Rebels of Reason

THE LONG ROAD FROM ARISTOTLE TO CHATGPT
& AI'S HEROES WHO KEPT THE FAITH

John Willis
WITH DEREK LEWIS

"He…carried the torch through the dark ages."

—a godfather of AI on a fellow rebel[1]

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John "the Crunchman" Draper

"I don't think there would have ever been an Apple Computer had there not been blue-boxing."

—Steve Jobs[2]

Imagine the world without John Draper.

Without Draper, you don't have blue-boxing.

No blue-boxing, no Apple.

Without Apple, the world today would look vastly different.

This is not a book about Apple. Draper doesn't even play a real role in the development of artificial intelligence. Why start off the book with him? Because his story is the perfect example to show you what you're about to read, a tapestry of what we're calling the rebels of reason—major names you've probably heard of (like Alan Turing) or ones you may never have run across (like Fei-Fei Li or Walter Pitts)—who were key links in the chain building to ChatGPT. Their ripples have been felt in the development of technology in general and AI in particular.

Everyone's heard of Apple and Steve Jobs, but Draper is a name you've almost certainly never read. Outside of tech circles, almost no one knows about him. Yet we wouldn't have an Apple without him.

So, the question is…who the hell is John Draper?

One psychiatrist deemed him psychotic. A US District Court judge dressed him down in court for his lack of morals. He did three stints in the Alameda County jail. All because this honorably discharged Air Force veteran liked to play with phones.[3] Back in the 1970s, the budding hacker community called people like Draper "phone phreaks."

While in the Air Force, Draper had taught himself how to make free phone calls through the old telephone switchboards. He and his fellow phone phreaks learned how to hack rotary phones. You see, before we switched our phone systems to digital in the 90s, we operated telephones with certain audio frequencies or tones. Dialing 1 transmitted a sound at a specific frequency. Dialing a 7 transmitted a different sound at a certain frequency. With a different tone for each numeral (0–9) plus the asterisk and pound/hashtag, a telephone could transmit twelve different tones. A telephone receiver on the other end of the line would hear the tones and translate them back into numerals and two symbols. *

What the everyday Joes and Janes of the world didn't know is that Ma Bell† had a backdoor frequency that put the telephone in operator mode. Phone phreaks like Draper used this to bypass the system and make free phone calls to anywhere in the world.

* Dual-tone multiple frequency (DTMF) is slightly more complicated. I've simplified it for the sake of the explanation.

† AT&T's Bell System before the US government broke its telephone monopoly in 1984.

Draper's particular claim to fame was his discovery of a mass-manufactured phone hack that emitted the pitch-perfect sound to hack the phone. A device hidden in a cardboard box on grocery shelves all over the US: the Cap'n Crunch Bo'sun whistle.

In keeping with the nautical theme of Cap'n Crunch, the children's toy imitated a sailor's bo'sun whistle. (For you Trekkies, it's the whistle sound you hear that brings everyone to attention before an important announcement.) By sheer coincidence, the whistle's tone sounded at 2600 hertz, the exact frequency to trigger Bell System's operator mode. Thus, Draper's nicknames "Captain Crunch" and "the Crunchman." At some point, he began building "blue boxes" to allow anyone using his device to hack telephones.

A young Steve Jobs and Steve Wozniak sought the Crunchman out to learn how to build their own blue boxes. (As Draper recounted, you didn't want to buy a blue box Wozniak made. The Woz's inferior tech tipped off the phone company's engineers and led the authorities to a customer of Wozniak's. The customer snitched, leading the boys in blue to Woz through whom they eventually discovered Draper, leading to his three separate stints in jail.[4]) Jobs and Woz founded Apple, in part, from the money they made off blue-boxing. Thus, the quote by Jobs: "I don't think there would have ever been an Apple Computer had there not been blue-boxing."[5]

You've heard of Apple. You know about Steve Jobs and Steve Wozniak. But have you ever heard of John Draper? Yet without the Crunchman, we wouldn't have iPhones. Without iPhones, the world would have developed along a different path (including the things that led us to AI).

AI's Rebels

At best, the Crunchman plays a minor role in the story of how we got here. That's not the point. *Rebels of Reason* is about the big links in the chain. If not for these people (again, some known but many of whom are unsung heroes), you and I wouldn't be living in the Age of AI. The launch of ChatGPT in November of 2022 marked the dawn of this new era. But this book isn't really about ChatGPT. It's about the pioneers, misfits, freaks, outcasts, and mavericks who did the hard work to make the Age of AI possible. They are the crucial links in the chain. Remove any of these links and we probably don't have the birth of AI until years later. Maybe decades.

In some ways, *Rebels of Reason* mirrors my book *Deming's Journey to Profound Knowledge*. Without the statistician-turned-management guru, the world wouldn't have had the Japanese Economic Miracle, Toyota, lean manufacturing, and DevOps, the software development movement I and a handful of my colleagues pioneered. Or, if those things were to happen, they certainly would have taken longer and looked quite different from what we know. Deming is a crucial link in a very long chain. Without him, history would not have unfolded like it did. But whereas *Deming's Journey* is the story of one man, the book you're holding or hearing has a different hero (or two!) in every chapter.

Draper almost literally embodies a typical rebel. Among his fellow military veterans of the 1970s, he was too much of a hippie to be one of them. But among the hackers, he had worked for The Man and Uncle Sam. He was too much a product of the system to be fully trusted. When first meeting Draper, Wozniak "was taken aback by his guest's appearance and odor."[6] Like many of our

brilliant rebels, the phone phreak often became so engrossed in his work that he completely forgot about the mundane necessities of everyday life. He ran afoul of the law often, not because he wanted to be a troublemaker but because his genius wouldn't let him leave technology alone. Talent doesn't know how to be quiet.

The opening quote at the beginning of this book reads, "He…kind of carried the torch through the dark ages."[7] That's from Geoff Hinton, one of the rebels you'll read about. He rightfully earned his place as one of the godfathers of AI. He's largely responsible for the backpropagation of neural networks. That is, the way AI mimics the human brain in how we learn and reason. He pursued his research even though the world had written off neural networks as a dead end and a waste of time. He eventually earned the 2024 Nobel in physics because he kept the faith where others had written off the entire field.[8]

In his quote, he's talking about his fellow AI godfather Yann LeCun, the French-American largely responsible for creating convolutional neural networks which, among other things, allow AI to read my handwritten scrawl. LeCun believed in the potential of his software so much so that, at the risk of being sued for corporate espionage, he continued to work on his invention in secret. He won the 2018 Turing Award, the "Nobel Prize" in computing.

