

"Bertrand Russell put it succinctly in a 1924 essay: "Machines are worshipped because they are beautiful and valued because they confer power; they are hated because they are hideous and loathed because they impose slavery." 6 As Russell's comment suggests, the tension in Macmillan's view of automated machines—they'd either destroy us or redeem us, liberate us or enslave us—has a long history. The same tension has run through popular reactions to factory machinery since the start of the Industrial Revolution more than two centuries ago. While many of our forebears celebrated the arrival of mechanized production, seeing it as a symbol of progress and a guarantor of prosperity, others worried that machines would steal their jobs and even their souls. "

"THE WORD automation entered the language fairly recently. As best we can tell, it was first spoken in 1946, when engineers at the Ford Motor Company felt the need to coin a term to describe the latest machinery being installed on the company's assembly lines. "Give us some more of that automatic business," a Ford vice president reportedly said in a meeting. "Some more of that—that —'automation.' "37 Ford's plants were already famously mechanized, with sophisticated machines streamlining every job on the line. "

"Through the 1960s, most automated machines continued to resemble the primitive robotic haulers on Ford's postwar assembly lines. They were big, expensive, and none too bright. Most of them could perform only a single, repetitive function, adjusting their movements in response to a few elementary electronic commands: speed up, slow down; move left, move right; grasp, release. The machines were extraordinarily precise, but otherwise their talents were few. Toiling anonymously inside factories, often locked within cages to protect passersby from their mindless twists and jerks, they certainly didn't look like they were about to take over the world. They seemed little more than very well-behaved and well-coordinated beasts of burden. But robots and other automated systems had one big advantage over the purely mechanical contraptions that came before them. Because they ran on software, they could hitch a ride on the Moore's Law Express. They could benefit from all the rapid advances—in processor speed, programming algorithms, storage and network capacity, interface design, and miniaturization—that came to characterize the progress of computers themselves. And that, as Wiener predicted, is what happened. Robots' senses grew sharper; their brains, quicker and more supple; their conversations, more fluent; their ability to learn, more capacious. By the early 1970s, they were taking over production work that required flexibility and dexterity—cutting, welding, assembling. By the end of that decade, they were flying planes as well as building them. And then, freed from their physical embodiments and turned into the pure logic of code, they spread out into the business world"

"And, like those antiaircraft gunners during World War II, we'll be compelled to adapt our own work, behavior, and skills to the capabilities and routines of the machines we depend on. The internet, it's often noted, has opened opportunities for people to make money through their own personal initiative, with little investment of capital. They can sell used goods through eBay or crafts through Etsy. They can rent out a spare room through Airbnb or turn their car into a ghost cab with Lyft. They can find odd jobs through TaskRabbit. But while it's easy to pick up spare change through such modest enterprise, few people are going to be able to earn a middle-class income from the work. The real money goes to the software companies running the online clearinghouses that connect buyer and seller or lessor and lessee—clearinghouses that, being highly automated themselves, need few employees."

"ON AUTOPILOT

ON THE EVENING OF FEBRUARY 12, 2009, a Continental Connection commuter flight made its way through blustery weather between Newark, New Jersey, and Buffalo, New York. As is typical of commercial flights these days, the two pilots didn't have all that much to do during the hour-long trip. The captain, an affable, forty-seven-year-old Floridian named Marvin Renslow, manned the controls briefly during takeoff, guiding the Bombardier Q400 turboprop into the air, then switched on the autopilot. He and his cabin mate, twenty-four-year-old first officer Rebecca Shaw, a newlywed from Seattle, kept an eye on the computer readouts that flickered across the cockpit's five large LCD screens. They exchanged some messages over the radio with air traffic controllers. They went through a few routine checklists. Mostly, though, they passed the time chatting amiably about this and that—families, careers, colleagues, money—as the turboprop cruised along its northwesterly route at sixteen thousand feet.¹ The Q400 was well into its approach to the Buffalo airport, its landing gear down, its wing flaps out, when the captain's control yoke began to shudder noisily. The plane's "stick shaker" had activated, a signal that the turboprop was losing lift and risked going into an aerodynamic stall.* The autopilot disconnected, as it's programmed to do in the event of a stall warning, and the captain took over the controls. He reacted quickly, but he did precisely the wrong thing. He jerked back on the yoke, lifting the plane's nose and reducing its air speed, instead of pushing the yoke forward to tip the craft down and gain velocity. The plane's automatic stall-avoidance system kicked in and attempted to push the yoke forward, but the captain simply redoubled his effort to pull it back toward him. Rather than prevent a stall, Renslow caused one. The Q400 spun out of control, then plummeted. "We're down," the captain said, just before the plane slammed into a house in a Buffalo suburb. The crash, which killed all forty-nine people onboard as well as one person on the ground, should not have happened. A National Transportation Safety Board investigation found no evidence of mechanical problems with the Q400. Some ice had accumulated on the plane, but nothing out of the ordinary for a winter flight. The deicing equipment had operated properly, as had the plane's other systems. Renslow had had a fairly demanding flight schedule over the preceding two days, and Shaw had been battling a cold, but both pilots seemed lucid and wakeful while in the cockpit. They were well trained, and though the stick shaker took them by surprise, they had plenty of time and airspace to make the adjustments necessary to avoid a stall. The NTSB concluded that the cause of the accident was pilot error. Neither Renslow nor Shaw had detected "explicit cues" that a stall warning was imminent, an oversight that suggested "a significant breakdown in their monitoring responsibilities." Once the warning sounded, the investigators reported, the captain's response "should have been automatic, but his improper flight control inputs were inconsistent with his training" and instead revealed "startle and confusion." An executive from the company that operated the flight for Continental, the regional carrier Colgan Air, admitted that the pilots seemed to lack "situational awareness" as the emergency unfolded.² Had the crew acted appropriately, the plane would likely have landed safely. The Buffalo crash was not an isolated incident. An eerily similar disaster, with far more casualties, occurred a few months later. On the night of May 31, an Air France Airbus A330 took off from Rio de Janeiro, bound for Paris.³ The jet ran into a storm over the Atlantic about three hours after takeoff. Its air-speed sensors, caked with ice, began giving faulty readings, which caused the autopilot to disengage. Bewildered, the copilot flying the plane, Pierre-Cédric Bonin, yanked back on the control stick. The A330 rose and a loud stall warning sounded, but Bonin continued to pull back heedlessly on the stick. As the plane

climbed sharply, it lost velocity. The air-speed sensors began working again, providing the crew with accurate numbers. It should have been clear at this point that the jet was going too slow. Yet Bonin persisted in his mistake at the controls, causing a further deceleration. The jet stalled and began to fall. If Bonin had simply let go of the stick, the A330 might well have righted itself. But he didn't. The flight crew was suffering what French investigators would later term a "total loss of cognitive control of the situation."⁴ After a few more harrowing seconds, another pilot, David Robert, took over the controls. It was too late. The plane dropped more than thirty thousand feet in three minutes. "This can't be happening," said Robert. "But what is happening?" replied the still-bewildered Bonin. Three seconds later, the jet hit the ocean. All 228 crew and passengers died.

