The Innovators: How a group of hackers, geniuses, and geeks created the digital revolution, by Walter Isaacson, Simon & Schuster, 2014

Written by the author of Steve Jobs, this is an extremely lucid and engaging exposition of how the computer age came about, with a focus on the people and teams who created each technology that has contributed to this age.

Chapter titles include: Ada, Countess of Lovelace; The Computer, Programming; The Transistor; The Microchip; Video Games; The Internet; The Personal Computer; Software; Online; The Web; Ada Forever.

The Inevitable: Understanding the 12 technological forces that will shape our future, by Kevin Kelly, Viking 2016

Much of what will happen in the next thirty years is inevitable, driven by technological trends that are already in motion. In this book, Kevin Kelly provides an optimistic road map for the future, showing how the coming changes in our lives—from virtual reality in the home to an on-demand economy to artificial intelligence embedded in everything we manufacture—can be understood as the result of a few long-term, accelerating forces.

Kelly both describes these deep trends—interacting, cognifying, flowing, screening, accessing, sharing, filtering, remixing, tracking, and questioning—and demonstrates how they overlap and are codependent on one another. These larger forces will completely revolutionize the way we buy, work, learn, and communicate with each other. By understanding and embracing them, says Kelly, it will be easier for us to remain on top of the coming wave of changes and to arrange our day-to-day relationships with technology in ways that bring forth maximum benefits.

“Anyone can claim to be a prophet, a fortune teller, or a futurist, and plenty of people do. What makes Kevin Kelly different is that he’s right. In this book, you’re swept along by his clear prose and unassailable arguments until it finally hits you: The technological, cultural, and societal changes he’s foreseeing really are inevitable. It’s like having a crystal ball, only without the risk of shattering.” —David Pogue, Yahoo Tech

“This book offers profound insight into what happens (soon!) when intelligence flows as easily into objects as electricity.” —Chris Anderson, author of The Long Tail

“How will the future be made? Kevin Kelly argues that the sequence of events ensuing from technical innovation has its own momentum . . . and that our best strategy is to understand and embrace it. Whether you find this prospect wonderful or terrifying, you will want to read this extremely thought-provoking book.” —Brian Eno, musician and composer
WALTER ISAACSON

author of Steve Jobs

“A stirring reminder of what Americans are capable of doing when they think big, risk failure, and work together.”

—The Atlantic

the innovators

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BEST OF 2014

The New York Times
The Washington Post
Financial Times
CAN MACHINES THINK?

As he thought about the development of stored-program computers, Alan Turing turned his attention to the assertion that Ada Lovelace had made a century earlier, in her final “Note” on Babbage’s Analytical Engine: that machines could not really think. If a machine could modify its own program based on the information it processed, Turing asked, wouldn’t that be a form of learning? Might that lead to artificial intelligence?

The issues surrounding artificial intelligence go back to the ancients. So do the related questions involving human consciousness. As with most questions of this sort, Descartes was instrumental in framing them in modern terms. In his 1637 Discourse on the Method, which contains his famous assertion “I think, therefore I am,” Descartes wrote:

If there were machines that bore a resemblance to our bodies and imitated our actions as closely as possible for all practical purposes, we should still have two very certain means of recognizing that they were not real humans. The first is that… it is not conceivable that such a machine should produce arrangements of words so as to give an appropriately meaningful answer to whatever is said in its presence, as the dullest of men can do. Secondly, even though some machines might do some things as well as we do them, or perhaps even better, they would inevitably fail in others, which would reveal that they are acting not from understanding.

Turing had long been interested in the way computers might replicate the workings of a human brain, and this curiosity was furthered by his work on machines that deciphered coded language. In early 1943, as Colossus was being designed at Bletchley Park, Turing sailed across the Atlantic on a mission to Bell Laboratories in lower Manhattan, where he consulted with the group working on electronic speech encipherment, the technology that could electronically scramble and unscramble telephone conversations.

There he met the colorful genius Claude Shannon, the former MIT graduate whose work had shown that such machines could take on sensible alternatives in theory. “Show me three things!” he used to play with Turing’s group of inventives in electronic brain. A hallmark of his intelligence.
MIT graduate student who wrote the seminal master's thesis in 1937 that showed how Boolean algebra, which rendered logical propositions into equations, could be performed by electronic circuits. Shannon and Turing began meeting for tea and long conversations in the afternoons. Both were interested in brain science, and they realized that their 1937 papers had something fundamental in common: they showed how a machine, operating with simple binary instructions, could tackle not only math problems but all of logic. And since logic was the basis for how human brains reasoned, then a machine could, in theory, replicate human intelligence.