Like LeCun, our rebels carried the torch for AI. The Chinese-American Fei-Fei Li worried she was leading her graduate students to dead-end careers as she pursued a computer vision project called ImageNet. Many academics shook their head at the woman's belief in her research, tsking at the wasted potential of her intellect in chasing a technological daydream long since

abandoned. Li had the last laugh. Because of ImageNet, Geoff Hinton's research team created a new method to allow AI to recognize images, from historic photographs to the background of the *Mona Lisa*. The team's AI, called AlexNet, came directly from an invention of Yann LeCun, LeNet.

Indian-American Soumith Chintala single-handedly kept the Torch library running during his free time, eventually leading to Facebook/Meta's success in AI. Janet Baker and her husband had a pivotal role in creating the tech that enables AI to understand human speech, even though they were swindled out of their decades of research and patents. Walter Pitts was a runaway vagabond who never earned a college degree in his life yet made profound advancements that would lead us to create software that replicated human thought. *Good Will Hunting* could have easily been his story. Ada Lovelace earned degrees and published research, defying societal expectations for a British noblewoman in the Victorian era. Her intellectual passion culminated in writing the world's first computer program.

Our rebels believed. They believed in themselves, their dreams, and the promise of technology even as they doubted themselves and ran counter to what the world expected and demanded of them. They carried the torch of AI through the dark ages, ultimately bringing us to the dawn of the Age of AI.

But for all their wondrous gifts to the world…AI ain't magic.

In no way do I want to diminish what our rebels have given us. At the same time, part of this book's purpose is to pull back the curtain on AI. To unmask the magic, if you will. A magician's act seems amazing and incomprehensible at the outset. But when

you learn the magician's trick, you say to yourself, "Oh." Once you understand it, it's not magic anymore.

AI is the same way. It feels like magic. And honestly, even AI experts don't fully understand how it works. Not really. But the technology underlying AI is quite understandable. Once you see how it works, you'll say, "Oh. Well anybody could do *that*." I call this…

The Elektro Effect

It's 1939. You're at the World's Fair in New York. (The same fairground that would later showcase the giant metal globe featured in movies like *Tomorrowland* and the showdown scene in *Men in Black*.) In one exhibition hall, you're in a crowd of people at the base of a dais raised several feet above you. Standing on it is a sharply dressed man and a six-foot-tall gleaming golden robot.

Sounding like a radio announcer from that period, the man says, "Will…you…tell…your…story…please?"[9] He pauses between each word, being careful to enunciate the sounds when he does speak.

After a moment, the robot—a word that's only been on the scene for nineteen years[10]—says, "Who? …Me?"

The man quickly says, "Yes, you."

Almost as if following a rhythmic beat, the robot says, "Okay, toots," earning laughter from your fellow spectators. Without breaking the beat, the artificial man continues, "Lad-ies…and…gen-tle-men…I'd…be…very…glad…to…tell…my…story?" He inflects the end of the last word as if it were a question. The speech is

choppy and stilted; odd and unnatural. "I…am…a…smart…fellow…as I…have…a…ver-y…*fine*…brain…" There is no question about the odd emphasis on the word fine. He continues, "…of…for-ty-eight…e-lec-tri-cal…relays…It…works…just…like…a…tel-e-phone…switch-board."

Of all the technological marvels showcased at the exposition that year, Elektro the talking robot took the prize. Ever since at least the days of Aristotle, humankind had dreamed about creating a machine that could think, an artificial human.[11] Not only could Elektro carry on a conversation, but he could walk, joke, and even smoke a cigarette. No wonder fairgoers believed we would have flying cars by the end of the century. The future seemed limitless. What a time to be alive!

But allow me to pull back the curtain and show you the secret. Elektro didn't speak English any more than I speak Swahili. If you were to take off his aluminum shell, you'd find the robot was just a chopped-up telephone and some servo motors to make his limbs move. This technological marvel was made of stuff people had been using for more than half a century, at least. Alexander Graham Bell patented his telephony technology in 1876. Like Draper's blue box, the telephone relays in Elektro were activated by a precise combination of sounds. That's why the presenter had to speak slowly and enunciate clearly. The telephone receiver, if you will, inside Elektro translated those sounds into electrical impulses. Different impulses would trigger different gadgets inside the robot. One sound might trigger him to clunkily walk a few feet. Another might trigger him to play a pre-recorded joke or start a "conversation." And by conversation, I mean another pre-recorded tape with pauses long enough for the presenter to say

things like, “Yes, you.” For all its wow factor, the robot was nothing more than a glorified telephone inside a Tin Man painted gold.

That said, he was still pretty cool.

AI as we know it today is kind of the same thing. I mean, you might not be an electrical engineer who can explain how telephone relays work, but even still, you can get the gist of how Elektro functioned. Siri amazed us all with her iPhone debut in 2011, but conceptually, she (as if Siri were a real person) does the same thing Elektro did.[12] You would say something, some software would decode those sounds, then run its program and create specific sounds you recognized as English. Cool, but not really magic.

The Elektro Effect.

The Mind Rocket

On the other hand, fantasy author Sir Terry Pratchett once penned the words, “It doesn’t stop being magic just because you know how it works.”[13] Take a bicycle, for example. Fairly simple technology. Yet it multiplies human effort. You can get farther faster expending the same amount of effort. This fact led Steve Jobs to call computers “a bicycle for the mind.”[14]

According to Jobs, he once read an article in *Scientific American* showing the speeds of different animals as compared to humans. Stacked against others in the animal kingdom, we are not the fastest nor are we the most efficient. But as Jobs said, “A human on a bicycle blew the condor away completely off the top of the

charts."[15*] Even with something as inane as the bicycle I ride to and from my local coffee shop, my energy-to-distance covered rate is more efficient than anything Mother Nature has ever created.