IF YOU want to understand the human consequences of automation, the first place to look is up. Airlines and plane manufacturers, as well as government and military aviation agencies, have been particularly aggressive and especially ingenious in finding ways to shift work from people to machines. What car designers are doing with computers today, aircraft designers did decades ago"

"ted the New York Times. "Commercial flying in the future will be automatic."⁷ The introduction of the gyroscopic autopilot set the stage for a momentous expansion of aviation's role in warfare and transport. By taking over much of the manual labor required to keep a plane stable and on course, the device relieved pilots of their constant, exhausting struggle with sticks and pedals, cables and pulleys. That not only alleviated the fatigue aviators endured on long flights; it also freed their hands, their eyes, and, most important, their minds for other, more subtle tasks. They could consult more instruments, make more calculations, solve more problems, and in general think more analytically and creatively about their work. They could fly higher and farther, and with less risk of crashing. They could go out in weather that once would have kept them grounded. And they could undertake intricate maneuvers that would have seemed rash or just plain impossible before. Whether ferrying passengers or dropping bombs, pilots became considerably more versatile and valuable once they had autopilots to help them fly. Their planes changed too: they got bigger, faster, and a whole lot more complicated. Automatic steering and stabilization tools progressed rapidly during the 1930s, as physicists learned more about aerodynamics and engineers incorporated air-pressure gauges, pneumatic controls, shock absorbers, and other refinements into autopilot mechanisms."

"A few weeks after the Skymaster's landmark trip, a writer with the British aviation magazine *Flight* contemplated the implications. It seemed inevitable, he wrote, that the new generation of autopilots would "dispose of the necessity for carrying navigators, radio operators, and flight engineers" on planes. The machines would render those jobs redundant. Pilots, he allowed, did not seem quite so dispensable. They would, at least for the foreseeable future, continue to be a necessary presence in cockpits, if only "to watch the various clocks and indicators to see that everything is going satisfactorily."⁹

" What really set the A320 apart—and made it, in the words of the American writer and pilot William Langewiesche, "the most audacious civil airplane since the Wright brothers' Flyer"¹¹—was its digital fly-by-wire system. Before the A320 arrived, commercial planes still operated mechanically. Their fuselages and wing cavities were rigged with cables, pulleys, and gears, along with a miniature waterworks of hydraulic pipes, pumps, and valves. The controls manipulated by a pilot—the yoke, the throttle levers, the rudder pedals—

were linked, by means of the mechanical systems, directly to the moving parts that governed the plane's orientation, direction, and speed. When the pilot acted, the plane reacted. To stop a bicycle, you squeeze a lever, which pulls a brake cable, which contracts the arms of a caliper, which presses pads against the tire's rim. You are, in essence, sending a command—a signal to stop—with your hand, and the brake mechanism carries the manual force of that command all the way to the wheel. Your hand then receives confirmation that your command has been received: you feel, back through the brake lever, the resistance of the caliper, the pressure of the pads against the rim, the skidding of the wheel on the road. That, on a small scale, is what it was like when pilots flew mechanically controlled planes. They became part of the machine, their bodies sensing its workings and feeling its responses, and the machine became a conduit for their will. Such a deep entanglement between human and mechanism was an elemental source of flying's thrill. It's what the famous poetpilot Antoine de Saint-Exupéry must have had in mind when, in recalling his days flying mail planes in the 1920s, he wrote of how "the machine which at first blush seems a means of isolating man from the great problems of nature, actually plunges him more deeply into them."¹² The A320's fly-by-wire system severed the tactile link between pilot and plane. It inserted a digital computer between human command and machine response."

"After the introduction of the A320, the story of airplanes and the story of computers became one. Every advance in hardware and software, in electronic sensors and controls, in display technologies reverberated through the design of commercial aircraft as manufacturers and airlines pushed the limits of automation. In today's jet-liners, the autopilots that keep planes stable and on course are just one of many computerized systems. Autothrottles control engine power. Flight management systems gather positioning data from GPS receivers and other sensors and use the information to set or refine a flight path. Collision avoidance systems scan the skies for nearby aircraft. Electronic flight bags store digital copies of the charts and other paperwork that pilots used to carry onboard. Still other computers extend and retract the landing gear, apply the brakes, adjust the cabin pressure, and perform various other functions that had once been in the hands of the crew. To program the computers and monitor their outputs, pilots now use large, colorful flat screens that graphically display data generated by electronic flight instrument systems, along with an assortment of keyboards, keypads, scroll wheels, and other input devices. Computer automation has become "all pervasive" on today's aircraft, says Don Harris, an aeronautics professor and ergonomics expert. The flight deck "can be thought of as one huge flying computer interface."¹³ And what of the modern flyboys and flygirls who, nestled in their high-tech glass cockpits, speed through the air alongside the ghosts of Sperry and Post and Saint-Exupéry? Needless to say, the job of the commercial pilot has lost its aura of romance and adventure. The storied stick-and-rudder man, who flew by a sense of feel, now belongs more to legend than to life. On a typical passeng"

"On a typical passenger flight

these days, the pilot holds the controls for a grand total of three minutes—a minute or two when taking off and another minute or two when landing. What the pilot spends a whole lot of time doing is checking screens and punching in data. "We've gone from a world where automation was a tool to help the pilot control his workload," observes Bill Voss, president of the Flight Safety Foundation, "to a point where the automation is really the primary flight control system in the aircraft."¹⁴ Writes aviation researcher and FAA advisor Hemant Bhana,

"As automation has gained in sophistication, the role of the pilot has shifted toward becoming a monitor or supervisor of the automation."¹⁵ The commercial pilot has become a computer operator. And that, many aviation and automation experts have come to believe, is a problem."

" In the United States and other Western countries, fatal airliner crashes have become exceedingly rare. Of the more than seven billion people who boarded U.S. commercial flights in the ten years from 2002 through 2011, only 153 ended up dying in a wreck, a rate of two deaths for every million passengers. In the ten years from 1962 through 1971, by contrast, 1.3 billion people took flights, and 1,696 of them died, for a rate of 133 deaths per million.¹⁷ But this sunny story carries a dark footnote. The overall decline in the number of plane crashes masks the recent arrival of "a spectacularly new type of accident," says Raja Parasuraman, a psychology professor at George Mason University and one of the world's leading authorities on automation.¹⁸ When onboard computer systems fail to work as intended or other unexpected problems arise during a flight, pilots are forced to take manual control of the plane. Thrust abruptly into a now rare role, they too often make mistakes"

