Andrew McAfee and Erik Brynjolfsson, "The triple revolution," in Machine, Platform, Crowd: Harnessing Our Digital Future (W.W. Norton, 2017).

CHAPTER 1

THE TRIPLE REVOLUTION

> These parallels are close and striking enough to make it almost certain that, as in the earlier industrial revolutions, the main effects of the information revolution on the next society still lie ahead.
>
> — *Peter Drucker, 2001*

Computers on the Go (Board)

Learning to play Go well has always been difficult for humans, but programming computers to play it well has seemed nearly impossible.

Go is a pure strategy game—no luck involved*—developed at least 2,500 years ago in China. One player uses white stones; the other, black. They take turns placing stones on the intersections of a 19×19 grid. If a stone or group of stones has all of its freedoms removed—if it's completely surrounded by opposing stones, essentially—it's "captured" and taken off the board. At the end of the game† the player with more captured territory wins.

People who love strategy love Go. Confucius advised that "gentlemen should not waste their time on trivial games—they should study Go." In many quarters, it's held in higher regard even than chess,

* A game theorist would call Go a "deterministic perfect information game."

† The game ends when both players agree that they can no longer make beneficial moves.

another difficult two-person, luck-free strategy game. As the chess grand master Edward Lasker says, "While the Baroque rules of chess could only have been created by humans, the rules of Go are so elegant, organic, and rigorously logical that if intelligent life forms exist elsewhere in the universe, they almost certainly play Go."

The game's apparent simplicity belies a complexity that's difficult to even conceptualize. Because of the large board and the great freedom that players have in placing their stones, it is estimated that there are about 2×10^{170} (that is, 2 followed by 170 zeros) possible positions on a standard Go board. How big is this number? It's larger than the number of atoms in the observable universe. In fact, that's a completely inadequate benchmark. The observable universe contains about 10^{82} atoms. So, if every atom in the universe were itself an entire universe full of atoms, there would still be more possible Go games than atoms.

The Game Nobody Can Explain

How do the top human Go players navigate this absurd complexity and make smart moves? Nobody knows—not even the players themselves.

Go players learn a group of heuristics and tend to follow them.* Beyond these rules of thumb, however, top players are often at a loss to explain their own strategies. As Michael Redmond, one of few Westerners to reach the game's highest rank, explains, "I'll see a move and be sure it's the right one, but won't be able to tell you exactly how I know. I just see it."

It's not that Go players are an unusually tongue-tied lot. It turns out the rest of us can't access all of our own knowledge either. When we recognize a face or ride a bike, on reflection we can't fully explain

* Many Go heuristics are somewhat vague—for example, "Don't use thickness to make territory."

how or why we're doing what we're doing. It is hard to make such tacit knowledge explicit—a state of affairs beautifully summarized by the twentieth-century Hungarian-British polymath Michael Polanyi's observation "We know more than we can tell."

"Polanyi's Paradox," as it came to be called, presented serious obstacles to anyone attempting to build a Go-playing computer. How do you write a program that includes the best strategies for playing the game when no human can articulate these strategies? It's possible to program at least some of the heuristics, but doing so won't lead to a victory over good players, who are able to go beyond rules of thumb in a way that even they can't explain.

Programmers often rely on simulations to help navigate complex environments like all the possible universes of Go games. They write programs that make a move that looks good, then explore all the opponent's plausible responses to that move, all the plausible responses to each response, and so on. The move that's eventually chosen is essentially the one that has the most good futures ahead of it, and the fewest bad ones. But because there are so many potential Go games—so many universes full of them—it's not possible to simulate more than an unhelpfully tiny fraction of them, even with a hangar full of supercomputers.

With critical knowledge unavailable and simulation ineffective, Go programmers made slow progress. Surveying the current state and likely trajectory of computer Go in a May 2014 article in *Wired* magazine, philosophy professor Alan Levinovitz concluded that "another ten years until a computer Go champion may prove too optimistic." A December 2015 *Wall Street Journal* article by Chris Chabris, a professor of psychology and the newspaper's game columnist, was titled "Why Go Still Foils the Computers."

Past Polanyi's Paradox

A scientific paper published the very next month—January 2016—unveiled a Go-playing computer that wasn't being foiled anymore.

A team at Google DeepMind, a London-based company specializing in machine learning (a branch of artificial intelligence we'll discuss more in Chapter 3), published "Mastering the Game of Go with Deep Neural Networks and Tree Search," and the prestigious journal *Nature* made it the cover story. The article described AlphaGo, a Go-playing application that had found a way around Polanyi's Paradox.