You get the analogy, right? With computers, we can do much more work for the same amount of effort. Instead of alphabetizing a list by hand, we can use Microsoft Excel to do it in an instant. Before Excel, every time an accountant added a new expense to a column, they would have to re-tally the total. Excel does it in the time it takes me to move my finger away after hitting enter.

If a computer is a bicycle for the mind, AI is a rocket.

ChatGPT debuted on November 30, 2022, and went viral. Whereas it took Netflix about six years to gain a million subscribers[16] and Facebook ten months[17], it took ChatGPT just five days[18]. I was one of those million. For the first time in my life, interacting with a computer felt like talking to a real human being.

I've used ChatGPT and its siblings to scour the internet for Dr. Deming lore, to create images for YouTube videos, and to come up with better code than I ever could write myself. I routinely use AI to turn my scribblings for stories and explanations into solid prose that I publish on my various blogs. I'm able to get far more work done in about the same amount of time as before. It's amazing. It's like strapping a rocket to all my ideas.

But it's the Elektro Effect again. For all its wondrous capabilities, ChatGPT and its kin perform these miraculous feats by applying some fancy math to a word cloud. You'll get to a place in this book where you see that underneath its cool exterior,

* The Scientific American article I believe he read didn't list condors in its study, but his point remains.

it's simply a cooler and more powerful version of the predictive text in your Google search box.

Just now, I went to google.com and typed "how far is." Immediately, the browser not only tried to predict what I would finish typing ("…the moon from earth") but underneath that it listed the answer.* The type of AI ChatGPT (called generative artificial intelligence because it can generate text, images, and code) is more complex than that, of course, but if you can grasp predictive text, you're halfway to understanding AI.

It's not magic. It's math.

Rebels of Reason

What *is* magic is the blood, sweat, and tears it took to get us here.

To tell that story, there are a lot of characters, many overlapping storylines, and lots of putting technological advances into layman's terms. In the beginning, Derek and I thought about structuring the book chronologically. When telling a story that spans more than a century, that would make sense, right? There was so much cause-and-effect, chicken-and-the-egg type of thing that we had to abandon that. Otherwise, you would read a thread that started in the 1950s but didn't pick back up until the 1980s. In the meantime, you'd have read three decades' worth of events. To keep the thread, you'd have to go back several chapters to have the context for what you were about to read. Somehow, we

* 238,900 miles, if you were wondering.

figured out the best way to explain how we got to ChatGPT was by function:

- how computers developed from glorified calculators to logic machines (Part I: AI Can Count!)
- how logic machines evolved into expert systems like Deep Blue (Part II: AI Can Think!)
- how an offshoot of AI gave us machines that process information like a human brain (Part III: AI Can Learn!)
- how AI learned to recognize human handwriting (Part IV: AI Can Read!)
- how AI came to interact with the world around it (Part V: AI Can See!)
- how AI learned to understand human speech (Part VI: AI Can Speak!)
- and, lastly, how AI became capable of original thought (Part VII: AI Can Dream!)

All of this coalesced into the pinnacle of humanity's quest: to create a machine that can think, act, and interact like a human being.

Part I: AI Can Count! traces the story of computers from Charles Babbage and Ada Lovelace in the early 1800s to Claude Shannon and Alan Turing in the 1950s. To understand where we're going, you have to understand where we're coming from.

In Part II: AI Can Think!, we look at the summer workshop where AI was birthed in 1956 and take the tale all the way to IBM's Deep Blue beating chess master Gary Kasparov in 1997.

But where it might look like Deep Blue is an artificial intelligence, it's not what led to ChatGPT's type of AI. In Part III: AI Can Learn!, we backtrack several decades to the 1950s. That's where neural networks (the kind of computers that can think like humans do) got their start.

Coding computers to run logic programs and then teaching them to reason like we do is one thing. Getting them to read the printed word is another. Getting them to read my handwriting is something else altogether. But Ray Kurzweil and Yann LeCun did it. Their discoveries and inventions opened the gates to allow whole new realms of human-to-human and human-to-machine communications. That's Part IV: AI Can Read!

The title of Part V: AI Can See! is slightly misleading. To read handwriting, of course, computers had to already be able to see. But scanning a document is fundamentally different than a computer making sense of a scanned photograph. Marvin Minsky started the quest in 1966. It wouldn't be until Fei-Fei Li's ImageNet and Geoff Hinton's AlexNet that the quest to get computers to make sense of what they see would finally finish. Woven in through the intervening years is a whole fascinating thread on autonomous vehicles, prominently featuring John Waraniak, one of the people who designed the B2 stealth bomber as well as automotive tech that has saved millions of lives.

Part VI: AI Can Speak! is also a bit of a misnomer. Elektro could technically speak. What he couldn't do was understand speech. Triggering an audio recording is one thing. That's a far cry from conversing with someone in English. Going back to 1939, we cover another invention from the same place that gave us Elektro, Bell Labs. (That was AT&T's R&D center. As you'll see, just about

every technological advancement we use today has some DNA from Bell Labs.) Elektro's brother was Voder, an Oz-like figure who really did converse with the crowd. Sort of. But Part VI really centers around Janet Baker and her husband's role in the saga of Siri.

You'll recognize far more names and events in Part VII: AI Can Dream! because it begins in the early 2000s. (With cat videos, oddly enough.) We almost named it "AI Can Create!" or "AI Can Generate!" Remember that ChatGPT is a specific type of AI called generative AI? This type of AI can create blog posts, video shorts, and *Dogs Playing Poker* as if Rembrandt had painted it. You'll read the stories of the Korean Go master Lee Sedol and his "god move" against the most powerful AI in the world, how the GANfather was inspired in a barroom to pit a digital art detective against a paint forger, and how an Israeli-Canadian from Geoff Hinton's AlexNet team became the key to inventing ChatGPT.

The ChatGPT Moment

Is ChatGPT the end all, be all in AI? No. Plenty of people argue it wasn't even the birth of the Age of AI (though few dispute we now live in the era of AI), that AlphaGo's win in 2015 marked the event. But I disagree. Think about what we call the Atomic Age. The first atomic detonation was at Los Alamos, yes, but only a handful of people knew about it. It wasn't until Hiroshima* that the world at large was introduced to the atom bomb. *That's* when the Atomic Age began. That's when it entered the mainstream consciousness. Likewise with modern AI. Until

* In the final chapter, I address the horror that was Hiroshima and Nagasaki.