"The analysis indicated that "manual flying skills decay quite rapidly towards the fringes of 'tolerable' performance without relatively frequent practice." Particularly "vulnerable to decay," Ebbatson noted, was a pilot's ability to maintain "airspeed control"—a skill crucial to recognizing, avoiding, and recovering from stalls and other dangerous situations. It's no mystery why automation degrades pilot performance. Like many challenging jobs, flying a plane involves a combination of psychomotor skills and cognitive skills—thoughtful action and active thinking. A pilot needs to manipulate tools and instruments with precision while swiftly and accurately making calculations, forecasts, and assessments in his head. And while he goes through these intricate mental and physical maneuvers, he needs to remain vigilant, alert to what's going on around him and able to distinguish important signals from unimportant ones. He can't allow himself either to lose focus or to fall victim to tunnel vision. Mastery of such a multifaceted set of skills comes only with rigorous practice. A beginning pilot tends to be clumsy at the controls, pushing and pulling the yoke with more force than necessary. He often has to pause to remember what he should do next, to walk himself methodically through the steps of a process. He has trouble shifting seamlessly between manual and cognitive tasks. When a stressful situation arises, he can easily become overwhelmed or distracted and end up overlooking a critical change in circumstances. In time, after much rehearsal, the novice gains confidence. He becomes less halting in his work and more precise in his actions. There's little wasted effort. As his experience continues to deepen, his brain develops so-called mental models—dedicated assemblies of neurons—that allow him to recognize patterns in his surroundings. The models enable him to interpret and react to stimuli intuitively, without getting bogged down in conscious analysis. Eventually, thought and action become seamless. Flying becomes second nature. Years before researchers began to plumb the workings of pilots' brains, Wiley Post described the experience of expert flight in plain, precise terms. He flew, he said in 1935, "without mental effort, letting my actions be wholly controlled by my subconscious mind."²⁵ He wasn't born with that ability. He developed it through hard work. When computers enter the picture, the nature and the rigor of the work change, as does the learning the work engenders. As software assumes moment-by-moment control of the craft, the pilot is, as we've seen, relieved of much manual labor. This reallocation of responsibility can provide an important benefit. It can reduce the pilot's workload and allow him to concentrate on the cognitive

aspects of flight. But there's a cost. Psychomotor skills get rusty, which can hamper the pilot on those rare but critical occasions when he's required to take back the controls. There's growing evidence that recent expansions in the scope of automation also put cognitive skills at risk. When more advanced computers begin to take over planning and analysis functions, such as setting and adjusting a flight plan, the pilot becomes less engaged not only physically but mentally. Because the precision and speed of pattern recognition appear to depend on regular practice, the pilot's mind may become less agile in interpreting and reacting to fast-changing situations. He may suffer what Ebbatson calls "skill fade" in his mental as well as his motor abilities. Pilots are not blind to automation's toll. They've always been wary about ceding responsibility to machinery. Airmen in World War I, justifiably proud of their skill in maneuvering their planes during dogfights, wanted nothing to do with the fancy Sperry autopilots.²⁶ In 1959, the original Mercury astronauts rebelled against NASA's plan to remove manual flight controls from spacecraft.²⁷ But aviators' concerns are more acute now. Even as they praise the enormous gains in flight technology, and acknowledge the safety and efficiency benefits, they worry about the erosion of their talents. As part of his research, Ebbatson surveyed commercial pilots, asking them whether "they felt their manual flying ability had been influenced by the experience of operating a highly automated aircraft." More than three-fourths reported that "their skills had deteriorated"; just a few felt their skills had improved.²⁸ A 2012 pilot survey conducted by the European Aviation Safety Agency found similarly widespread concerns, with 95 percent of pilots saying that automation tended to erode "basic manual and cognitive flying skills."²⁹ Rory Kay, a long-time United Airlines captain who until recently served as the top safety official with the Air Line Pilots Association, fears the aviation industry is suffering from "automation addiction." In a 2011 interview with the Associated Press, he put the problem in stark terms: "We're forgetting how to fly."³⁰ "Sixty years ago, an airliner's flight deck often had seats for five skilled and well-paid professionals: a navigator, a radio operator, a flight engineer, and a pair of pilots. The radioman lost his chair during the 1950s, as communication systems became more reliable and easier to use. The navigator was pushed off the deck in the 1960s, when inertial navigation systems took over his duties. The flight engineer, whose job involved monitoring a plane's instrument array and relaying important information to the pilots, kept his seat until the advent of the glass cockpit at the end of the 1970s. Seeking to cut costs following the deregulation of air travel in 1978, American airlines made a push to get rid of the engineer and fly with just a captain and copilot. A bitter battle with pilots' unions ensued, as the unions mobilized to save the engineer's job. The fight didn't end until 1981, when a U.S. presidential commission declared that engineers were no longer necessary for the safe operation of passenger flights. Since then, the two-person flight crew has become the norm—at least for the time being. Some experts, pointing to the success of military drones, have begun suggesting that two pilots may in the end be two too many.³¹ "A pilotless airliner is going to come," James Albaugh, a top Boeing executive, told an aviation conference in 2011; "it's just a question of when."³² The spread of automation has also been accompanied by a steady decline in the compensation of commercial pilots. While veteran jetliner captains can still pull down salaries close to \$200,000, novice pilots today are paid as little as \$20,000 a year, sometimes even less. The average starting salary for experienced pilots at major airlines is around \$36,000, which, as a Wall Street Journal reporter notes, is "darn low for mid-career professionals."³³

"Every technological advance alters the work they do and the role they play, and that in turn changes how they view themselves and how others see them. Their social status and even their sense of self are in play. So when pilots talk about automation, they're speaking not just technically but autobiographically. Am I the master of the machine, or its servant? Am I an actor in the world, or an observer? Am I an agent, or an object? "At heart," MIT technology historian David Mindell writes in his book *Digital Apollo*, "debates about control and automation in aircraft are debates about the relative importance of human and machine." In aviation, as in any field where people work with tools, "technical change and social change are intertwined."³⁵ Pilots have always defined themselves by their relationship to their craft. Wilbur Wright, in a 1900 letter to Octave Chanute, another aviation pioneer, said of the pilot's role, "What is chiefly needed is skill rather than machinery."³⁶ "

"The transformation that aviation has gone through over the last few decades—the shift from mechanical to digital systems, the proliferation of software and screens, the automation of mental as well as manual work, the blurring of what it means to be a pilot—offers a roadmap for the much broader transformation that society is going through now. The glass cockpit, Don Harris has pointed out, can be thought of as a prototype of a world where "there is computer functionality everywhere." ⁴³ The experience of pilots also reveals the subtle but often strong connection between the way automated systems are designed and the way the minds and bodies of the people using the systems work. The mounting evidence of an erosion of skills, a dulling of perceptions, and a slowing of reactions should give us all pause. As we begin to live our lives inside glass cockpits, we seem fated to discover what pilots already know: a glass cockpit can also be a glass cage."