“Shannon wants to feed not just data to [a machine], but cultural things!” Turing told Bell Lab colleagues at lunch one day. “He wants to play music to it!” At another lunch in the Bell Labs dining room, Turing held forth in his high-pitched voice, audible to all the executives in the room: “No, I’m not interested in developing a powerful brain. All I’m after is just a mediocre brain, something like the President of the American Telephone and Telegraph Company.”

When Turing returned to Bletchley Park in April 1943, he became friends with a colleague named Donald Michie, and they spent many evenings playing chess in a nearby pub. As they discussed the possibility of creating a chess-playing computer, Turing approached the problem not by thinking of ways to use brute processing power to calculate every possible move; instead he focused on the possibility that a machine might learn how to play chess by repeated practice. In other words, it might be able to try new gambits and refine its strategy with every new win or loss. This approach, if successful, would represent a fundamental leap that would have dazzled Ada Lovelace: machines would be able to do more than merely follow the specific instructions given them by humans; they could learn from experience and refine their own instructions.

“It has been said that computing machines can only carry out the purposes that they are instructed to do,” he explained in a talk to the London Mathematical Society in February 1947. “But is it necessary that they should always be used in such a manner?” He then discussed the implications of the new stored-program computers that could modify their own instruction tables. “It would be like a pupil who had
learnt much from his master, but had added much more by his own work. When this happens I feel that one is obliged to regard the machine as showing intelligence.”

When he finished his speech, his audience sat for a moment in silence, stunned by Turing's claims. Likewise, his colleagues at the National Physical Laboratory were flummoxed by Turing's obsession with making thinking machines. The director of the National Physical Laboratory, Sir Charles Darwin (grandson of the evolutionary biologist), wrote to his superiors in 1947 that Turing “wants to extend his work on the machine still further towards the biological side” and to address the question “Could a machine be made that could learn by experience?”

Turing's unsettling notion that machines might someday be able to think like humans provoked furious objections at the time—as it has ever since. There were the expected religious objections and also those that were emotional, both in content and in tone. “Not until a machine can write a sonnet or compose a concerto because of thoughts and emotions felt, and not by the chance fall of symbols, could we agree that machine equals brain,” declared a famous brain surgeon, Sir Geoffrey Jefferson, in the prestigious Lister Oration in 1949. Turing's response to a reporter from the London Times seemed somewhat flippant, but also subtle: “The comparison is perhaps a little bit unfair because a sonnet written by a machine will be better appreciated by another machine.”

The ground was thus laid for Turing's second seminal work, “Computing Machinery and Intelligence,” published in the journal Mind in October 1950. In it he devised what became known as the Turing Test. He began with a clear declaration: “I propose to consider the question, ‘Can machines think?’” With a schoolboy's sense of fun, he then invented a game—one that is still being played and debated—to give empirical meaning to that question. He proposed a purely operational definition of artificial intelligence: If the output of a machine is indistinguishable from that of a human brain, then we have no meaningful reason to insist that the machine is not “thinking.”

Turing's test, which he called “the imitation game,” is simple: An interrogator sends written questions to a human and a machine in
another room and tries to determine from their answers which one is the human. A sample interrogation, he wrote, might be the following:

Q: Please write me a sonnet on the subject of the Forth Bridge.
A: Count me out on this one. I never could write poetry.

Q: Add 34957 to 70764.
A: (Pause about 30 seconds and then give as answer) 105621.

Q: Do you play chess?
A: Yes.

Q: I have K at my K1, and no other pieces. You have only K at K6 and R at R1. It is your move. What do you play?
A: (After a pause of 15 seconds) R–R8 mate.

In this sample dialogue, Turing did a few things. Careful scrutiny shows that the respondent, after thirty seconds, made a slight mistake in addition (the correct answer is 105,721). Is that evidence that the respondent was a human? Perhaps. But then again, maybe it was a machine cagily pretending to be human. Turing also flicked away Jefferson’s objection that a machine cannot write a sonnet; perhaps the answer above was given by a human who admitted to that inability. Later in the paper, Turing imagined the following interrogation to show the difficulty of using sonnet writing as a criterion of being human:

Q: In the first line of your sonnet which reads “Shall I compare thee to a summer’s day,” would not “a spring day” do as well or better?
A: It wouldn’t scan.