ChatGPT, it was mostly relegated to the realm of science fiction and data scientists. It wasn't what I'd call a mainstream phenomenon until November of 2022. ChatGPT brought AI to the masses.

For all we know, by the time you read this, ChatGPT and its maker may not even exist. Speaking about them may sound like someone my age remembering their Sputnik moment. The young men and women who graduated high school just before Covid weren't even alive on 9/11 much less have a memory of that awful day. But that doesn't matter. Wherever and whenever these words find you, whatever the state of artificial intelligence, it doesn't change the fact that ChatGPT was when the Age of AI began for the world at large.

When you read "ChatGPT" throughout this book, we're not really talking about ChatGPT as a software product. We're talking about ChatGPT as a moment in time, like other moments in human history where you can divide the world into before and after. Neil Armstrong stepping foot on the moon, the fall of the Berlin Wall, the public launch of the iPhone—these are watershed events. The launch of a chatbot to enable anyone anywhere to interact with a powerful AI is another one.

But before we dive into the story of AI (beginning with an ancestor of Geoff Hinton), I want to speak to one of the biggest debates that has spanned decades. Can AI think?

My answer?

Can a Submarine Swim?

In a 1984 speech, Dutch computer scientist professor Edsger Dijkstra said,

> *…at the beginning, the computing community was very uncertain as to what its topic was really about…*
>
> *The fathers of the field had been pretty confusing: John von Neumann speculated about computers and the human brain in analogies sufficiently wild to be worthy of medieval thinking and Alan M. Turing thought about criteria to settle the question of whether machines can think, a question…about as relevant as the question of whether a submarine can swim.*[19]

That is to say, it doesn't matter.

Debate the semantics, technicalities, and nature of humanity all you want. It isn't going to change the fact submarines exist and do an infinitely better job of propelling humans underwater than we could ever do ourselves. Are they actually swimming? Who cares?

Does AI think? Or is it just a bunch of electrical impulses guided by some sort of rationale? Then again, isn't that what the human brain is? To create prose, pictures, and poetry, isn't AI just stealing from others' work and remixing it into something never before seen? In his excellent book *Steal Like an Artist*, Austin Kleon argues that's all *any* of us ever do.

A broader question people endlessly debate is whether AI is good or bad. Have we discovered Promethean fire or have we opened Pandora's box? Again, I channel Dijkstra: Does it really matter? Believe one or the other. Believe both. Believe nothing.

None of it changes the fact AI is here. To mix metaphors and cultural mythology, the genie ain't going back in the bottle. We have to learn to live with it. We can't pretend that it's going to enable some grand utopia. We can't put our heads in the sand and wait until we get the all-clear signal. (Believe it or not, I know an old-timer who still believes "that internet thing" is a fad that will blow over.) ChatGPT and the generations of AI following it are now an inextricable part of our reality.

If that's the case (and it is), wouldn't you like to understand how we got here? To know that, you have to understand the crazy rogues and rebels who brought us here. These are the people who carried the torch through the dark ages. The unsung John Galts who kept the engine of the world turning.

Oh, who is John Galt?

It doesn't matter.

PART I: AI CAN COUNT!

To know where we're going, you have to know where we've been.

It took a *lot* of work to invent basic calculators out of gears, cogs, and levers. The story of how artificial intelligence went from a dream of Aristotle's to the dawn of the Age of AI with ChatGPT begins, as you might imagine, with math. And not just your basic mathematics. Humanity had to first invent algebra and then algebraic logic. That's what all computers are predicated on.

We quickly jump ahead to Alan Turing, the famous British cryptographer to whom all democracies owe a debt of gratitude. Even while designing the first "real" computers as we know them today, he was already thinking beyond mathematical functions to artificial reasoning. He's the subject of Chapter 5 and also Chapter 9, the final one in this section. The chapters in-between shine a spotlight on others without whom it would have taken decades longer before all the elements aligned to bring ChatGPT into being.

2| Mathematical Minds & Mechanical Thinkers

George Boole

"Any sufficiently advanced technology is indistinguishable from magic."

—Sir Arthur Clarke[20]

Legend has it Mark Twain once wrote, "Never let schooling interfere with your education." He didn't pen those words (at least, as far as any scholars can verify), but it sounds like him and definitely feels like him. Much to my mother's eternal regret, I never finished college.* At this point in my life, I'm glad I didn't because I don't know if I would have made it this far. It hasn't been a handicap and has often been what let me see things differently from the mainstream.

* Much to my eternal pride, my sons have.

That happened to George Boole in 1830 when his father published his translation of a Greek poem ("Ode to Spring") in the local Lincolnshire newspaper.[21] An academic accused Boole of plagiarism, claiming it was too good for someone without a formal education. See? A smart person without a degree achieves something remarkable and what's the reaction? Disbelief. Boole was even criticized by a scholar saying Boole's English version was a "juvenile production."[22] Then again, the doubting Thomas could be forgiven considering the fact Boole was only fourteen years old and the son of a cobbler.

But that's the story of so many of our rebels. Geniuses often from families of modest means who shone in the darkness. Boole did not have the opportunity to earn a formal degree because at sixteen years old he became the breadwinner for his parents and siblings.[23] Later, he wanted to go to Cambridge but couldn't afford to attend the university and make a living at the same time. Honestly, he didn't need to. Despite the lack of a Cambridge education (or because of it, perhaps), Boole invented a significant advance in the field of mathematics, what his successors would later call Boolean algebra, including the binary code of zeroes and ones—the language of computers.

Boole extensively studied mathematics, especially the calculus of Sir Isaac Newton (coincidentally, another native of Lincolnshire.)[24] But it was the ideas of German mathematician-philosopher Gottfried Leibniz (who, independently of Newton, also invented calculus[*25]) that really put Boole on track to create the ones and zeroes we computer nerds have come to love and hate.

* The question of which genius invented calculus ignited a controversy that lasted years. Secret investigations, anonymous publications, smear campaigns, accusations—it's quite the dramatic read.

Leibniz rightly believed mathematics and logical reasoning could be combined. At that time, and continuing until George Boole, logic* was the purview of philosophers in the tradition of Aristotle, unrelated to numbers. Boole seized on Leibniz's notion and bridged the divide with Boolean algebra.

