding of how the ultraconnected world that they enjoyed as computer science (CS) students was about to spread throughout society. Both shared a core belief in the primacy of data. And both were rock stubborn when it came to pursuing their beliefs. When Page settled in that September, he became close friends with Brin, to the point where people thought of them as a set: [LarryAndSergey](#).

Born in Russia, Brin was four when his family immigrated to the United States. His English still maintained a Cyrillic flavor, and his speech was dotted with anachronistic Old World touches such as the use of "what-not" when peers would say "stuff like that." He had arrived at Stanford nineteen after whizzing through the University of Maryland, where his father taught, in three years; he was one of the youngest students ever to start the Stanford PhD program. "He skipped a million years," says Craig Silverstein, who arrived at Stanford a year later, and would eventually become Google's first employee. Sergey was a quirky kid who would zip through Stanford's hallways on omnipresent Rollerblades. He also had an interest in trapeze. But the professors understood that behind the goofiness was a formidable mathematical mind. Soon after arriving at Stanford, he knocked off all the required tests for a doctorate and was free to sample the courses until he found a suitable entree for a thesis. He supplemented his academics with swimming, gymnastics, and sailing. (When his father asked him in frustration whether he planned to take advanced courses, he said that he might take [advanced swimming](#).) Donald Knuth, a Stanford professor whose magisterial series of books on the art of computer programming made him the Proust of computer code, recalls driving down the Pacific coast to a conference with Sergey one afternoon and being impressed at his grasp of complicated issues. His adviser, Hector Garcia-Molina, had seen a lot of bright kids go through Stanford, but Brin stood out. "He was brilliant," Garcia-Molina says.

One task that Brin took on was a numbering scheme for the new Gates Computer Science Building, which was to be the home of the department. (His system used mathematical flourishes.) The structure was named after William Henry Gates III, better known as Bill, the cofounder of Microsoft. Though Gates had spent a couple of years at Harvard and endowed a building named after his mother there, he went on a spree of splurge of funding palatial new homes for computer science departments at top technical institutions that he *didn't* attend, including MIT and Carnegie Mellon—along with Stanford, the trifecta of top CS programs. Even as they sneered at Windows, the next generation of wizards would study in buildings named after Bill Gates.

Did Gates ever imagine that one of those buildings would incubate a rival that might destroy Microsoft?

The graduate computer science program at Stanford was built around close relationships between students and faculty members. They would team up to work on big, real-world problems; the fresh perspective of the young people maintains the vitality of the professor's interests. "I always follow the students," says Terry Winograd, who was Page's adviser. (Page would often remind him that they had met during his dad's Stanford sabbatical.) Over the years Winograd had become an expert at figuring out where students stood on the spectrum of brainiacs who found their way into the department. Some were kids whose undergrad record was straight A pluses, GRE scores scraping perfection, who would come in and say, "What thesis should I work on?" On the other end of the spectrum were kids like Larry Page, who would come in and say, "Here's what I think I can do." And his proposals were *crazy*. He'd come into the office and talk about doing something with space tethers or solar kites. "It was science fiction more than computer science," recalls Winograd. But an outlandish mind was a valuable asset, and there was definitely a place in current science to channel wild creativity.

In 1995, that place was the World Wide Web. It had sprung from the restless brain of a (then)-obscure British engineer named Tim Berners-Lee, who was working as a technician at the CERN physics research lab in Switzerland. Berners-Lee could sum up his vision in a sentence: "[Suppose all the information](#) stored on computers everywhere were linked ... there would be a single global information space."

[The web's pedigree](#) could be traced back to a 1945 paper by the American scientist Vannevar Bush. Entitled "As We May Think," it outlined a vast storage system called a "memex," where documents would be connected, and could be recalled, by information breadcrumbs called "trails of association." The timeline continued to the work of Douglas Engelbart, whose team at the Stanford Research Institute devised a linked document system that lived behind a dazzling interface that introduced the metaphors of windows and files to the digital desktop. Then came a detour to the brilliant but erratic work of an autodidact named Ted Nelson, whose ambitious Xanadu Project (though never completed) was a vision of disparate information linked by "hypertext" connections. Nelson's work inspired Bill Atkinson, a software engineer who had been part of the original Macintosh team; in 1987 he came up with a link-based system called HyperCard, which he sold to Apple for \$100,000 on the condition that the company give it away to all its users. But to really fulfill Vannevar Bush's vision, you needed a huge system where people could freely post and link their documents.

By the time Berners-Lee had his epiphany, that system was in place: the Internet. While the earliest websites were just ways to distribute academic papers more efficiently, soon people began writing sites with information of all sorts, and others created sites just for fun. By the mid-1990s, people were starting to use the web for profit, and a new word, “e-commerce,” found its way into the lexicon. Amazon.com and eBay became Internet giants. Other sites positioned themselves as gateways, or portals, to the wonders of the Internet.

As the web grew, its linking structure accumulated a mind-boggling value. It treated the aggregate of all its contents as a huge composition of ideas, any one of which could be reached by the act of connecting one document to another. When you looked at a page you could see, usually highlighted in blue, the pointers to other sites that the webmaster had coded on the page—that was the hypertext idea that galvanized Berners-Lee, Nelson, and Atkinson. But for the first time, as Berners-Lee had intended, the web was coaxing a critical mass of these linked sites and documents into a single network. In effect, the web was an infinite database, a sort of crazily expanding universe of human knowledge that, in theory, could hold every insight, thought, image, and product for sale. And all of it had an intricate lattice of cross-connections created by the independent linking activity of anyone who had built a page and coded in a link to something elsewhere on the web.