""Operations of thought are like cavalry charges in battle—they are strictly limited in number, they require fresh horses, and must only be made at decisive moments."¹ It's hard to imagine a more succinct or confident expression of faith in automation as a cornerstone of progress. Implicit in Whitehead's words is a belief in a hierarchy of human action. Every time we offload a job to a tool or a machine, or to a symbol or a software algorithm, we free ourselves to climb to a higher pursuit, one requiring greater dexterity, richer intelligence, or a broader perspective. We may lose something with each upward step, but what we gain is, in the end, far greater. Taken to an extreme, Whitehead's sense of automation as liberation turns into the technoutopianism of Wilde and Keynes, or Marx at his sunniest—the dream that machines will free us from our earthly labors and deliver us back to an Eden of leisurely delights. But Whitehead didn't have his head in the clouds. He was making a pragmatic point about how to spend our time and exert our effort. In a publication from the 1970s, the U.S. Department of Labor summed up the job of secretaries by saying that they "relieve their employers of routine duties so they can work on more important matters."² Software and other automation technologies, in the Whitehead view, play an analogous role. History provides plenty of evidence to support Whitehead. People have been handing off chores, both physical and mental, to tools since the invention of the lever, the wheel, and the counting bead. The transfer of work has allowed us to tackle thornier challenges and rise to greater achievements. That's been true on the farm, in the factory, in the laboratory, in the home. But we shouldn't take Whitehead's observation for a universal truth. He was writing when automation was limited to distinct, well-defined, and repetitive tasks—weaving fabric with a steam loom, harvesting grain with a combine, multiplying numbers with a slide rule. Automation is different now."

"Our tendency toward complacency reveals how easily our concentration and awareness can fade when we're not routinely called on to interact with our surroundings. Our propensity to be biased in evaluating and weighing information shows that our mind's focus is selective and can easily be skewed by misplaced trust or even the appearance of seemingly helpful prompts. Both complacency and bias tend to become more severe as the quality and reliability of an automated system improve.¹⁰ Experiments show that when a system produces errors fairly frequently, we stay on high alert. We maintain awareness of our surroundings and carefully monitor information from a variety of sources. But when a system is more reliable, breaking down or making mistakes only occasionally, we get lazy. We start to assume the system is infallible. Because automated systems usually work fine even when we lose awareness or objectivity, we are rarely penalized for our complacency or our bias. That ends up compounding the problems, as Parasuraman pointed out in a 2010 paper written with his German colleague Dietrich Manzey. "Given the usually high reliability of automated systems, even highly complacent and biased behavior of operators rarely leads to obvious performance consequences," the scholars wrote. The lack of negative feedback can in time induce "a cognitive process that resembles what has been referred to as 'learned carelessness.'"¹¹ Think about driving a car when you're sleepy. If you begin to nod off and drift out of your lane, you'll usually go onto a rough shoulder, hit a rumble strip, or earn a honk from another motorist—signals that jolt you back awake. If you're in a car that automatically keeps you within a lane by monitoring the lane markers and adjusting the steering, you won't receive such warnings. You'll drift into a deeper slumber. Then if something unexpected happens—an animal runs into the road, say, or a car stops short in front of you—you'll be much more likely to have an accident. By isolating us from negative feedback, automation makes it harder for us to stay alert and engaged. We tune out even more."

"In one early and famous experiment, conducted by University of Toronto psychologist Norman Slamecka, people used flash cards to memorize pairs of antonyms, like hot and cold. Some of the test subjects were given cards that had both words printed in full, like this: HOT : COLD Others used cards that showed only the first letter of the second word, like this: HOT : C The people who used the cards with the missing letters performed much better in a subsequent test measuring how well they remembered the word pairs. Simply forcing their minds to fill in a blank, to act rather than observe, led to stronger retention of information.¹² The generation effect, it has since become clear, influences memory and learning in many different circumstances. Experiments have revealed evidence of the effect in tasks that involve not only remembering letters and words but also remembering numbers, pictures, and sounds, completing math problems, answering trivia questions, and reading for comprehension. Recent studies have also demonstrated the benefits of the generation effect for higher forms of teaching and learning. A 2011 paper in *Science* showed that students who read a complex science assignment during a study period and then spent a second period recalling as much of it as possible, unaided, learned the material more fully than students who read the assignment repeatedly over the course of four study periods.¹³ "The results were the same. People who relied on the help of software prompts displayed less strategic thinking, made more superfluous moves, and ended up with a weaker conceptual understanding of the assignment. Those using unhelpful programs planned better, worked smarter, and learned more.¹⁷ What van Nimwegen observed in his laboratory—that when we automate cognitive tasks like problem solving, we hamper the

mind's ability to translate information into knowledge and knowledge into know-how—is also being documented in the real world. In many businesses, managers and other professionals depend on so-called expert systems to sort and analyze information and suggest courses of action. Accountants, for example, use decision-support software in corporate audits. The applications speed the work, but there are signs that as the software becomes more capable, the accountants become less so. One study, conducted by a group of Australian professors, examined the effects of the expert systems used by three international accounting firms. Two of the companies employed advanced software that, based on an accountant's answers to basic questions about a client, recommended a set of relevant business risks to include in the client's audit file. The third firm used simpler software that provided a list of potential risks but required the accountant to review them and manually select the pertinent ones for the file. The researchers gave accountants from each firm a test measuring their knowledge of risks in industries in which they had performed audits. Those from the firm with the less helpful software displayed a significantly stronger understanding of different forms of risk than did those from the other two firms. The decline in learning associated with advanced software affected even veteran auditors—those with more than five years of experience at their current firm.¹⁸ Other studies of expert systems reveal similar effects. The research indicates that while decision-support software can help novice analysts make better judgments in the short run, it can also make them mentally lazy. By diminishing the intensity of their thinking, the software retards their ability to encode information in memory, which makes them less likely to develop the rich tacit knowledge essential to true expertise.¹⁹ The drawbacks to automated decision aids can be subtle, but they have real consequences, particularly in fields where analytical errors have far-reaching repercussions. Miscalculations of risk, exacerbated by high-speed computerized trading programs, played a major role in the near meltdown of the world's financial system in 2008. As Tufts University management professor Amar Bhidé has suggested, “robotic methods” of decision making led to a widespread “judgment deficit” among bankers and other Wall Street professionals.²⁰ While it may be impossible to pin down the precise degree to which automation figured in the disaster, or in subsequent fiascos like the 2010 “flash crash” on U.S. exchanges, it seems prudent to take seriously any indication that a widely used technology may be diminishing the knowledge or clouding the judgment of people in sensitive jobs. In a 2013 paper, computer scientists Gordon Baxter and John Cartlidge warned that a reliance on automation is eroding the skills and knowledge of financial professionals even as computer-trading systems make financial markets more risky.²¹ Some software writers worry that their profession's push to ease the strain of thinking is taking a toll on their own skills. Programmers today often use applications called integrated development environments, or IDEs, to aid them in composing code. The applications automate many "IDEs, to aid them in composing code. The applications automate many tricky and time-consuming chores. They typically incorporate auto-complete, error-correction, and debugging routines, and the more sophisticated of them can evaluate and revise the structure of a program through a process known as refactoring. But as the applications take over the work of coding, programmers lose opportunities to practice their craft and sharpen their talent. “Modern IDEs are getting ‘helpful’ enough that at times I feel like an IDE operator rather than a programmer,” writes Vivek Halder, a veteran software developer with Google. “The behavior all these tools encourage is not ‘think deeply about your code and write it

carefully,' but 'just write a crappy first draft of your code, and then the tools will tell you not just what's wrong with it, but also how to make it better.' " His verdict: "Sharp tools, dull minds." 22 Google acknowledges that it has even seen a dumbing-down effect among the general public as it has made its search engine more responsive and solicitous, better able to predict what people are looking for. Google does more than correct our typos; it suggests search terms as we type, untangles semantic ambiguities in our requests, and anticipates our needs based on where we are and how we've behaved in the past. We might assume that as Google gets better at helping us refine our searching,"

"In 2013, a reporter from the Observer newspaper in London interviewed Singhal about the many improvements that have been made to Google's search engine over the years.

