How We Got to Now: Six Innovations That Made the Modern World

From the New York Times-bestselling author of Where Good Ideas Come From and Farsighted, a new look at the power and legacy of great ideas.
In this illustrated history, Steven Johnson explores the history of innovation over centuries, tracing facets of modern life (refrigeration, clocks, and eyeglass lenses, to name a few) from their creation by hobbyists, amateurs, and entrepreneurs to their unintended historical consequences. Filled with surprising stories of accidental genius and brilliant mistakes-from the French publisher who invented the phonograph before Edison but forgot to include playback, to the Hollywood movie star who helped invent the technology behind Wi-Fi and Bluetooth-How We Got to Now investigates the secret history behind the everyday objects of contemporary life.

In his trademark style, Johnson examines unexpected connections between seemingly unrelated fields: how the invention of air-conditioning enabled the largest migration of human beings in the history of the species-to cities such as Dubai or Phoenix, which would otherwise be virtually uninhabitable; how pendulum clocks helped trigger the industrial revolution; and how clean water made it possible to manufacture computer chips. Accompanied by a major six-part television series on PBS, How We Got to Now is the story of collaborative networks building the modern world, written in the provocative, informative, and engaging style that has earned Johnson fans around the globe.

Steven Johnson is the bestselling author of eleven books, including Where Good Ideas Come From, Wonderland, and The Ghost Map. He's the host and co-creator of the Emmy-winning PBS/BBC series How We Got To Now, and the host of the podcast American Innovations. He lives in Brooklyn and Marin County, California with his wife and three sons.

Introduction

A little more than two decades ago, the Mexican-American artist and philosopher Manuel De Landa published a strange and wonderful book called War in the Age of Intelligent Machines. The book was, technically speaking, a history of military technology, but it had nothing in common with what you might naturally expect from the genre. Instead of heroic accounts of submarine engineering written by some Naval Academy professor, De Landa's book wove chaos theory, evolutionary biology, and French post-structuralist philosophy into histories of the conoidal bullet, radar, and other military innovations. I remember reading it as a grad student in my early twenties and thinking that it was one of those books that seemed completely sui generis, as though De Landa had arrived on Earth from some other intellectual planet. It seemed mesmerizing and deeply confusing at the same time.

De Landa began the book with a brilliant interpretative twist. Imagine, he suggested, a work of history written sometime in the future by some form of artificial intelligence, mapping out the history of the preceding millennium. "We could imagine," De Landa argued, "that such a robot historian would write a different kind of history than would its human

counterpart." Events that loom large in human accounts-the European conquest of the Americas, the fall of the Roman Empire, the Magna Carta-would be footnotes from the robot's perspective. Other events that seem marginal to traditional history-the toy automatons that pretended to play chess in the eighteenth century, the Jacquard loom that inspired the punch cards of early computing-would be watershed moments to the robot historian, turning points that trace a direct line to the present. "While a human historian might try to understand the way people assembled clockworks, motors and other physical contraptions," De Landa explained, "a robot historian would likely place a stronger emphasis on the way these machines affected human evolution. The robot would stress the fact that when clockworks once represented the dominant technology on the planet, people imagined the world around them as a similar system of cogs and wheels."

There are no intelligent robots in this book, alas. The innovations here belong to everyday life, not science fiction: lightbulbs, sound recordings, air-conditioning, a glass of clean tap water, a wristwatch, a glass lens. But I have tried to tell the story of these innovations from something like the perspective of De Landa's robot historian. If the lightbulb could write a history of the past three hundred years, it too would look very different. We would see how much of our past was bound up in the pursuit of artificial light, how much ingenuity and struggle went into the battle against darkness, and how the inventions we came up with triggered changes that, at first glance, would seem to have nothing to do with lightbulbs.

This is a history worth telling, in part, because it allows us to see a world we generally take for granted with fresh eyes. Most of us in the developed world don't pause to think how amazing it is that we drink water from a tap and never once worry about dying forty-eight hours later from cholera. Thanks to air-conditioning, many of us live comfortably in climates that would have been intolerable just fifty years ago. Our lives are surrounded and supported by a whole class of objects that are enchanted with the ideas and creativity of thousands of people who came before us: inventors and hobbyists and reformers who steadily hacked away at the problem of making artificial light or clean drinking water so that we can enjoy those luxuries today without a second thought, without even thinking of them as luxuries in the first place. As the robot historians would no doubt remind us, we are indebted to those people every bit as much as, if not more than, we are to the kings and conquerors and magnates of traditional history.