But Leibniz plays a larger role in the story of making machines that can think.

Pascal's Calculator, the Leibniz Wheel, and the Elusive *Ratiocinator*

Humankind has long imagined nonliving beings endowed with human intelligence. In Greek mythology, there's Talos, a metal giant created by Zeus to protect Crete from pirates and invaders.[26] In Jewish mythology, there are golems, hulking man-like creatures fashioned from clay. In *A Thousand and One Nights*, we read about genies.

The first time (as far as history tells us) that anyone seriously thought about building something that could think for itself was Aristotle. Over 2,300 years ago, he mused, "If every tool, when ordered, or even of its own accord, could do the work that befits it…then there would be no need either of apprentices for the master workers or of slaves† for the lords."[27]

He sort of predicted ChatGPT, didn't he? It doesn't do my thinking for me. However, the AI does cut down or entirely cut out a lot of the drudgery that goes with my work. It's not simply a machine like a robotic arm on an assembly line or a spreadsheet

* Specifically, deductive logic. But more on that later.
† We've kept the original quote even if it casually refers to an abominable practice.

that automatically adds up my travel expenses. ChatGPT can reason. It can think for itself. When it comes back to me with a bad response, I can point it out, and ChatGPT, on its own, will figure out why. Aristotle's dream come true.

Speaking of apprentices and accounting, one of Leibniz's greatest inspirations was Blaise Pascal, the apprentice and son of a French tax collector. You've heard that necessity is the mother of invention? In Pascal's case, his father was the necessity of his invention. The teenage boy hated the endless adding and subtracting he was tasked with. Like every good engineer I've ever known, Pascal wanted a lazier way to do his work, spurring him to invent the first mechanical calculator in 1642, dubbed the Pascaline.[28]

Thirty-one years later, Leibniz was inducted into the Royal Society of London for his invention inspired by Pascal's calculator. Besides adding and subtracting like the Pascaline, the "Leibniz wheel" could also multiply and divide.[29] Unlike Pascal, Leibniz envisioned something greater than a handy tool to do tax returns. He saw a machine to be used by the "managers of financial affairs, the administrators of others' estates, merchants, surveyors, geographers, navigators, [and] astronomers…"[30] In summarizing his effusive praise for his invention, he echoed Aristotle's sentiments by saying, "For it is unworthy of excellent men to lose hours like slaves in the labor of calculation which could safely be relegated to anyone else if the machine were used."[31]

Around 1675, Leibniz presented a revolutionary idea.[32] What if we had a way to turn logical thinking into a language of symbols? We already did that with numbers. The numeral 8 is two circles sitting on top of each other. It symbolizes the idea of eight—eight

dots, eight people, eight dollars, or whatever you want to count. The only numeral that isn't a symbol is 1. It's a single mark, a one count. All the other numerals are symbols we made up to represent the number we mean.

Leibniz wondered if we could do the same thing with logic. Specifically, logical functions. (Think of an "if-then" statement: If A = 1, then B = 1; otherwise B= 0.) Leibniz created a clunky set of symbols and then spent the rest of his life attempting (and failing) to build a *calculus ratiocinator*. Whereas the Leibniz wheel could perform mathematical functions like multiplication and division, the *ratiocinator* would perform logical functions such as the if-then statement you just read.

Almost two centuries later, George Boole brought Leibniz's ideas of a symbolic language to fruition in Boolean algebra as presented in his 1854 book *Laws of Thought*.[33] As an aside, that's the story for so many of our rebels. They often do not have the chance to see the legacy of their work during their lifetime. They carry the torch in blind faith that someone somewhere in time will pick it up. Leibniz's dream of the *calculus ratiocinator* would take almost another century after Boole before it was seized and fleshed out in the designs of a guy who would become famous at Bell Labs.* Designs like that of electrical switching circuits (how Elektro worked) and digital circuitry (how every computer today works).

Computers can do amazing things, but when you strip it down to its building blocks…it's just a bunch of on-and-off switches. Conceptually, a computer processor is like the light switch in your bathroom. It's either on or it's not.

* One Claude Shannon, the father of information theory.

On or off. True or false. Black or white. One or zero.

Granted, your laptop performs billions of these logical functions per second (and often does some crap that seems pretty *il*logical) but at the end of the day, it's a glorified light switch. One that we can easily write commands for thanks to George Boole creating the language of mathematical logic.

Boole's book *Law of Thought* is where the story begins of creating machines that think. But it was in a book of a completely different nature published in 1726 that we see a particularly prescient example of ChatGPT. Believe it or not, people read about this technological prophecy in *Gulliver's Travels*.

Jonathan Swift's Engine and the Infinite Monkey Theorem

In Gulliver's wide-ranging travels, the fictional hero came upon The Engine. It looked like a cross between a giant abacus and a Rubik's Cube. It had rows and rows of wooden dice. But instead of the playing dice with dots we use in Yahtzee, these dice had a different word carved into each face.

To run the machine, an intricate series of gears and pulleys would shuffle the dice as the attending workers pulled various levers. After each run, the workers would look at all the rows of shuffled words. When they found a phrase that made sense, they'd write it down. After reading every row, they'd run the machine again and start the whole process over. Put enough of these random phrases together and *voila!* The Engine would write a whole book for you. No intelligence needed.

Swift wrote,

> *Every one knew how laborious the usual method is of attaining to arts and sciences; whereas, by his contrivance, the most ignorant person, at a reasonable charge, and with a little bodily labour, might write books in philosophy, poetry, politics, laws, mathematics, and theology, without the least assistance from genius or study.*[34]

All the greatness without any of the grunt work.