"Presumably," the journalist remarked, "we have got more precise in our search terms the more we have used Google." Singhal sighed and, "somewhat wearily," corrected the reporter: " 'Actually, it works the other way. The more accurate the machine gets, the lazier the questions become.' "23 More than our ability to compose sophisticated queries may be compromised by the ease of search engines. A series of experiments reported in Science in 2011 indicates that the ready availability of information online weakens our memory for facts.

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"Google and other software companies are, of course, in the business of making our lives easier. That's what we ask them to do, and it's why we're devoted to them. But as their programs become adept at doing our thinking for us, we naturally come to rely more on the software and less on our own smarts. We're less likely to push our minds to do the work of generation. When that happens, we end up learning less and knowing less. We also become less capable. As the University of Texas computer scientist Mihai Nadin has observed, in regard to modern software, "The more the interface replaces human effort, the lower the adaptivity of the user to new situations."25 In place of the generation effect, computer automation gives us the reverse: a degeneration effect."

" Gary Marcus offers a more detailed explanation: "At the neural level, proceduralization consists of a wide array of carefully coordinated processes, including changes to both gray matter (neural cell bodies) and white matter (axons and dendrites that connect between neurons). Existing neural connections (synapses) must be made more efficient, new dendritic spines may be formed, and proteins must be synthesized."26 Through the neural modifications of automatization, the brain develops automaticity, a capacity for rapid, unconscious perception, interpretation, and action that allows mind and body to recognize patterns and respond to changing circumstances instantaneously. All of us experienced automatization and achieved automaticity when we learned to read. Watch a young child in the early stages of reading instruction, and you'll witness a taxing mental struggle. The child has to identify each letter by studying its shape. She has to sound out how a set of letters combine to form a syllable and how a series of syllables combine to form a word. If she's not already familiar with the word, she has to figure out or be told its meaning. And then, word by word, she has to interpret the meaning of a sentence, often resolving the ambiguities inherent to language. It's a slow, painstaking process, and it requires the full attention of the conscious mind. Eventually, though, letters and then words get encoded in the neurons of the visual cortex—the part of the brain that processes sight—and the young reader begins to recognize them without conscious thought. Through a symphony of brain changes, reading becomes effortless. The greater the automaticity the child achieves, the more fluent and accomplished a reader she becomes.27 Whether it's Wiley Post in a cockpit, Serena

Williams on a tennis court, or Magnus Carlsen at a chessboard, the otherworldly talent of the virtuoso springs from automaticity. What looks like instinct is hard-won skill. Those changes in the brain don't happen through passive observation. They're generated through repeated confrontations with the unexpected. They require what the philosopher of mind Hubert Dreyfus terms "experience in a variety of situations, all seen from the same perspective but requiring different tactical decisions."²⁸ Without lots of practice, lots of repetition and rehearsal of a skill in different circumstances, you and your brain will never get really good at anything, at least not anything complicated. And without continuing practice, any talent you do achieve will get rusty. It's popular now to suggest that practice is all you need. Work at a skill for ten thousand hours or so, and you'll be blessed with expertise—you'll become the next great pastry chef or power forward. That, unhappily, is an exaggeration. Genetic traits, both physical and intellectual, do play an important role in the development of talent, particularly at the highest levels of achievement. Nature matters. Even our desire and aptitude for practice has, as Marcus points out, a genetic component: "How we respond to experience, and even what type of experience we seek, are themselves in part functions of the genes we are born with."²⁹ But if genes establish, at least roughly, the upper bounds of individual talent, it's only through practice that a person will ever reach those limits and fulfill his or her potential. While innate abilities make a big difference, write psychology professors David Hambrick and Elizabeth Meinz, "research has left no doubt that one of the largest sources of individual differences in performance on complex tasks is simply what and how much people know: declarative, procedural, and strategic knowledge acquired through years of training and practice in a domain."³⁰ Automaticity, as its name makes clear, can be thought of as a kind of internalized automation. It's the body's way of making difficult but repetitive work routine. Physical movements and procedures get programmed into muscle memory; interpretations and judgments are made through the instant recognition of environmental patterns apprehended by the senses. The conscious mind, scientists discovered long ago, is surprisingly cramped, its capacity for taking in and processing information limited. Without automaticity, our consciousness would be perpetually overloaded. Even very simple acts, such as reading a sentence in a book or cutting a piece of steak with a knife and fork, would strain our cognitive capabilities. Automaticity gives us more headroom. It increases, to put a different spin on Alfred North Whitehead's observation, "the number of important operations which we can perform without thinking about them." Tools and other technologies, at their best, do something similar, as Whitehead appreciated. The brain's capacity for automaticity has limits of its own. Our unconscious mind can perform a lot of functions quickly and efficiently, but it can't do everything. You might be able to memorize the times table up to twelve or even twenty, but you would probably have trouble memorizing it much beyond that. Even if your brain didn't run out of memory, it would probably run out of patience."

"K. Anders Ericsson, an expert on talent development, points out, regular feedback is essential to skill building. It's what lets us learn from our mistakes and our successes. "In the absence of adequate feedback," Ericsson explains, "efficient learning is impossible and improvement only minimal even for highly motivated subjects."³¹ Automaticity, generation, flow: these mental phenomena are diverse, they're complicated, and their biological underpinnings are understood only fuzzily. But they are all related, and they tell us something important about ourselves. The kinds of effort that give rise to talent—characterized by challenging tasks, clear goals, and direct feedback—are very

similar to those that provide us with a sense of flow. They're immersive experiences. They also describe the kinds of work that force us to actively generate knowledge rather than passively take in information. Honing our skills, enlarging our understanding, and achieving personal satisfaction and fulfillment are all of a piece. And they all require tight connections, physical and mental, between the individual and the world. They all require, to quote the American philosopher Robert Talisse, "getting your hands dirty with the world and letting the world kick back in a certain way."³²

"Automaticity is the inscription the world leaves on the active mind and the active self. Know-how is the evidence of the richness of that inscription. From rock climbers to surgeons to pianists, Mihaly Csikszentmihalyi explains, people who "routinely find deep enjoyment in an activity illustrate how an organized set of challenges and a corresponding set of skills result in optimal experience." The jobs or hobbies they engage in "afford rich opportunities for action," while the skills they develop allow them to make the most of those opportunities. The ability to act with aplomb in the world turns all of us into artists. "The effortless absorption experienced by the practiced artist at work on a difficult project always is premised upon earlier mastery of a complex body of skills."³³ When automation distances us from our work, when it gets between us and the world, it erases the artistry from our lives."