The humans who built AlphaGo didn't try to program it with superior Go strategies and heuristics. Instead, they created a system that could learn them on its own. It did this by studying lots of board positions in lots of games. AlphaGo was built to discern the subtle patterns present in large amounts of data, and to link actions (like playing a stone in a particular spot on the board) to outcomes (like winning a game of Go).*

The software was given access to 30 million board positions from an online repository of games and essentially told, "Use these to figure out how to win." AlphaGo also played many games against itself, generating another 30 million positions, which it then analyzed. The system did conduct simulations during games, but only highly focused ones; it used the learning accumulated from studying millions of positions to simulate only those moves it thought most likely to lead to victory.

Work on AlphaGo began in 2014. By October of 2015, it was ready for a test. In secret, AlphaGo played a five-game match against Fan Hui, who was then the European Go champion. The machine won 5–0.

* Throughout this book we'll characterize technologies as doing humanlike things such as discerning, learning, seeing, and so on. We do this because we believe it's the right way to convey what's going on, even though it's true that computers don't reason like people do. We realize this convention is unpopular in some quarters; the old admonition is "Don't anthropomorphize computers—they hate it."

A computer Go victory at this level of competition was completely unanticipated and shook the artificial intelligence community. Virtually all analysts and commentators called AlphaGo's achievement a breakthrough. Debates did spring up, however, about its magnitude. As the neuroscientist Gary Marcus pointed out, "Go is scarcely a sport in Europe; and the champion in question is ranked only #633 in the world. A robot that beat the 633rd-ranked tennis pro would be impressive, but it still wouldn't be fair to say that it had 'mastered' the game."

The DeepMind team evidently thought this was a fair point, because they challenged Lee Sedol to a five-game match to be played in Seoul, South Korea, in March of 2016. Sedol was regarded by many as the best human Go player on the planet,* and one of the best in living memory. His style was described as "intuitive, unpredictable, creative, intensive, wild, complicated, deep, quick, chaotic"—characteristics that he felt would give him a definitive advantage over any computer. As he put it, "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." He predicted he would win at least four games out of five, saying, "Looking at the match in October, I think (AlphaGo's) level doesn't match mine."

The games between Sedol and AlphaGo attracted intense interest throughout Korea and other East Asian countries. AlphaGo won the first three games, ensuring itself of victory overall in the best-of-five match. Sedol came back to win the fourth game. His victory gave some observers hope that human cleverness had discerned flaws in a digital opponent, ones that Sedol could continue to exploit. If so, they

* By August of 2016, the thirty-three-year-old Sedol had already collected eighteen international titles, second only to the twenty-one held by his countryman Lee Chang-ho, who was more than eight years older.

were not big enough to make a difference in the next game. AlphaGo won again, completing a convincing 4–1 victory in the match.

Sedol found the competition grueling, and after his defeat he said, "I kind of felt powerless. . . . I do have extensive experience in terms of playing the game of Go, but there was never a case as this as such that I felt this amount of pressure."

Something new had passed Go.

What Happened to the Assets?

In March of 2015, strategist Tom Goodwin pointed out a pattern. "Uber, the world's largest taxi company, owns no vehicles," he wrote. "Facebook, the world's most popular media owner, creates no content. Alibaba, the most valuable retailer, has no inventory. And Airbnb, the world's largest accommodation provider, owns no real estate."

A skeptical reader might respond that some of these developments were less revolutionary than they at first appeared. Many companies in the taxi industry, for example, don't themselves own cars. They instead own medallions that confer the right to operate a taxi in a city, and they rent the medallions to vehicle owners and drivers. Similarly, many of the largest hotel companies don't actually own all the properties that bear their names, opting instead to sign licensing or management agreements with real estate holders.

But in all of these cases, the companies in question held long-lived assets, like licenses and contracts, that are important to the industry and thus valuable. Uber and Airbnb have none of these. Uber has no claim on any vehicle or medallion in any city in the world, and Airbnb has no long-term contract with any lodging owners anywhere. Yet both companies quickly reached millions of customers and billions in valuation, making the success that Goodwin observed all the

more remarkable. At the time of his column, over a million people each day "took an Uber" to get somewhere in one of 300 cities in 60 countries, and Airbnb offered 640,000 different lodging options in 191 countries, ranging from a yurt in Mongolia to James Joyce's childhood home in Ireland.

China's Alibaba brought an asset-light approach to retailing, an industry where large reach had historically meant ownership of a great many things. Walmart, for example, owned by the end of 2016 more than 150 distribution centers and a private fleet of 6,000 trucks that drove 700 million annual miles to get products on the shelves of 4,500 shops across the United States. By October 31 of that year, the company's balance sheet included $180 billion of property and equipment assets. Yet on the same day, Walmart's total market value was less than that of Alibaba, which enabled sales of over half a trillion dollars in 2016.