Swift's Engine reminds me of the Infinite Monkey Theorem. The tongue-in-cheek idea says that if you sat a monkey in front of a typewriter and let it start banging away, given an infinite amount of time, the monkey will reproduce the complete works of Shakespeare. Not by intent, mind you, but by virtue of the fact that, if you put enough random letters together, at some point they'll spell a word. Do that for eternity and at some point, the monkey will accidentally string together *Hamlet* and *Macbeth*.*

Monkeys aside, Gulliver's fictional Engine works eerily like ChatGPT. The AI allows "the most ignorant person" to "write books in philosophy, poetry, politics…without…genius or study." I can ask it to create virtually anything in words or pictures. While I'm told I'm a good writer and a pretty good songwriter, I've never tried my hand at poetry. But I don't have to be even an amateur poet to come up with a fairly decent poem. I asked ChatGPT to write a short poem about a forlorn, bittersweet lost love. In seconds it came back with a passage that included these lines:

* My spoilsport of a son sent me an NPR article talking about a research project revealing that there wasn't enough time between now and the end of the universe for this to happen—and that's not even including breaks to eat bananas and scooping up poop to throw at people walking by the room.

The stars, they weep in silence, for tales of love so sweet,
That danced upon the precipice, where earth and heaven meet.
Yet in their light, a solace, for all that's come to pass,
The beauty in the sorrow, of love that could not last.
Amidst the ruins of passion, where dreams lay bare and crossed,
Lies the tender ache of knowing, some loves are meant as lost.[35]

Does that not tug at your heartstrings? This is precisely what Jonathan Swift envisioned with The Engine: a machine that without understanding the complexities of emotion, love, and loss could nevertheless create something so emotional.

But like the monkey hitting random keys at a typewriter, ChatGPT doesn't truly *understand* what it wrote. It scanned a lot of human-created material on the internet, performed a lot of logical functions, and came up with its best guess of what I wanted. Once you remove Elektro's cover plate, the inner workings are far less impressive and far less frightening.

No, Jonathan Swift isn't really a link in our story's chain. I include his fanciful tale because of how spot-on the writer was about artificial intelligence in 1726, nearly three hundred years before ChatGPT…although it wasn't too long after that science fiction became fact. In 1997, chess grandmaster Gary Kasparov famously squared off against the IBM supercomputer Deep Blue. Would it blow your mind to know that more than two hundred years before, another chess-playing artificial intelligence amazed the Western world?

3 | The Fraud that Inspired the First Computer

Charles Babbage

"Man makes man in his own image. This seems to be the echo…of the act of creation, by which God is supposed to have made man in His image. Can something similar occur in the…case of the nonliving systems that we call machines?"

—Dr. Norbert Wiener, *God & Golem, Inc.*[36]

In 1769, Wolfgang von Kempelen sat in the court of Maria Theresa (the Habsburg empress who ruled Austria, Hungary, and Bohemia) and watched a magic trick.[37] The arrogant French performer before him mixed science with sleight of hand to deliver a convincing performance. Sitting beside his empress, throughout the event Kempelen explained to her how the showman pulled off his magic acts. At the conclusion, she invited Kempelen to address the court. Perhaps bored with life, insecure in his abilities, or incensed by the Frenchman's condescending

attitude, Kempelen told assembled nobles and notables that he could do better. Perhaps wanting to one-up the French, she officially excused Kempelen from his official duties for six months and told him to put his money where his mouth was.

He returned the following year.[38] He did not disappoint.

He presented his empress the Mechanical Turk. The wooden cabinet was about the size of a steamer trunk or large coffee table. Its top held a traditional chessboard. On one side of the board sat an oriental sorcerer. A wooden one, that is.

Turkish culture was the latest rage in Vienna, Austria, at the time. Austrians drank scalding Turkish coffee and added such exotic instruments as drums and cymbals to their classical compositions. In keeping with the exotic Eastern theme, the life-sized carving wore ballooning trousers, an ermine-lined robe, and a sorcerer's turban, looking very much like Zoltar from the Tom Hanks movie *Big*. In one hand, he held a long smoking pipe. (Apparently, humankind is fascinated with the idea of smoking robots.) The sorcerer's other hand was empty.

Kempelen opened the sides of the box to reveal what looked like a giant Swiss clock. Gleaming gears, clicking cogs, whirling wheels—it looked exactly like you would expect the inside of a thinking machine to. He even opened the side panels and then the end panels, allowing the onlookers to see right through to the other side. I can almost hear him say, "Nothing up my sleeve!" He turned the crank and the Turk lurched to life.

His head slowly turned from side to side, taking in his surroundings. His gaze came back to the chessboard before him. His free hand suddenly reached forward, deftly grabbing a chess piece and moving it across the board. He was ready to play.

As I said, the Mechanical Turk did not disappoint. Courtier after courtier lost to the mechanical marvel. The learned men and women of the day were dumbfounded. The less learned men and women whispered dark magic. No one could figure out how Kempelen had pulled it off.

The Mechanical Turk would go on to tour Europe. In a famous game against Napoleon, the French general cheated three different times. The first time, the sorcerer moved the offending piece back to its original square. The second time, the emperor's piece was confiscated. After the third illegal move, the Turk swept his hand across the board, upsetting all the chess pieces and ending the game. (Apparently, not only had Kempelen built a thinking machine but an emotional one as well.) World conqueror or not, even Napoleon was forced to play by the rules. The French emperor wasn't offended. Quite the opposite: He thought it great fun and complimented its ingenious design.

Other notables who sat across from the Zoltar-looking chess master included Benjamin Franklin while in Paris, Russian empress Catherine the Great (who also tried to cheat), and even Edgar Allen Poe* during the Turk's tour of the US. Years later, after the contraption had been lost to fire, Kempelen's son finally revealed the secret.

A human hid in the chest.

Kempelen's cleverness was in designing the chest like a sliding block puzzle. When he opened the panels, the interior looked one way. When he shut those panels and opened the other

* Some scholars believe Poe's account of the Mechanical Turk, "Maelzel's Chess-Player," was the seed of the mystery genre, directly inspiring "The Murders in the Rue Morgue."

two, everything inside reconfigured. The hidden chess player had to be a bit of a contortionist, but the illusion held.

Years later, Fei-Fei Li would take advantage of Amazon's Mechanical Turks as the missing piece of her puzzle in giving "sight" to AI. Amazon so-named the job board chock-full of menial tasks that could only be done by humans because, like the original Mechanical Turk, it looked like artificial intelligence but was really the work of humans.

So, yes, the famed Mechanical Turk turned out to be a fraud, but like so much of science fiction, it inspired true science.* Its existence set a series of events into motion that would eventually give us digital computers and ultimately AI. Despite playing some of the most powerful and influential people in the world, the Mechanical Turk's most important game pitted the illusory sorcerer against a British student visiting France. The young man "was certain the automaton was not a pure machine and was under human control, though he was not sure quite how. But he started to wonder whether a genuine chess-playing machine could, in fact, be built."[39]

The student, one Charles Babbage, built the world's first computer.