Q: How about “a winter’s day.” That would scan all right.
A: Yes, but nobody wants to be compared to a winter’s day.

Q: Would you say Mr. Pickwick reminded you of Christmas?
A: In a way.
Q: Yet Christmas is a winter’s day, and I do not think Mr. Pickwick would mind the comparison.
A: I don’t think you’re serious. By a winter’s day one means a typical winter’s day, rather than a special one like Christmas.

Turing’s point was that it might not be possible to tell whether such a respondent was a human or a machine pretending to be a human.

Turing gave his own guess as to whether a computer might be able to win this imitation game: “I believe that in about fifty years’ time it will be possible to programme computers...to make them play the imitation game so well that an average interrogator will not have more than 70 percent chance of making the right identification after five minutes of questioning.”

In his paper Turing tried to rebut the many possible challenges to his definition of thinking. He swatted away the theological objection that God has bestowed a soul and thinking capacity only upon humans, arguing that this “implies a serious restriction of the omnipotence of the Almighty.” He asked whether God “has freedom to confer a soul on an elephant if He sees fit.” Presumably so. By the same logic, which, coming from the nonbelieving Turing was somewhat sardonic, surely God could confer a soul upon a machine if He so desired.

The most interesting objection, especially for our narrative, is the one that Turing attributed to Ada Lovelace. “The Analytical Engine has no pretensions whatever to originate anything,” she wrote in 1843. “It can do whatever we know how to order it to perform. It can follow analysis; but it has no power of anticipating any analytical relations or truths.” In other words, unlike the human mind, a mechanical contrivance cannot have free will or come up with its own initiatives. It can merely perform as programmed. In his 1950 paper, Turing devoted a section to what he dubbed “Lady Lovelace’s Objection.”

His most ingenious parry to this objection was his argument that a machine might actually be able to learn, thereby growing into its own agent and able to originate new thoughts. “Instead of trying to produce a programme to simulate the adult mind, why not rather try to produce one which simulates the child’s?” he asked. “If this were then subjected
to an appropriate course of education, one would obtain the adult brain." A machine's learning process would be different from a child's, he admitted. "It will not, for instance, be provided with legs, so that it could not be asked to go out and fill the coal scuttle. Possibly it might not have eyes... One could not send the creature to school without the other children making excessive fun of it." The baby machine would therefore have to be tutored some other way. Turing proposed a punishment and reward system, which would cause the machine to repeat certain activities and avoid others. Eventually such a machine could develop its own conceptions about how to figure things out.

But even if a machine could mimic thinking, Turing's critics objected, it would not really be conscious. When the human player of the Turing Test uses words, he associates those words with real-world meanings, emotions, experiences, sensations, and perceptions. Machines don't. Without such connections, language is just a game divorced from meaning.

This objection led to the most enduring challenge to the Turing Test, which was in a 1980 essay by the philosopher John Searle. He proposed a thought experiment, called the Chinese Room, in which an English speaker with no knowledge of Chinese is given a comprehensive set of rules instructing him on how to respond to any combination of Chinese characters by handing back a specified new combination of Chinese characters. Given a good enough instruction manual, the person might convince an interrogator that he was a real speaker of Chinese. Nevertheless, he would not have understood a single response that he made, nor would he have exhibited any intentionality. In Ada Lovelace's words, he would have no pretensions whatever to originate anything but instead would merely do whatever actions he was ordered to perform. Similarly, the machine in Turing's imitation game, no matter how well it could mimic a human being, would have no understanding or consciousness of what it was saying. It makes no more sense to say that the machine "thinks" than it does to say that the fellow following the massive instruction manual understands Chinese.95

One response to the Searle objection is to argue that, even if the man does not really understand Chinese, the entire system incorpo-
people could join, to find out how I could retrain myself.” What struck him was that any effort to improve the world was complex. He thought about people who tried to fight malaria or increase food production in poor areas and discovered that led to a complex array of other issues, such as overpopulation and soil erosion. To succeed at any ambitious project, you had to assess all of the intricate ramifications of an action, weigh probabilities, share information, organize people, and more. “Then one day, it just dawned on me—BOOM—that complexity was the fundamental thing,” he recalled. “And it just went click. If in some way, you could contribute significantly to the way humans could handle complexity and urgency, that would be universally helpful.”

Such an endeavor would address not just one of the world’s problems; it would give people the tools to take on any problem.