"Some mice were given a weak shock, others were given a strong one, and still others were given a moderate one. The researchers wanted to see if the strength of the stimulus would influence the speed with which the mice learned to avoid the black passage and go into the white one. What they discovered surprised them. The mice receiving the weak shock were relatively slow to distinguish the white and the black passageways, as might be expected. But the mice receiving the strong shock exhibited equally slow learning. The rodents quickest to understand their situation and modify their behavior were the ones given a moderate shock. "Contrary to our expectations," the scientists reported, "this set of experiments did not prove that the rate of habit-formation increases with increase in the strength of the electric stimulus up to the point at which the shock becomes positively injurious. Instead an intermediate range of intensity of stimulation proved to be most favorable to the acquisition of a

habit."³ A subsequent series of tests brought another surprise. The scientists put a new group of mice through the same drill, but this time they increased the brightness of the light in the white passageway and dimmed the light in the black one, strengthening the visual contrast between the two. Under this condition, the mice receiving the strongest shock were the quickest to avoid the black doorway. Learning didn't fall off as it had in the first go-round. Yerkes and Dodson traced the difference in the rodents' behavior to the fact that the setup of the second experiment had made things easier for the animals. Thanks to the greater visual contrast, the mice didn't have to think as hard in distinguishing the passageways and associating the shock with the dark corridor. "The relation of the strength of electrical stimulus to rapidity of learning or habit-formation depends upon the difficultness of the habit," they explained.⁴ As a task becomes harder, the optimum amount of stimulation decreases. In other words, when the mice faced a really tough challenge, both an unusually weak stimulus and an unusually strong stimulus impeded their learning. In something of a Goldilocks effect, a moderate stimulus inspired the best performance. Since its publication in 1908, the paper that Yerkes and Dodson wrote about their experiments, "The Relation of Strength of Stimulus to Rapidity of Habit-Formation," has come to be recognized as a

landmark in the history of psychology. The phenomenon they discovered, known as the Yerkes-Dodson law, has been observed, in various forms, far beyond the world of dancing mice and differently colored doorways."

"Human-factors scholars Mark Young and Neville Stanton have found evidence that a person's "attentional capacity" actually "shrinks to accommodate reductions in mental workload." In the operation of automated systems, they argue, "underload is possibly of greater concern [than overload], as it is more difficult to detect."⁵ Researchers worry that the lassitude produced by information underload is going to be a particular danger with coming generations of automotive automation."

"One of the common assumptions about electronic records is that by providing easy and immediate access to past test results, they would reduce the frequency of diagnostic testing. But this study indicates that, as its authors put it, "the reverse may be true." By making it so easy to receive and review test results, the automated systems appear to "provide subtle encouragement to physicians to order more imaging studies," the researchers argue. "In borderline situations, substituting a few keystrokes for the sometimes time-consuming task of tracking down results from an imaging facility may tip the balance in favor of ordering a test."¹² Here again we see how automation changes people's behavior, and the way work gets done, in ways that are virtually impossible to predict—and that may run directly counter to expectations."

"Ofri writes, "all visits look the same from the outside, so it is impossible to tell which were thorough visits with extensive evaluation and which were only brief visits for medication refills." Faced with the computer's relatively inflexible interface, doctors often end up scanning a patient's records for "only the last two or three visits; everything before that is effectively consigned to the electronic dust heap."¹⁶

"Drawing on their knowledge and experience, they simply "see" what's wrong—oftentimes making a working diagnosis in a matter of seconds—and proceed to do what needs to be done. "The key cues to a patient's condition," explains Jerome Groopman in his book *How Doctors Think*, "coalesce into a pattern that the physician identifies as a specific disease or condition." This is talent of a very high order, where, Groopman says, "thinking is inseparable from acting."²⁶ Like other forms of mental automaticity, it develops only through continuing practice with direct, immediate feedback. Put a screen between doctor and patient, and you put distance between them. You make it much harder for automaticity and intuition to develop."

"Is an eighteenth-century cobbler making a pair of shoes at a bench in his workshop more or less skilled than a twenty-first-century marketer using her computer to develop a promotional plan for a product? Is a plasterer more or less skilled than a hairdresser? If a pipefitter in a shipyard loses his job and, after some training, finds new work repairing computers, has he gone up or down the skill ladder? The criteria necessary to provide good answers to such questions elude us. As a result, debates about trends in deskilling, not to mention upskilling, reskilling, and other varieties of skilling, often bog down in bickering over value judgments. But if the broad skill-shift theories of Braverman and others are fated to remain controversial, the picture becomes clearer when the focus shifts to particular trades and professions. In case after case, we've seen that as machines become more sophisticated, the work left to people becomes less so. Although it's now been largely forgotten, one of the most rigorous explorations of the effect of automation on skills was completed during the 1950s by the Harvard Business School professor James Bright. He examined, in exhaustive detail, the

consequences of automation on workers in thirteen different industrial settings, ranging from an engine-manufacturing plant to a bakery to a feed mill. From the case studies, he derived an elaborate hierarchy of automation. It begins with the use of simple hand tools and proceeds up through seventeen levels to the use of complex machines programmed to regulate their own operation with sensors, feedback loops, and electronic controls. Bright analyzed how various skill requirements—physical effort, mental effort, dexterity, conceptual understanding, and so on—change as machines become more fully automated. He found that skill demands increase only in the very earliest stages of automation, with the introduction of power hand tools. As more complex machines are introduced, skill demands begin to slacken, and the demands ultimately fall off sharply when workers begin to use highly automated, self-regulating machinery. “It seems,” Bright wrote in his 1958 book *Automation and Management*, “that the more automatic the machine, the less the operator has to do.”³⁴ To illustrate how deskilling proceeds, Bright used the example of a metalworker”