* Did you know, for instance, that when cell phones went mainstream, there was no real reason for designing "clam shell" phones? That is, other than flipping a cell phone open looked exactly like Captain Kirk flipping open his communicator to say, "Beam me up, Scotty." (For my fellow Trekkies nerds, I know: in no episode of the original series did William Shatner ever utter those exact words. For the record, William Shakespeare never penned "Methinks she doth protest too much." The correct Hamlet quote is, "The lady doth protest too much, methinks." Good luck convincing the unwashed masses of either.)

The Difference Engine

The Pascaline and the Leibniz wheel saved bookkeepers incalculable amounts of time. That was good and fine for the pace of life in the 1600s, but Babbage lived in the early 1800s, the age of the First Industrial Revolution. We were creating and calculating numbers at previously unimaginable quantities. Babbage, enchanted since childhood by the automata predecessors of the Mechanical Turk, believed he could create a mechanical device to compute tables' worth of figures at a time. The Leibniz wheel attached to a NASCAR engine, if you will.

In 1822, he revealed a scale model of such an invention to the British Royal Astronomical Society.[40] He called it the Difference Engine. Impressed by the promise of such technology, the British government stepped in to fund further development to the tune of £1,700.[41]

It's appropriate that the government pony up for the inventions that would lead to AI because as you'll see throughout this book, it's been the public coffers that financed the journey. The vast majority of that came from DARPA, the US military's Defense Advanced Research Projects Agency. Like many of DARPA's investments, the Difference Engine was a dead end.

There were at least three contributing factors to why Babbage's mechanical design never worked. The first was metallurgical. Quite simply, Britain's best machinists couldn't make the precision cuts necessary for his Engine to effectively work. The second was financial. After spending nearly ten times the original amount pledged, the government turned off the spigot. Babbage's own family fortune had been dramatically depleted. So, money problems. But my guess is that the third

hurdle was the true reason the Difference Engine never saw the light of day. Like so many of our rebels following where their curiosity took them, Babbage was entranced by his new idea: the Analytical Engine.

But first, a lesson on looms.

Programming Patterns with Punch Cards

Babbage began thinking about his new pet project at least as early as 1834[42], the same year Joseph-Marie Jacquard died[43]. Like fellow Frenchman Blaise Pascal, Jacquard grew up apprenticed to his father, a weaver. Also like Pascal, Jacquard created several inventions and innovations to multiply the fruits of his labor. In his crowning achievement (as far as the story of AI goes), he created the Jacquard loom.

Building on the ideas, designs, and devices of a handful of inventors before him, Jacquard created the world's first automatic loom. You might even say the world's first programmable machine. Jacquard used punch cards to map out which color threads were needed at different points during weaving to create different pattern designs.

The best way I know how to describe it is like a music box. When you wind it up, the metal cylinder inside begins to turn. The cylinder is covered in what looks like Braille dots. The surface of it sits a hairsbreadth away from a metal comb. When a raised dot passes underneath one of the comb's tines, it plucks the metal. Different metal tine lengths vibrate to make different sounds.

When the cylinder's surface is smooth as it passes under a tine, the tine is "off" and doesn't make a sound. When there's a dot, it plucks the tine (you could say it briefly switches the tine "on") and you get a single musical note.

A Jacquard loom mapped punch cards to work sort of the same way. For a single thread row, most of the card was solid but there were a few holes. When the loom's mechanical shuttle ran across that row, those holes let it pluck the thread on the other side of the card. The rest of the row was solid, so the shuttle couldn't get to those respective spools of thread. That is, each time the shuttle wove another row in the fabric, most thread colors were in the "off" position (or inaccessible) but a select few were switched "on" (or accessible).

Hole or no hole. Accessible or not. On or off. True or false. Yes or no.

Laid out like that, it's pretty easy to see the connection with Boole's ones and zeroes, right? But plenty of things are obvious in hindsight. In 1834, Babbage's idea of using a loom as inspiration for a calculating machine seemed revolutionary.

As the inventor of the first computer, Babbage's life has been chronicled to death. Instead of rehashing it all, let's talk about someone just as important, just as pivotal, even more intriguing, and far more of a visionary. The year before his idea for the Analytical Engine, Babbage had met another brilliant mind who was immediately fascinated by his inventions.[44] I'm talking about his assistant, the world's first computer programmer.

A woman named Ada Lovelace.

4| Enchantress of Numbers

Ada Lovelace

"The Analytical Engine has no pretensions whatever to originate anything. 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 revelations or truths. Its province is to assist us in making available what we are already acquainted with."

—Ada Lovelace[45]

Ada Lovelace loved ponies.

You might expect that of a British noblewoman in the early 1800s, especially one brought up in privilege and wealth. Her father was none other than Lord Byron, the famous English poet who towers over the Romantic movement. (You might remember one of his most famous poems, "She Walks in Beauty" from the Robin Williams movie *Dead Poets Society*.) Her mother was a baroness. Her husband was an earl. I imagine her childhood was

one British tea party after another. Unfortunately, I'm not talking about the kind of ponies little girls wish for on their birthdays.

She liked *the* ponies.

Horse racing. More specifically, betting on horse races. Heavily. She once bet on the wrong horse and lost £3,200.[46] That equates to roughly half a million dollars today. Her grandfather had nearly squandered the family fortune with his gambling losses. Lovelace seemed to inherit his addiction and wasn't perhaps as choosy as she should have been about the company she kept. The problem was that she was smart. Incredibly smart. She had been schooled in trigonometry, languages, and logic. Her wide-ranging interests included mechanical engineering and music. She thoroughly studied statistics and probability. These last two subjects gave her the confidence to attempt to beat the betting odds. No doubt, Lovelace was smart. But not that wise.

A biographer of Lovelace's mother wrote, "Ada, encouraged by con men, would turn her prodigious talents toward gambling and programming the outcomes of horse races."[47] The same biographer wrote about a mysterious little book passed back and forth between Lovelace and her mentor, Charles Babbage. Maybe the invention of the computer came about in some part to wanting to calculate the odds (a foreshadowing of the rebel in Chapter 14 who wanted to beat the odds with AI and wound up creating the most successful hedge fund in history).