Alibaba, founded in 1999 by former schoolteacher Jack Ma and seventeen colleagues, acted as an online middleman connecting buyers and sellers. Its most popular sites were the Taobao Marketplace, where individuals and small businesses sold goods to consumers, and Tmall, where larger companies did the same. By the end of 2016, the number of Chinese people using Alibaba's apps every month was greater than the entire US population.

In 2009, Tmall began promoting "Singles Day" in China. This was originally a celebration, apparently begun in the mid-1990s at Nanjing University, of not being in a relationship. It was held on the eleventh day of the eleventh month because that's the date with the maximum number of ones, or "bare sticks" that symbolize being alone. Tmall's "Singles Day" effort started out with just twenty-seven participating merchants, but it quickly became the most important shopping event in the country, with participants buying presents not only for their single selves, but also for people they're interested in.

On November 11, 2016, Alibaba's marketplaces enabled sales of $17.8 billion, three times the combined total of Black Friday and Cyber Monday in the United States.*

Of the four companies mentioned by Goodwin, though, Facebook might have the most extraordinary story. From its start in Mark Zuckerberg's Harvard dorm room eleven years earlier, it had grown from a social networking site at a few elite US universities into a global utility of communication, connection, and content, visited daily by 936 million people. As Goodwin pointed out, Facebook drew all these people in and kept them engaged for an average of fifty minutes per day without generating any of the information that appeared on the site. Its members' status updates, opinions, photos, videos, pointers, and other contributions were presented to other visitors in an ever-increasing flood that kept people coming back.

As it presented all this content to its users, Facebook also showed them ads, and eventually a lot of them. Facebook's revenues in the second quarter of 2016, virtually all of which came from advertising, were $6.4 billion. Profits were $2 billion.

News organizations and others online that develop their content the old-fashioned way—by spending money on salaries, travel, and so on—were alarmed not only because Facebook's costs were lower, but because in the eyes of advertisers, its quality was higher in important ways. The social networking giant knew so much about its members (they were, after all, telling the site a great deal about themselves with the information they provided and the contributions they made) that it could often target ads more precisely to them.

Every advertiser is haunted by some version of the rueful remark often attributed to the American department store pioneer John Wanamaker: "Half the money I spend on advertising is wasted. The trouble is I don't know which half." Advertising has always been a hugely inexact science, in large part, it is commonly believed, because it can't be targeted to just the people most likely to respond. Facebook offered many advertisers a level of specificity in targeting that no mainstream media site could match, and it could do it continuously, globally, and at scale.

* Black Friday (the day after Thanksgiving) is historically the busiest in-person shopping day of the year in the United States. Cyber Monday, three days later, is the day when many online merchants offer holiday deals to their customers.

A Thin Layer, Spreading Quickly

Goodwin described the companies he was talking about as an "indescribably thin layer" and said "there is no better business to be in." Because they're so thin—because they own mainly applications and code and not physical assets and infrastructure—they could grow rapidly. Airbnb, for example, doubled the number of nights booked through the site in the twelve months after Goodwin's article appeared, and it became so popular that the governments of cities including Paris, Barcelona, Lisbon, Berlin, and San Francisco began to worry that it was negatively affecting the character of historic residential neighborhoods. The company's growth was so fast and so contentious that in July of 2016, technology writer Tom Slee blogged on *Harvard Business Review*'s site that "Airbnb is facing an existential expansion problem" as more cities and regions fought against its expansion.

Uber also continued experiencing both rapid growth and frequent controversies, and testing out new offerings. Its UberPool carpooling service, introduced in 2014, quickly proved popular in many cities, including New York. In May of 2016 the company announced that all weekly rush-hour UberPool rides in Manhattan below 125th Street would cost a flat $5, and in July of that year a special offer allowed New Yorkers to buy four weeks' worth of such rides for $79. At this price, the service would be cheaper than the subway for many commuters.

And Facebook, already a huge and profitable company when Goodwin wrote about it in March of 2015, continued to grow in size and influence, to greatly affect mainstream content producers, and to make sizable investments in innovation. In August of 2015 the web traffic analysis company Parse.ly released a report showing that across the major news and media sites it tracked, more viewers came via Facebook than from Google and other search engines. In March of 2016, Mark Zuckerberg unveiled the company's ten-year road map, which included major initiatives in artificial intelligence, virtual reality and augmented reality, and even solar-powered airplanes to bring Internet access to millions of people who live far from any telecommunications infrastructure.

How could companies that consisted of only an "indescribably thin layer" be having such an impact, and such success?

As Goodwin observed, "Something interesting is happening."