In retrospect, the web was to the digital world what the Louisiana Purchase was to the young United States: the opportunity of a century.

Berners-Lee’s creation was so new that when Stanford got funding from the National Science Foundation in the early 1990s to start a program called the Digital Library Project, the web wasn’t mentioned in the proposal. “The theme of that project was interoperability—how can we make these resources work together?” recalls Hector Garcia-Molina, who cofounded the project. By 1995 though, Garcia-Molina knew that the World Wide Web would inevitably be part of the projects concocted by the students who worked with the program, including Page and Brin.

Brin already had a National Science Foundation fellowship and didn’t need funding, but he was trying to figure out a dissertation topic. His loose focus was data mining, and with Rajeev Motwani, a young professor he became close with, he helped start a research group called MIDA which stood for Mining Data at Stanford. In a résumé he posted on the Stanford site in 1995, he talked about “a new project” to generate [personalized movie ratings](#). “The way it works is as follows,” he wrote. “You rate the movies you have seen. Then the system finds other users with similar tastes to extrapolate how much you like other movies.” Another project he worked on with Garcia-Molina and another student was a system that detected copyright violations by automating searches for duplicates of documents. “He came up with some good algorithms for detecting copies,” says Garcia-Molina. “Now you use Google.”

Page was also seeking a dissertation topic. One idea he presented to Winograd, a collaboration with Brin, seemed more promising than others: creating a system where people could make annotations and comments on websites. But the more Page thought about annotation, the messier it got. For big sites, there would probably be a lot of people who wanted to mark up a page. How would you figure out who gets to post a comment or whose comment would be the one you’d see first? For that, he says, “We needed a rating system.”

Having a human being determine the ratings was out of the question. First, it was inherently impractical. Further, humans were unreliable. Computer algorithms—well drawn, efficiently executed, and based on sound data—could deliver unbiased results. So the problem became finding the right data to determine whose comments were more trustworthy, or interesting, than others. Page realized that such data already existed and no one else was really using it. He asked Brin, “[Why don’t we use the links](#) on the web to do that?”

Page, a child of academia, understood that web links were like citations in a scholarly article. It was widely recognized that you could identify which papers were really important without reading them—simply tally up how many other papers cited them in notes and bibliographies. Page believed that this principle could also work with web pages. But getting the right data would be difficult. Web pages made their outgoing links transparent: built into the code were easily identifiable markers for the destinations you could travel to with a mouse click from that page. But it wasn’t obvious at all what linked *to* a page. To find that out, you’d have to somehow collect a database of links that connected to some other page. Then you’d go *backward*.

That’s why Page called his system BackRub. “[The early versions of hypertext](#) had a tragic flaw: you couldn’t follow links in the other direction,” Page once told a reporter. “BackRub was about reversing that.”

Winograd thought this was a great idea for a project, but not an easy one. To do it right, he told Page, you’d really have to capture a significant chunk of the World Wide Web’s link structure. Page said, sure, he’d go and download the web and get the structure. He figured it would take a week or something. “And of course,” he later recalled, “it took, like, years.” But Page and Brin attacked it. Every other week Page would come to Garcia-Molina’s office asking for disks and equipment. “That’s fine,” Garcia-Molina would say. “This is a great project, but you need to give me a budget.” He asked Page to pick a number, to say how much of the web he needed to crawl, and to estimate how many disks that would take. “I want to crawl the *whole* web,” Page said.

Page indulged in a little vanity in naming the part of the system that rated websites by the incoming links: he called it PageRank. But it was a little sly vanity; many people assumed the name referred to web pages, not a surname.

Since Page wasn’t a world-class programmer, he asked a friend to help out. Scott Hassan was a full-time research assistant at Stanford working for the Digital Library Project program while doing part-time grad work. Hassan was also good friends with Brin, whom he’d met at an Ultimate Frisbee game during his first week at Stanford. Page’s program “had so many bugs in it, it wasn’t funny,” says Hassan. Part of the problem was that Page was using the relatively new computer language Java for his ambitious project, and Java kept crashing. “I went and tried to fix some of the bugs in Java itself, and after doing this ten times, I decided it was a waste of time,” says Hassan. “I decided to take his stuff and rewrite it into the language I knew much better that didn’t have any bugs.”

He wrote a program in Python—a more flexible language that was becoming popular for web-based programs—that would act as a “spider” so called because it would crawl the web for data. The program would visit a web page, find all the links, and put them into a queue. Then it would check to see if it had visited those link pages previously. If it hadn’t, it would put the link on a queue of future destinations to visit and repeat the process. Since Page wasn’t familiar with Python, Hassan became a member of the team. He and another student, Alan Steremberg, became page assistants to the project.

Brin, the math prodigy, took on the huge task of crunching the mathematics that would make sense of the mess of links uncovered by the monster survey of the growing web.

Even though the small team was going somewhere, they weren’t quite sure of their destination. “Larry didn’t have a plan,” says Hassan. “The research you explore something and see what sticks.”

By March 1996, they began a test, starting at a single page, the Stanford computer science department home page. The spider located all the links on the page and fanned out to all the sites that linked to Stanford, then to the sites that linked to *those* websites. “That first one just used titles of documents because collecting the documents themselves required a lot of data and work,” says Page. After they snared about 15 million of those titles, they tested the program to see which websites it deemed more authoritative.

“Even the first set of results was very convincing,” Hector Garcia-Molina says. “It was pretty clear to everyone who saw this demo that this was a very good, very powerful way to order things.”

“We realized it worked really, really well,” says Page. “And I said, ‘Wow, the big problem here is not annotation. We should now use it not just

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