“To illustrate how deskilling proceeds, Bright used the example of a metalworker. When the worker uses simple manual tools, such as files and shears, the main skill requirements are job knowledge, including in this case an appreciation of the qualities and uses of metal, and physical dexterity. When power hand tools are introduced, the job grows more complicated and the cost of errors is magnified. The worker is called on to display “new levels of dexterity and decision-making” as well as greater attentiveness. He becomes a “machinist.” But when hand tools are replaced by mechanisms that perform a series of operations, such as milling machines that cut and grind blocks of metal into precise three-dimensional shapes, “attention, decision-making, and machine control responsibilities are partially or largely reduced” and “the technical knowledge requirement of machine functioning and adjustment is reduced tremendously.” The machinist becomes a “machine operator.” When mechanization becomes truly automatic—when machines are programmed to control themselves—the worker “contributes little or no physical or mental effort to the production activity.” He doesn’t even require much job knowledge, as that knowledge has effectively gone into the machine through its design and coding. His job, if it still exists, is reduced to “patrolling.” The metalworker becomes “a sort of watchman, a monitor, a helper.” He might best be thought of as “a liaison man between machine and operating management.” Overall, concluded Bright, “the progressive effect of automation is first to relieve the operator of manual effort and then to relieve him of the need to apply continuous mental effort.”³⁵ When Bright began his study, the prevailing assumption, among business executives, politicians, and academics alike, was that automated machinery would demand greater skills and training on the part of workers. Bright discovered, to his surprise, that the opposite was more often the case: “I was startled to find that the upgrading effect had not occurred to anywhere near the extent that is often assumed. On the contrary, there was more evidence that automation had reduced the skill requirements of the operating work force.” In a 1966 report for a U.S. government commission on automation and employment, Bright reviewed his original research and discussed the technological developments that had occurred in the succeeding years. The advance of automation, he noted, had continued apace, propelled by the rapid deployment of mainframe computers in business and industry. The early evidence suggested that the broad adoption of computers would continue rather than reverse the deskilling trend. “The lesson,” he wrote, “should be increasingly clear—it is

not necessarily true that highly complex equipment requires skilled operators. The 'skill' can be built into the machine."³⁶

IT MAY seem as though a factory worker operating a noisy industrial machine has little in common with a highly educated professional entering esoteric information through a touchscreen or keyboard in a quiet office. But in both cases, we see a person sharing a job with an automated system—with another party. And, as Bright's work and subsequent studies of automation make clear, the sophistication of the system, whether it operates mechanically or digitally, determines how roles and responsibilities are divided and, in turn, the set of skills each party is called upon to exercise. As more skills are built into the machine, it assumes more control over the work, and the worker's opportunity to engage in and develop deeper talents, such as those involved in interpretation and judgment, dwindles. When automation reaches its highest level, when it takes command of the job, the worker, skillwise, has nowhere to go but down. The immediate product of the joint machine-human labor, it's important to emphasize, may be superior, according to measures of efficiency and even quality, but the human party's responsibility and agency are nonetheless curtailed. "What if the cost of machines that think is people who don't?" asked George Dyson, the technology historian, in 2008.³⁷

"Architecture is at the edge, between art and anthropology, between society and science, technology and history," explains the Italian architect Renzo Piano, designer of the Pompidou Center in Paris and the New York Times Building in Manhattan. "Sometimes it's humanistic and sometimes it's materialistic."³⁸ The work of an architect bridges the imaginative mind and the calculative mind, two ways of thinking that are often in tension, if not outright conflict. Since most of us spend most of our time in designed spaces—the constructed world at this point feels more natural to us than nature itself—architecture also exerts a deep if sometimes unappreciated influence over us, individually and collectively. Good architecture elevates life, while bad or mediocre architecture diminishes or cheapens it."

"Through drawing, writes the British design scholar Nigel Cross in his book *Designerly Ways of Knowing*, an architect not only progresses toward a final design but also hashes out the nature of the problem he's trying to solve: "We have seen that sketches incorporate not only drawings of tentative solution concepts but also numbers, symbols and texts, as the designer relates what he knows of the design problem to what is emerging as a solution. Sketching enables exploration of the problem space and the solution space to proceed together." In the hands of a talented architect, a sketchpad becomes, Cross concludes, "a kind of intelligence amplifier." ⁴¹ Drawing might best be thought of as manual thinking. It is as much tactile as cerebral, as dependent on the hand as on the brain. "

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"TO REALLY know shoelaces," the political scientist and motorcycle mechanic Matthew Crawford has observed, "you have to tie shoes." That's a simple illustration of a deep truth that Crawford explores in his 2009 book *Shop Class as Soulcraft*: "If thinking is bound up with action, then the task of getting an adequate grasp on the world, intellectually, depends on our doing stuff in it." ⁴⁹ Crawford draws on the work of the German philosopher Martin Heidegger, who argued that the deepest form of understanding available to us "is not mere perceptual cognition, but, rather, a handling, using, and taking care of things, which has its own kind of 'knowledge.'" ⁵⁰ We tend to talk about knowledge work as if it's something different from and even incompatible with manual labor—I confess to having said as much in

earlier sections of this book—but the distinction is a smug and largely frivolous one. All work is knowledge work. The carpenter's mind is no less animated and engaged than the actuary's."

"The democratic, humanitarian ideals of the Enlightenment culminated in the revolutions in America and France, and those ideals also infused society's view of science and technology. Technical advances were valued—by intellectuals, if not always by workers—as means to political reform. Progress was defined in social terms, with technology playing a supporting role. Enlightenment thinkers such as Voltaire, Joseph Priestley, and Thomas Jefferson saw, in the words of the cultural historian Leo Marx, "the new sciences and technologies not as ends in themselves, but as instruments for carrying out a comprehensive transformation of society." By the middle of the nineteenth century, however, the reformist view had, at least in the United States, been eclipsed by a new and very different concept of progress in which technology itself played the starring role. "With the further development of industrial capitalism," writes Marx, "Americans celebrated the advance of science and technology with increasing fervor, but they began to detach the idea from the goal of social and political liberation." Instead, they embraced "the now familiar view that innovations in science-based technologies are in themselves a sufficient and reliable basis for progress."¹⁵ New technology, once valued as a means to a greater good, came to be revered as a good in itself. It's hardly a surprise, then, that in our own time the capabilities of computers have, as Bainbridge suggested, determined the division of labor in complex automated systems. To boost productivity, reduce labor costs, and avoid human error—to further progress—you simply allocate control over as many activities as possible to software, and as software's capabilities advance, you extend the scope of its authority even further. The more technology, the better. The flesh-and-blood operators are left with responsibility only for those tasks that the designers can't figure out how to automate, such as watching for anomalies or providing an emergency backup in the event of a system failure."

"The division of labor between the software and the human operator is adjusted continually, depending on what's happening at any given moment.²² When the computer senses that the operator has to perform a tricky maneuver, for example, it might take over all the other tasks. Freed from distractions, the operator can concentrate her full attention on the critical challenge. Under routine conditions, the computer might shift more tasks over to the operator, increasing her workload to ensure that she maintains her situational awareness and practices her skills. Putting the analytical capabilities of the computer to humanistic use, adaptive automation aims to keep the operator at the peak of the Yerkes-Dodson performance curve, preventing both cognitive overload and cognitive underload. DARPA, the Department of Defense laboratory that spearheaded the creation of the internet, is even working on developing "neuroergonomic" systems that, using various brain and body sensors, can "detect an individual's cognitive state and then manipulate task parameters to overcome perceptual, attentional, and working memory bottlenecks."²³

"There's no sign of trouble, but your car slows slightly, its computer preferring to err on the side of safety. Suddenly, there's a tussle, and a little boy is pushed into the road. Busily tapping out a message on your smartphone, you're oblivious to what's happening. Your car has to make the decision: either it swerves out of its lane and goes off the opposite side of the bridge, possibly killing you, or it hits the child. What does the software instruct the steering wheel to do? Would the program make a different choice if it knew that one of your own children was riding with you, strapped into a sensor-equipped car seat in the back?