But the other reason to write this kind of history is that these innovations have set in motion a much wider array of changes in society than you might reasonably expect. Innovations usually begin life with an attempt to solve a specific problem, but once they get into circulation, they end up triggering other changes that would have been extremely difficult to predict. This is a pattern of change that appears constantly in evolutionary history. Think of the act of pollination: sometime during the Cretaceous age, flowers began to evolve colors and scents that signaled the presence of pollen to insects, who simultaneously evolved complex equipment to extract the pollen and, inadvertently, fertilize other flowers with pollen. Over time, the flowers supplemented the pollen with even more energy-rich nectar to lure the insects into the rituals of pollination. Bees and other insects evolved the sensory tools to see and be drawn to flowers, just as the flowers evolved the properties that attract bees. This is a different kind of survival of the fittest, not the usual

zero-sum competitive story that we often hear in watered-down versions of Darwinism, but something more symbiotic: the insects and flowers succeed because they, physically, fit well with each other. (The technical term for this is coevolution.) The importance of this relationship was not lost on Charles Darwin, who followed up the publication of On the Origin of Species with an entire book on orchid pollination.

These coevolutionary interactions often lead to transformations in organisms that would seem to have no immediate connection to the original species. The symbiosis between flowering plants and insects that led to the production of nectar ultimately created an opportunity for much larger organisms-the hummingbirds-to extract nectar from plants, though to do that they evolved an extremely unusual form of flight mechanics that enables them to hover alongside the flower in a way that few birds can even come close to doing. Insects can stabilize themselves midflight because they have fundamental flexibility to their anatomy that vertebrates lack. Yet despite the restrictions placed on them by their skeletal structure, hummingbirds evolved a novel way of rotating their wings, giving power to the upstroke as well as the downstroke, enabling them to float midair while extracting nectar from a flower. These are the strange leaps that evolution makes constantly: the sexual reproduction strategies of plants end up shaping the design of a hummingbird's wings. Had there been naturalists around to observe the insects first evolving pollination behavior alongside the flowering plants, they would have logically assumed that this strange new ritual had nothing to do with avian life. And yet it ended up precipitating one of the most astonishing physical transformations in the evolutionary history of birds.

The history of ideas and innovation unfolds the same way. Johannes Gutenberg's printing press created a surge in demand for spectacles, as the new practice of reading made Europeans across the continent suddenly realize that they were farsighted; the market demand for spectacles encouraged a growing number of people to produce and experiment with lenses, which led to the invention of the microscope, which shortly thereafter enabled us to perceive that our bodies were made up of microscopic cells. You wouldn't think that printing technology would have anything to do with the expansion of our vision down to the cellular scale, just as you wouldn't have thought that the evolution of pollen would alter the design of a hummingbird's wing. But that is the way change happens.

This may sound, at first blush, like a variation on the famous "butterfly effect" from chaos theory, where the flap of a butterfly's wing in California ends up triggering a hurricane in the mid-Atlantic. But in fact, the two are fundamentally different. The extraordinary (and unsettling) property of the butterfly effect is that it involves a virtually unknowable chain of causality; you can't map the link between the air molecules bouncing around the butterfly and the storm system brewing in the Atlantic. They may be connected, because everything is connected on some level, but it is beyond our capacity to parse those connections or, even harder, to predict them in advance. But something very different is at work with the flower and the hummingbird: while they are very different organisms, with very different needs and aptitudes, not to mention basic biological systems, the flower clearly influences the hummingbird's physiognomy in direct, intelligible ways.

This book is then partially about these strange chains of influence, the "hummingbird effect." An innovation, or cluster of innovations, in one field ends up triggering changes that seem to belong to a different domain altogether. Hummingbird effects come in a variety of forms. Some are intuitive enough: orders-of-magnitude increases in the sharing of energy or information tend to set in motion a chaotic wave of change that easily surges over intellectual and social boundaries. (Just look at the story of the Internet over the past thirty years.) But other hummingbird effects are more subtle; they leave behind less conspicuous causal fingerprints. Breakthroughs in our ability to measure a phenomenon-time, temperature, mass-often open up new opportunities that seem at first blush to be unrelated. (The pendulum clock helped enable the factory towns of the industrial revolution.) Sometimes, as in the story of Gutenberg and the lens, a new innovation creates a liability or weakness in our natural toolkit, that sets us out in a new direction, generating new tools to fix a "problem" that was itself a kind of invention. Sometimes new tools reduce natural barriers and limits to human growth, the way the invention of air-conditioning enabled humans to colonize the hotspots of the planet at a scale that would have startled our ancestors just three generations ago. Sometimes the new tools influence us metaphorically, as in the robot historian's connection between the clock and the mechanistic view of early physics, the universe imagined as a system of "cogs and wheels."