A Giant Reaches Out

By any standard, General Electric is one of the most successful US companies. Tracing its roots back to the iconic inventor Thomas Edison and his Edison Electric Light Company, GE was selected in 1896 as one of the twelve companies to be listed on the original Dow Jones Industrial Average. It's the only one of the group that remains on the index today. It has entered (and sometimes left) many industrial businesses, including power generation, aerospace and defense, plastics, health care, and finance, but throughout its long history, GE has always also developed products for consumers, from Edison's electric lamps to radios and TVs to household appliances.

GE also pioneered and excelled at running a large, diversified, global corporation. It invested heavily in research and development, often in partnership with universities. It was also one of the first large companies to devote substantial time and effort to advancing not only its technologies, but also the skills of its managers. The first dedicated corporate university was established by GE in 1956 in Crotonville, New York, a place name that has become synonymous with the professionalization of the practice of management.

The twenty-first century saw a major initiative in Crotonville, and throughout the company, to deepen capabilities in marketing, defined as understanding and then satisfying customers' needs across all lines of business. A 2013 review of GE's efforts in this area found that the company's most sought-after capability was to "create marketing innovation internally."

Then why did General Electric, a company that has an annual budget of $5.2 billion for R&D and that spends $393 million on marketing in the United States alone, opt in 2015 to work with a group of strangers across the Internet to help the company think up and design a new consumer product? And why was a company with a market cap of $280 billion and $90 billion cash on hand asking potential customers to commit to a several-hundred-dollar preorder well in advance of the product's availability?

Nuggets of Wisdom about Nuggets of Ice

In 2014, GE and the University of Louisville had launched a joint initiative called FirstBuild, a "co-creation community that is changing the way products come to market." It consisted of both an online presence and a "microfactory" equipped with the tools and materials needed to prototype products.

Alan Mitchell, an advanced development engineer at GE Appliances in Louisville, decided to use FirstBuild as a test-bed. He wondered whether it would be possible to more easily satisfy the craving many people have for . . . a particular kind of ice.

Most ice cubes are just frozen blocks of water of various sizes and shapes. Nugget ice is something different. Its small, barrel-shaped chunks are porous and only semifrozen. These qualities allow the ice to absorb flavors well and make it easier to chew, which is apparently what some people want—very much. A 2008 *Wall Street Journal* story by Ilan Brat had found that "munchable ice sells like hotcakes." The Sonic fast-food chain, which used nugget ice in its drinks, found that many of its customers just wanted the ice. So the company started selling the chilled nuggets in everything from cups to 10-pound bags.

Because making nugget ice is more complex than simply freezing water,* the machines that produce it cost several thousand dollars—too expensive for most households.† Mitchell wanted to see whether the FirstBuild community could design and prototype a viable nugget ice maker for the home, and an online competition was launched in 2015.

The winner was Ismael Ramos, a designer from Guadalajara, Mexico, whose "Stone Cold" design entry envisioned a cubical machine well suited to kitchen countertops, with a removable clear-plastic ice bucket. Ramos was awarded $2,000 and one of the first working versions of his brainchild. (Two runners-up in the contest were also awarded cash prizes and ice makers.)

People at the FirstBuild microfactory began making and refining prototypes of the nugget maker. All along, they interacted frequently with the online community that had formed around the project, asking questions about how the removable ice bucket should look, how

* To make the chewable nuggets, ice must be shaved off a surface while it's still being formed, then encouraged into chunks of the right size and shape.

† Some more affluent households indulged their passion for nugget ice (Ilan Brat, "Chew This Over: Munchable Ice Sells like Hot Cakes," *Wall Street Journal*, January 30, 2008). Amy Grant gave her husband, country music star Vince Gill, a restaurant-grade Scotsman ice machine for Christmas one year.

to sense when it was full, whether the machine should include an ice scoop, and so on.

If You Like It, Buy It—Even Though It Doesn't Exist Yet

While this work was going on, GE also engaged in a newly available and nontraditional combination of marketing and market research. In July of 2015 it launched an Indiegogo campaign for the ice maker, which it had named the Opal. Indiegogo is an online "crowdfunding" community; it describes itself as a "launchpad for creative and entrepreneurial ideas of every shape and size." People providing financial support to these ideas are not investors; they do not receive an ownership stake or share of revenues or profits in exchange for their money. Very often, though, supporters are promised rewards. If they back a film, for example, they could be invited to an early screening, and if they support a product, they could be among the first to receive it. In essence, they preorder a product that doesn't exist yet, and might never exist without their votes of confidence.