The best way to help people handle complexity was along the lines that Bush had proposed, Engelbart decided. As he tried to imagine conveying information on graphic screens in real time, his radar training came in handy. “It was within an hour that I had the image of sitting at a big screen with all kinds of symbols,” he recalled, “and you could be operating all kinds of things to drive the computer.” That day he set out on a mission to find ways to allow people to visually portray the thinking they were doing and link them to other people so they could collaborate—in other words, networked interactive computers with graphic displays.

This was in 1950, five years before Bill Gates and Steve Jobs were born. Even the very first commercial computers, such as UNIVAC, were not yet publicly available. But Engelbart bought into Bush’s vision that someday people would have their own terminals, which they could use to manipulate, store, and share information. This expansive conception needed a suitably grand name, and Engelbart came up with one: augmented intelligence. In order to serve as the pathfinder for this mission, he enrolled at Berkeley to study computer science, earning his doctorate in 1955.

Engelbart was one of those people who could project intensity by speaking in an eerily calm monotone. “When he smiles, his face is
wistful and boyish, but once the energy of his forward motion is halted and he stops to ponder, his pale blue eyes seem to express sadness or loneliness," a close friend said. "His voice, as he greets you, is low and soft, as though muted from having traveled a long distance. There is something diffident yet warm about the man, something gentle yet stubborn."29

To put it more bluntly, Engelbart sometimes gave the impression that he had not been born on this planet, which made it difficult for him to get funding for his project. He finally was hired in 1957 to work on magnetic storage systems at the Stanford Research Institute, an independent nonprofit set up by the university in 1946. A hot topic at SRI was artificial intelligence, especially the quest to create a system that mimicked the neural networks of the human brain.

But the pursuit of artificial intelligence didn’t excite Engelbart, who never lost sight of his mission to augment human intelligence by creating machines like Bush’s memex that could work closely with people and help them organize information. This goal, he later said, was born out of his respect for the “ingenious invention” that was the human mind. Instead of trying to replicate that on a machine, Engelbart focused on how “the computer could interact with the different capabilities that we’ve already got.”30

For years he worked on draft after draft of a paper describing his vision, until it grew to forty-five thousand words, the length of a small book. He published it as a manifesto in October 1962 titled "Augmenting Human Intellect.” He began by explaining that he was not seeking to replace human thought with artificial intelligence. Instead he argued that the intuitive talents of the human mind should be combined with the processing abilities of machines to produce “an integrated domain where hunches, cut-and-try, intangibles, and the human ‘feel for a situation’ usefully co-exist with powerful concepts, streamlined terminology and notation, sophisticated methods, and high-powered electronic aids.” In painstaking detail, he gave many examples of how this human-computer symbiosis would work, including an architect using a computer to design a building and a professional putting together an illustrated report.31

As he was working on the paper, Engelbart wrote a fan letter
to Vannevar Bush, and he devoted an entire section of his paper to describing the memex machine.72 Seventeen years after Bush had written “As We May Think,” there was still a radical feel to his concept that humans and computers should interact in real time through simple interfaces that included graphical screens, pointers, and input devices. Engelbart emphasized that his system wouldn’t be just for math: “Every person who does his thinking with symbolized concepts (whether in the form of the English language, pictographs, formal logic, or mathematics) should be able to benefit significantly.” Ada Lovelace would have been thrilled.

Engelbart’s treatise appeared the same month that Licklider, who had explored the same concepts two years earlier in his “Man-Computer Symbiosis” paper, took over ARPA’s Information Processing Techniques Office. Part of Licklider’s new job was to give out federal grants to promising projects. Engelbart got in line. “I was standing at the door with this 1962 report and a proposal,” he recalled. “I thought, ‘Oh boy, with all the things he’s saying he wants to do, how can he refuse me?’”33 He couldn’t, so Engelbart got an ARPA grant. Bob Taylor, who was then still at NASA, also gave Engelbart some funding. Thus it was that he was able to create his own Augmentation Research Center at SRI. It became another example of how government funding of speculative research eventually paid off hundreds of times over in practical applications.

THE MOUSE AND NLS

The NASA grant from Taylor was supposed to be applied to a stand-alone project, and Engelbart decided to use it to find an easy way for humans to interact with machines.34 “Let’s go after some screen-select devices,” he suggested to his colleague Bill English.35 His goal was to find the simplest way for a user to point to and select something on a screen. Dozens of options for moving an on-screen cursor were being tried by researchers, including light pens, joysticks, trackballs, trackpads, tablets with styli, and even one that users were supposed to control with their knees. Engelbart and English tested each. “We timed how long it took each user to move the cursor to