Observing hummingbird effects in history makes it clear that social transformations are not always the direct result of human agency and decision-making. Sometimes change comes about through the actions of political leaders or inventors or protest movements, who deliberately bring about some kind of new reality through their conscious planning. (We have an integrated national highway system in the United States in large part because our political leaders decided to pass the Federal-Aid Highway Act of 1956.) But in other cases, the ideas and innovations seem to have a life of their own, engendering changes in society that were not part of their creators' vision. The inventors of air-conditioning were not trying to redraw the political map of America when they set about to cool down living rooms and office buildings, but, as we will see, the technology they unleashed on the world enabled dramatic changes in American settlement patterns, which in turn transformed the occupants of Congress and the White House.

I have resisted the understandable temptation to assess these changes with some kind of value judgment. Certainly this book is a celebration of our ingenuity, but just because an innovation happens, that doesn't mean there aren't, in the end, mixed consequences as it ripples through society. Most ideas that get "selected" by culture are demonstrably improvements in terms of local objectives: the cases where we have chosen an inferior technology or scientific principle over a more productive or accurate one are the exceptions that prove the rule. And even when we do briefly choose the inferior VHS over Betamax, before long we have DVDs that outperform either option. So when you look at the arc of history from that perspective, it does trend toward better tools, better energy sources, better ways to transmit information.

The problem lies with the externalities and unintended consequences. When Google launched its original search tool in 1999, it was a momentous improvement over any previous technique for exploring the Web's vast archive. That was cause for celebration on

almost every level: Google made the entire Web more useful, for free. But then Google started selling advertisements tied into the search requests it received, and within a few years, the efficiency of the searches (along with a few other online services like Craigslist) had hollowed out the advertising base of local newspapers around the United States. Almost no one saw that coming, not even the Google founders. You can make the argument-as it happens, I would probably make the argument-that the trade-off was worth it, and that the challenge from Google will ultimately unleash better forms of journalism, built around the unique opportunities of the Web instead of the printing press. But certainly there is a case to be made that the rise of Web advertising has been, all told, a negative development for the essential public resource of newspaper journalism. The same debate rages over just about every technological advance: Cars moved us more efficiently through space than did horses, but were they worth the cost to the environment or the walkable city? Air-conditioning allowed us to live in deserts, but at what cost to our water supplies?

This book is resolutely agnostic on these questions of value. Figuring out whether we think the change is better for us in the long run is not the same as figuring out how the change came about in the first place. Both kinds of figuring are essential if we are to make sense of history and to map our path into the future. We need to be able to understand how innovation happens in society; we need to be able to predict and understand, as best as we can, the hummingbird effects that will transform other fields after each innovation takes root. And at the same time we need a value system to decide which strains to encourage and which benefits aren't worth the tangential costs. I have tried to spell out the full range of consequences with the innovations surveyed in this book, the good and the bad. The vacuum tube helped bring jazz to a mass audience, and it also helped amplify the Nuremberg rallies. How you ultimately feel about these transformations-Are we ultimately better off thanks to the invention of the vacuum tube?-will depend on your own belief systems about politics and social change.

I should mention one additional element of the book's focus: The "we" in this book, and in its title, is largely the "we" of North Americans and Europeans. The story of how China or Brazil got to now would be a different one, and every bit as interesting. But the European/North American story, while finite in its scope, is nonetheless of wider relevance because certain critical experiences-the rise of the scientific method, industrialization-happened in Europe first, and have now spread across the world. (Why they happened in Europe first is of course one of the most interesting questions of all, but it's not one this book tries to answer.) Those enchanted objects of everyday life-those lightbulbs and lenses and audio recordings-are now a part of life just about everywhere on the planet; telling...

Other Books
Enemy of All Mankind, "Thoroughly engrossing . . . a spirited, suspenseful, economically told tale whose significance is manifest and whose pace never flags." —The Wall Street Journal From The New York Times-bestselling author of The Ghost Map and Extra Life, the story of a pirate who changed the world Henry Every was the seventeenth century's most notorious pirate. The press published wildly popular—and wildly inaccurate—reports of his nefarious adventures. The British government offered enormous bounties for his capture, alive or

(preferably) dead. But Steven Johnson argues that Every's most lasting legacy was his inadvertent triggering of a major shift in the global economy. Enemy of All Mankind focuses on one key event—the attack on an Indian treasure ship by Every and his crew—and its surprising repercussions across time and space. It's the gripping tale of one of the most lucrative crimes in history, the first international manhunt, and the trial of the seventeenth century. Johnson uses the extraordinary story of Henry Every and his crimes to explore the emergence of the East India Company, the British Empire, and the modern global marketplace: a densely interconnected planet ruled by nations and corporations. How did this unlikely pirate and his notorious crime end up playing a key role in the birth of multinational capitalism? In the same mode as Johnson's classic nonfiction historical thriller The Ghost Map, Enemy of All Mankind deftly traces the path from a single struck match to a global conflagration.

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