Indiegogo was originally intended as a site for people and small companies without access to the financing required to realize their visions, but by mid-2015 large companies were using the site to test demand for potential products. With their campaign for the Opal, GE and FirstBuild asked people to contribute $399 (later increased to $499) and set a goal of raising $150,000. Within a few hours the campaign raised more than twice that, and within a week it attracted in excess of $1.3 million. By the time it closed in late August of 2015, the Opal campaign had attracted more than $2.7 million on Indiegogo, making it one of the site's ten most popular campaigns. The finished product was shipped to more than 5,000 preorder customers across the last three months of 2016 before going on sale to the general public. GE didn't need the money from the preorders, but it desperately wanted the market intelligence.

GE had found a new way to tap into the many minds that weren't on its payroll, as well as a market for its ice machine.

Machine | Platform | Crowd

The three examples we've just described—AlphaGo's triumph over the best human Go players, the success of new companies like Facebook and Airbnb that have none of the traditional assets of their industries, and GE's use of an online crowd to help it design and market a product that was well within its expertise—illustrate three great trends that are reshaping the business world.

The first trend consists of the rapidly increasing and expanding capabilities of *machines*, as exemplified by AlphaGo's unexpected emergence as the world's best Go player.

The second is captured by Goodwin's observations about the recent appearance of large and influential young companies that bear little resemblance to the established incumbents in their industries, yet are deeply disrupting them. These upstarts are *platforms*, and they are fearsome competitors.

The third trend, epitomized by GE's unconventional development process for its Opal ice maker, is the emergence of the *crowd*, our term for the startlingly large amount of human knowledge, expertise, and enthusiasm distributed all over the world and now available, and able to be focused, online.

From the rise of billion-dollar, Silicon Valley unicorns to the demise or transformation of Fortune 500 stalwarts, the turbulence and transformation in the economy can seem chaotic and random. But the three lenses of machine, platform, and crowd are based on

sound principles of economics and other disciplines. The application of these principles isn't always easy, but with the right lenses, chaos gives way to order, and complexity becomes simpler. Our goal in this book is to provide these lenses.

The Work Ahead: Three Rebalancings

In all companies and industries, machine, platform, and crowd have counterparts. For machine intelligence, the counterpart is the human *mind*. Accountants with spreadsheets, engineers with computer-aided design software, and assembly line workers next to robots are all examples of mind-and-machine combinations.

The counterparts of platforms are *products*—in other words, goods and services. A ride across town is a product, while Uber is the platform people use to access it. The same is true with accommodations and Airbnb, or news stories and Facebook.

For the crowd, the counterpart is the *core*: the knowledge, processes, expertise, and capabilities that companies have built up internally and across their supply chains. The core of GE Appliances designs, manufactures, and markets refrigerators and ovens; NASA's core builds spaceships and tries to better understand our universe; Microsoft's core capabilities include developing personal computer operating systems and applications.

We're not going to tell you that minds, products, and the core are obsolete, or headed that way. Such a claim would be absurd. As we'll show repeatedly, human abilities, excellent goods and services, and strong organizational capabilities remain essential to business success.

We *will* try to convince you that because of recent technological changes, companies need to rethink the balance between minds and machines, between products and platforms, and between the core and the crowd. The second element in each pair has become much more capable and more powerful just within the past few years, so it needs to be considered with fresh eyes. Understanding when, where, how, and why these machines, platforms, and crowds can be effective is the key to success in the economy today. Our goal with this book is to help you with this important work. We'll try to convince you, in fact, that it's more than just important; it's essential.

Why Now?

We documented fast technological progress and discussed some of its economic consequences in our previous book *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies.* Since its publication, one of the most common questions we've been asked about it is, *When did this age start?* It's a great question, and a surprisingly difficult one to answer. We've had digital computers for well over half a century, after all, yet just about all of the advances we described in our earlier book were quite recent. So when did this important new, second machine age start?

We've arrived at a two-phase answer to this question. Phase one of the second machine age describes a time when digital technologies demonstrably had an impact on the business world by taking over large amounts of routine work—tasks like processing payroll, welding car body parts together, and sending invoices to customers. In July of 1987 the MIT economist Robert Solow, who later that year would win a Nobel prize for his work on the sources of economic growth, wrote, "You can see the computer age everywhere but in the productivity statistics." By the mid-1990s, that was no longer true; productivity started to grow much faster, and a large amount of research (some of it conducted by Erik* and his colleagues) revealed that computers and other digital technologies were a main reason why. So, we can date the start of phase one of the second machine age to the middle of the 1990s.

* Where we mention ourselves in this book, we use first names only: Andy and Erik.