What if there was an oncoming vehicle in the other lane? What if that vehicle was a school bus? Isaac Asimov's first law of robot ethics—"a robot may not injure a human being, or, through inaction, allow a human being to come to harm"¹—sounds reasonable and reassuring, but it assumes a world far simpler than our own. The arrival of autonomous vehicles, says Gary Marcus, the NYU psychology professor, would do more than "signal the end of one more human niche." It would mark the start of a new era in which machines will have to have "ethical systems."² Some would argue that we're already there. In small but ominous ways, we have started handing off moral decisions to computers."

"The first shot freely taken by a robot will be a shot heard round the world. It will change war, and maybe society, forever."

"Arthur C. Clarke once asked, "Can the synthesis of man and machine ever be stable, or will the purely organic component become such a hindrance that it has to be discarded?"¹⁹ In the business world at least, no stability in the division of work between human and computer seems in the offing. The prevailing methods of computerized communication and coordination pretty much ensure that the role of people will go on shrinking. We've designed a system that discards us. If technological unemployment worsens in the years ahead, it will be more a result of our new, subterranean infrastructure of automation than of any particular installation of robots in factories or decision-support applications in offices."

"We're behind the wheel, but we can't be sure who's driving."

"Artificial renderings of space may provide stimulation to our eyes and to a lesser degree our ears, but they tend to starve our other senses—touch, smell, taste—and greatly restrict the movements of our bodies. A study of rodents, published in *Science* in 2013, indicated that the brain's place cells are much less active when animals make their way through computer-generated landscapes than when they navigate the real world.¹⁵ "Half of the neurons just shut up," reported one of the researchers, UCLA neurophysicist Mayank Mehta. He believes that the drop-off in mental activity likely stems from the lack of "proximal cues"—environmental smells, sounds, and textures that provide clues to location—in digital simulations of space.¹⁶ ""

" Ours may be a time of material comfort and technological wonder, but it's also a time of aimlessness and gloom. During the first decade of this century, the number of Americans taking prescription drugs to treat depression or anxiety rose by nearly a quarter. One in five adults now regularly takes such medications.¹⁹ The suicide rate among middle-aged Americans increased by nearly 30 percent over the same ten years, according to a report from the Centers for Disease Control and Prevention.²⁰ More than 10 percent of American schoolchildren, and nearly 20 percent of highschool-age boys, have been given a diagnosis of attention deficit hyperactivity disorder, and two-thirds of that group take drugs like Ritalin and Adderall to treat the condition.²¹ The reasons for our discontent are many and far from understood. But one of them may be that through the pursuit of a frictionless existence, we've succeeded in turning what Merleau-Ponty termed the ground of our lives into a barren place."

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FROST'S SONNET also contains, as one of its many whispers, a warning about technology's ethical hazards. There's a brutality to the mower's scythe. It indiscriminately cuts down flowers—those tender, pale orchises—along with the stalks of grass.* It frightens innocent animals, like the bright green snake. If technology embodies our dreams, it also embodies other, less benign qualities in our makeup, such as our will to power and the

arrogance and insensitivity that accompany it. Frost returns to this theme a little later in *A Boy's Will*, in a second lyric about cutting hay, "The Tuft of Flowers." The poem's narrator comes upon a freshly mown field and, while following the flight of a passing butterfly with his eyes, discovers in the midst of the cut grass a small cluster of flowers, "a leaping tongue of bloom" that "the scythe had spared": The mower in the dew had loved them thus, By leaving them to flourish, not for us, Nor yet to draw one thought of us to him, But from sheer morning gladness to the brim.²² Working with a tool is never just a practical matter, Frost is telling us, with characteristic delicacy. It always entails moral choices and has moral consequences. It's up to us, as users and makers of tools, to humanize technology, to aim its cold blade wisely. That requires vigilance and care. The scythe is still employed in subsistence farming in many parts of the world. But it has no place on the modern farm, the development of which, like the development of the modern factory, office, and home, has required ever more complex and efficient equipment. The threshing machine was invented in the 1780s, the mechanical reaper appeared around 1835, the baler came a few years after that, and the combine harvester began to be produced commercially toward the end of the nineteenth century. The pace of technological advance has only accelerated in the decades since, and today the trend is reaching its logical conclusion with the computerization of agriculture. The working of the soil, which Thomas Jefferson saw as the most vigorous and virtuous of occupations, is being offloaded almost entirely to machines."

"Even if society were to come up with some magic spell, or magic algorithm, for equitably parceling out the spoils of automation, there's good reason to doubt whether anything resembling the "economic bliss" imagined by Keynes would ensue. In a prescient passage in *The Human Condition*, Hannah Arendt observed that if automation's utopian promise were actually to pan out, the result would probably feel less like paradise than like a cruel practical joke. The whole of modern society, she wrote, has been organized as "a laboring society," where working for pay, and then spending that pay, is the way people define themselves and measure their worth. Most of the "higher and more meaningful activities" revered in the distant past have been pushed to the margin or forgotten, and "only solitary individuals are left who consider what they are doing in terms of work and not in terms of making a living." For technology to fulfill humankind's abiding "wish to be liberated from labor's 'toil and trouble'" at this point would be perverse. It would cast us deeper into a purgatory of malaise. What automation confronts us with, Arendt concluded, "is the prospect of a society of laborers without labor, that is, without the only activity left to them. Surely, nothing could be worse."³⁵ Utopianism, she understood, is a form of miswanting. The social and economic problems caused or exacerbated by automation aren't going to be solved by throwing more software at them. Our inanimate slaves aren't going to chauffeur us to a utopia of comfort and harmony. If the problems are to be solved, or at least attenuated, the public will need to grapple with them in their full complexity. To ensure society's well-being in the future, we may need to place limits on automation. We may have to shift our view of progress, putting the emphasis on social and personal flourishing rather than technological advancement. We may even have to entertain an idea that's come to be considered unthinkable, at least in business circles: giving people precedence over machines."

"Out of ignorance or laziness or timidity, we've turned the Luddites into caricatures, emblems of backwardness. We assume that anyone who rejects a new tool in favor of an older one is guilty of nostalgia, of making choices sentimentally rather than rationally. But the real sentimental fallacy is the assumption that the new thing is always better suited to our

purposes and intentions than the old thing. That's the view of a child, naive and pliable. What makes one tool superior to another has nothing to do with how new it is. What matters is how it enlarges us or diminishes us, how it shapes our experience of nature and culture and one another. To cede choices about the texture of our daily lives to a grand abstraction called progress is folly. Technology has always challenged people to think about what's important in their lives, to ask themselves, as I suggested at the outset of this book, what human being means. Automation, as it extends its reach into the most intimate spheres of our existence, raises the stakes. We can allow ourselves to be carried along by the technological current, wherever it may be taking us, or we can push against it. To resist invention is not to reject invention. It's to humble invention, to bring progress down to earth."