Phase two, which we believe we're in now, has a start date that's harder to pin down. It's the time when science fiction technologies—the stuff of movies, books, and the controlled environments of elite research labs—started to appear in the real world. In 2010, Google unexpectedly announced that a fleet of completely autonomous cars had been driving on US roads without mishap. In 2011, IBM's Watson supercomputer beat two human champions at the TV quiz show *Jeopardy!* By the third quarter of 2012, there were more than a billion users of smartphones, devices that combined the communication and sensor capabilities of countless sci-fi films. And of course, the three advances described at the start of this chapter happened in the past few years. As we'll see, so did many other breakthroughs. They are not flukes or random blips in technological progress. Instead, they are harbingers of a more fundamental transformation in the economy—a transformation that's rooted in both significant technological advances and sound economic principles.

Phase two of the second machine age differs markedly from phase one. First, it's a time when technologies are demonstrating that they can do work that we've never thought of as preprogrammed or "routine." They're winning at Go, diagnosing disease accurately, interacting naturally with people, and engaging in creative work like composing music and designing useful objects. Within the past few years, they've clearly blown past Polanyi's Paradox and other limitations on their way to new territory. Machines aren't simply following carefully codified instructions provided by human programmers;* they're learning how to solve problems on their own. This development vastly enlarges the scope of applications and tasks that machines can now address.

Second, hundreds of millions of people started to have powerful,

* There's a reason we often call programmers "coders"; after all, they have historically codified knowledge, making the tacit explicit.

flexible, and connected computers with them at all times. These are smartphones and other similar devices, which have spread around the world with astonishing speed. By 2015, only eight years after the iPhone was introduced, more than 40% of the adults in twenty-one emerging and developing countries surveyed by the Pew Research Center reported owning a smartphone. In 2016, approximately 1.5 billion more were sold.

For the first time in human history a near-majority of the world's adults are now connected with each other digitally, and with a large chunk of the world's accumulated knowledge. What's more, they can contribute to this knowledge themselves, creating a virtuous cycle. They can also engage in many kinds of exchanges and transactions, bringing billions more participants into the modern global economy.

We find it difficult to overstate how important this is. Until quite recently, access to large knowledge repositories (like good libraries) and advanced communication and information-processing technologies was limited to the world's wealthy—those of us fortunate enough to be born into nonpoor families in nonpoor countries. That is no longer the case. And more and more powerful technologies will spread around the world in the years to come.

Computers that can excel at nonroutine work and the digital interconnection of humanity are both phenomena of the past few years. So we think a decent starting point for the second phase of the second machine age is the second decade of the new millennium. It's when minds and machines, products and platforms, and the core and the crowd came together quickly, and started throwing off sparks. As a result, many long-standing assumptions have been overturned and well-established practices made obsolete.

What Happened the Last Time?

A century ago, electricity was in the process of taking over from steam power in manufacturing. We bring up this period because it offers a critical caution: many successful incumbent companies—in fact, most of them—did not survive the transition from one power source to the other. Businesses that want to thrive in the coming era of digital transformation need to understand why this happened and to heed some critical lessons from the past.

By the 1910s, the United States had surpassed the United Kingdom as the world's largest economy. The reason was largely the strength of US manufacturing companies, which accounted for approximately 50% of the country's GDP at the time.

American factories were powered first by flowing water that turned waterwheels, then by steam. Around the start of the twentieth century, electricity appeared as another viable option. It first gained traction as a more efficient replacement for the single big steam engine that sat in the basements of factories and supplied power to all of their machines. But as companies gained experience with the new technology, they came to realize that it provided other benefits. F. B. Crocker, a professor at Columbia, wrote the following in 1901:

> There were many factories which introduced electric power because we engaged to save from 20 to 60 percent of their coal bills; but such savings as these are not what has caused the tremendous activity in electric power equipment that is today spreading all over this country. . . . those who first introduced electric power on this basis found that they were making other savings than those that had been promised, which might be called indirect savings.

Adopters of the new technology eventually came to realize that some long-standing constraints no longer applied. Once they were made electric, power sources could spread throughout a building (after all, they no longer needed to be next to smokestacks and piles of coal). There could also be several power sources instead of one huge one that drove every machine in the factory via an elaborate (and temperamental) system of shafts, gears, pulleys, and belts.

Most manufacturers eventually adopted some form of this "group drive"—a configuration in which a factory had several large electric motors, each providing power to a group of machines.* Some wanted to push this decentralization of power much farther and begin talking about "unit drive," or giving every individual machine in the building its own electric motor. After all, unlike steam engines, electric motors can be made quite small without any significant loss in efficiency.

Today, of course, it's completely ridiculous to imagine doing anything *other* than this; indeed, many machines now go even further and have multiple electric motors built into their design. But the concept of unit drive was met with deep skepticism when it first arose, and for a surprisingly long time afterward. The economic historian Warren Devine Jr. found that

> the merits of driving machines in groups or driving them individually were discussed in the technical literature throughout the first quarter of the twentieth century. Between 1895 and 1904, this subject was vigorously debated in meetings of technical societies; neither technique could be said to be best in all cases. . . . And, over 20 years later, group drive was still being strongly recommended for many applications. . . . Two textbooks printed in 1928 . . . make it clear that there were many situations in which group drive was justified.

* These motors were themselves powered by an electric generator located close to the factory, or by the then-new electric grid.

It's So Obvious in Hindsight; Why Was It So Hard to See at the Time?

Why are technology progressions that are so obvious in retrospect so hard to see accurately while they're unfolding? And why are so many of the smartest and most experienced people and companies, and the ones most affected by the change, the least able to see it?

Research in many different fields points to the same conclusion: it's exactly *because* incumbents are so proficient, knowledgeable, and caught up in the status quo that they are unable to see what's coming, and the unrealized potential and likely evolution of the new technology. This phenomenon has been described as the "curse of knowledge" and "status quo bias," and it can affect even successful and well-managed companies. Existing processes, customers and suppliers, pools of expertise, and more general mind-sets can all blind incumbents to things that should be obvious, such as the possibilities of new technologies that depart greatly from the status quo.

This certainly appears to have been the case with factory electrification. A great deal of research has been done on this period, and much of it reaches the same conclusion. As economists Andrew Atkeson and Patrick J. Kehoe summarize, "At the beginning of the transition [to electric power], manufacturers [were] reluctant to abandon [their] large stock of knowledge to adopt what, initially, [was] only a marginally superior technology."* Another duo of economic historians, Paul David and Gavin Wright, found that a big reason it took so long to fully realize electricity's transformation potential was "the need for organizational and above all for conceptual changes in the ways tasks and products are defined and structured." Assembly lines, conveyor belts, and over-

* From the start, electric power was more consistent and cheaper than steam. But since those were its only immediate advantages in a factory powered by steam, electricity was considered only "marginally superior."

head cranes were examples of such conceptual changes. They were essential to unlocking electricity's full potential, yet unimaginable to many incumbents that had become large and successful during the steam era.

Electricity's Shocks

Clay Christensen built his career as a rock-star business academic by highlighting how often disruptive technologies have brought down high-flying companies. Electrification was one of the most disruptive technologies ever; in the first decades of the twentieth century, it caused something close to a mass extinction in US manufacturing industries.

At the start of that century, manufacturing industries in the United States were dominated by firms called "industrial trusts." These were large companies born of mergers; their owners aimed to take advantage of scale economies in production, purchasing, distribution, marketing, and so on. Certain trust builders also hoped to create companies so large that they would become monopolies, thereby gaining more power to set prices. A survey published in 1904 tallied more than 300 such trusts.

At the time, US industrial trusts seemed positioned to reign for a long time. They were well capitalized, staffed by the first generation of professional managers, and far from hostile to new technologies. They had easily learned to communicate by telegraph and ship goods via railroad, and they were willing to switch from steam to electric power in their factories. But all their resources and capabilities were not enough to keep them on top—or in many cases, in business—as electrification spread.

A survey conducted by the economist Shaw Livermore and published in 1935 found that over 40% of the industrial trusts formed between 1888 and 1905 had failed by the early 1930s. Another 11% were "'limping' units, whose records were . . . a mixture of good and bad. . . . In general, the bad results have been witnessed in the more recent years of the period under review." Of the trusts that survived, most became much smaller. A study by economist Richard Caves and his colleagues of forty-two manufacturing firms that were dominant in 1905 and still in existence in 1929 found that their average market share declined by over one-third, from 69% to 45%.

These studies and others suggest that the competitive environment in US manufacturing industries turned nasty in the twentieth century, and that by the end of the 1920s many companies had been knocked from their previously strong positions. Was this at least in part because of electrification?

We believe it was. It's clear that intelligent electrification made a factory much more productive than it could otherwise be. The big gains came not from simple substitution of electric motors for steam engines, but from the redesign of the production process itself. Intelligently electrified factories—those with motors attached to every machine, with assembly lines and conveyor belts, with overhead cranes, and so on—were formidable weapons in any competitive battle. They could do more with less and enabled their owners to undercut their rivals on price and flexibility and to saturate the market with their goods. We also know that not all factories were able to electrify intelligently. Some companies and their leaders saw the potential of unit drive and embraced it, while others debated the matter for decades. For all these reasons, it seems likely that early-adopting factories contributed directly to the deaths of many of the old industrial trusts.

The great shake-up in early-twentieth-century American manufacturing had multiple causes, including the upheavals of World War I and President Teddy Roosevelt's trust-busting crusade, but the many shocks of electrification were one of the fundamental reasons why so many top companies failed or floundered.

Factory owners who considered electrification simply a better power source missed the point entirely, and over time they found themselves falling behind their electrified rivals. These laggards might have been making wonderful products, marketed brilliantly and sold through efficient distribution networks to loyal customers. But if their factories didn't electrify intelligently, they eventually went out of business. They couldn't compete on price, couldn't get their goods to market as quickly, and couldn't switch as easily from one set of products to another. They simply became uncompetitive, even though—or more accurately, because—they were doing exactly the same things that had previously led to success.

The Universal Machine

Today we're in the early stages of another industrial shake-up, but an even bigger and broader one. We struggle to think of any significant company in any market anywhere in the world that won't be affected by the technology surge under way now. The successful companies of the second machine age will be those that bring together minds and machines, products and platforms, and the core and crowd very differently than most do today. Those that don't undertake this work, and that stick closely to today's technological and organizational status quo, will be making essentially the same choice as those that stuck with steam power or group drive. And eventually, they'll meet the same fate.

Our goal for this book is to help you see where you might have the early-twenty-first-century equivalent of steam engines or group-drive configurations in your company, and to help you think about how to replace them with something that takes better advantage of the amazing technologies of today and tomorrow.

What's Ahead

This book is a guide to the world being created by the new machines, platforms, and crowds. It is, by necessity, an incomplete work. The business world is always changing, and during transitions as profound as this one, things are even more unsettled than usual. So we would never claim to have discovered the final and complete answers to business success as our economies and societies move deeper into the second machine age. The three rebalancings we describe here will take years, and their end points and exact trajectories are far from clear.

But in chaos lies opportunity. We know enough—from history, from previous research, from recent examples and developments, and from our own investigations—to say some things that we believe are both accurate and of value. As you'll see, a lot of these insights are rooted in economics, the field we draw on most heavily in our work.

Why is this? The Austrian economist Carl Menger gave a good answer in 1870: "Economic theory is concerned . . . with the conditions under which men engage in provident activity directed to the satisfaction of their needs."* Economics is the study of how organizations and people understand and shape their environments and futures, and of what happens as they come together and exchange goods, services, and information in order to achieve their goals. The discipline has developed a large and solid body of insight and theories on these topics, making it the right base for a book about how machines, platforms, and the crowd are shaking things up.

But we can't rely on economics alone. The phenomena we're interested in here are far too rich for one discipline and cut across many

* Nineteenth-century writers frequently used the term "men" when they meant "people."

other fields of study. So, we'll also bring in engineering, computer science, psychology, sociology, history, management science, and lots of others. The technology surge under way now is recent, but it has a long, rich, and fascinating heritage. We'll draw on it as we describe what's happening today and what might happen tomorrow.

We divide the discussion into three parts. Part 1 is about bringing together minds and machines. Part 2 does the same for products and platforms, and Part 3 for the core and the crowd. The broad theme of each part is the same: since the second element of the pair has become so much more powerful and capable in recent years, it's now critical to reexamine how best to bring the two together.

Part 1 shows how new combinations of minds and machines are rapidly changing the way businesses execute their most important *processes*. Part 2 reveals how pioneering companies are bringing together products and platforms to transform their *offerings*. Part 3 shows that the core and the crowd are altering what *organizations* themselves look like, and how they work.

The opening chapter in each part reaches back into the first phase of the second machine age and describes both the status quo that existed and the early indications that things were about to change. These chapters show that, about twenty years ago, a "standard partnership" was forged between minds and machines, products and platforms, and the core and the crowd. They also show the ways that this partnership came under stress as technology advanced and experience accumulated.

The remaining chapters in each part explore what we've seen and learned in recent years around each of the three rebalancings. They show the power of machines, platforms, and the crowd today, and tomorrow. Within each part the chapters are arranged on a "science fiction gradient," or ascending order of weirdness. We'll describe increasingly far-out developments, innovations, and business models. The final chapter of each part will consider topics like whether computers can ever be "creative," whether the entire economy will soon become an on-demand economy, and whether companies themselves are an endangered species.*

Throughout the book, each chapter will end with a short section summarizing its main insights and giving practical guidance. This is not a how-to book, or one that lays out a detailed playbook for business success with machines, platforms, and the crowd. We suspect that people who offer such a playbook are kidding either themselves or their readers. There's simply too much change and too much uncertainty at present. Indeed, if such a formulaic cookbook could be written, there would be little opportunity to gain competitive advantage by understanding the deeper forces and principles at work. So instead, we'll end with brief distillations of each chapter's main ideas, along with questions intended to help you think about applying these ideas in your organization.

* Very briefly, the answers to these questions are yes, kind of, and no.