Evidently, Babbage saw the brilliant intellect in the unconventional Victorian countess because of the favor he asked a decade later. But Lovelace doesn't figure in until Babbage's second engine. Between the time they met and began working

together, they maintained a professional relationship through contact and correspondence.

I say "unconventional Victorian" because Lovelace did not fit the societal norms of a proper woman of breeding. But with her family and childhood, how could she have turned out any other way?

Proper Breeding and Improper Inbreeding

You know Lovelace's pedigree. Now, let's spill the British tea.

Lord Byron's father led a hedonistic life as an adulterer, fornicator, and degenerate gambler. Lord Byron followed in his father's footsteps but one-upped his old man by adding incest with his half-sister to the list.[48*] When Byron's wife confronted him about his incestuous relationship, he threw her and their daughter out of the home when Ada was only a few weeks old.[49]

As a testament to Lady Byron's intellect and interest in mathematics, early in their marriage, Lord Byron bestowed upon his wife the backhanded compliment of a nickname "the princess of parallelograms."[50] Lady Byron made it her life's mission that Ada would break the cycle. In an effort to counter any of Lord Byon's DNA, the woman set out to make Ada a robot before robots were even a thing. Almost before she could talk, the little girl was subjected to a rigorous and rigid course of study, focusing on math and science. Her mother believed such logical

* The world learned of this when the author of Uncle Tom's Cabin, Harriett Beecher Stowe, chronicled Lady Byron's life. I assume the two met through their shared passion for abolition, something instilled in Lady Byron by her father.

thinking would "avoid the 'poetic' influences of her father's nature"[51] and rid her of any romantic* flights of fancy. It did not. Quite the opposite, because when Ada was just twelve years old, she envisioned a steam-powered flying machine.[52] Throughout her life, she continued her pursuit of imagining the impossible made possible by science. She called her way of thinking poetical science.[53]

As the kids say, rebel's gotta rebel.

All this made her uniquely (or even ideally) suited for Babbage's favor.

The Analytical Engine

In the business classic *Think and Grow Rich*, Napoleon Hill wrote, "Tell the world what you intend to do, but first show it." Thank goodness Charles Babbage did the opposite. While a functioning Analytical Engine existed only on paper, he toured the European continent explaining his conceptual design.

In 1840, he gave a lecture in Turin, Italy. An Italian military engineer in attendance took copious notes and published a paper detailing Babbage's design. Two years later, the Italian published *Notions sur la machine analytique de M. Charles Babbage* (written in French, for whatever reason).

Like many mad scientists and software developers too excited about their work to document it, Babbage had no detailed explanations about his ideas. They existed mostly in his head and on sheaves and sheaves of paper notes. He asked Ada, the

* See what I did there?

Countess of Lovelace, if she would be so kind as to translate them into English. She was, and she did.

Her translation, "Sketch of the Analytical Engine Invented by Charles Babbage by L.F. Menabrea of Turin, Officer of the Military Engineers. With Notes by the Translator," came out in 1843.[54] I wonder if Lovelace had any inkling of what her legacy would be. You see, in her mere "Notes by the Translator" she demonstrated how the Analytical Engine would work by detailing how to create a series of punch cards to calculate the Bernoulli numbers (a math problem that had interested Pythagoras of Pythagorean Theorem fame as well as Archimedes, the inventor of Archimedes screw).

That is, Lovelace wrote a program to calculate logical functions for a machine that did not exist. She wrote the world's first computer program before the invention of computers.

As an example of her poetical approach to science, she described Babbage's invention as, "We may say most aptly that the Analytical Engine weaves algebraic patterns just as the Jacquard loom weaves flowers and leaves."[55]

(As a testament to Babbage's admiration of the Frenchman, Babbage had a fabric self-portrait of Jacquard woven by a Jacquard loom hanging on his wall.[56] That's even cooler than Elvis on velvet.)

Lovelace's paper earned her respect and admiration among her mostly male peers, and perhaps none more so than Babbage who named her his "enchantress of numbers."[57] At the end of the last chapter, I wrote that Lovelace was more of a visionary than Babbage. Whereas Babbage had originally imagined the Analytical Engine as his Difference Engine on steroids, Lovelace saw a machine that could do far more. That's why her program to

analyze Bernoulli's numbers was so groundbreaking: It demonstrated the invention's potential far beyond mere number crunching.

In remarking on his great invention, he said, "…it could do everything but compose country dances."[58] (Ironically, the Analytical Engine's great-great-great-grandbaby ChatGPT can indeed compose a country dance.) More poetically, but more importantly more presciently, Lovelace mused in her notes whether Babbage's machine "might act upon other things besides number… the Engine might compose elaborate and scientific pieces of music of any degree of complexity or extent."[59]

How right she was.

History With and Without Lovelace

As with the Difference Engine, due to the technological limits of the day, Babbage never saw his dream of the Analytical Engine come to fruition. The inventor was ahead of his time. Too far ahead. As one of his spiritual successors (Vannevar Bush, who you'll meet in a chapter to come) would years later write,

> *Babbage, even with remarkably generous support for his time, could not produce his great arithmetical machine. His idea was sound enough, but construction and maintenance costs were then too heavy. Had a Pharaoh been given detailed and explicit designs of an automobile, and had he understood them completely, it would have taxed the resources of his kingdom to have fashioned the thousands of parts for a single car, and that car would have broken down on the first trip to Giza.*[60]

Babbage died "disappointed and embittered…frustrated over the failure to complete this project."[61] He and Lovelace did not toil in vain, however. Though it would take another century of progress, the Analytical Engine would eventually come into being, thanks in large part to Claude Shannon's designs for electrical circuits.[*]

But once computers were invented, we began to ask, "Can it think?" In 1953, an IBM engineer named Arthur Samuel wrote an article, "Computing Bit by Bit, or Digital Computers Made Easy." In it, he quoted Ada Lovelace's notes where she wrote,

> *The Analytical Engine has no pretensions whatever to originate anything. 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 revelations or truths. Its province is to assist us in making available what we are already acquainted with.*[62]

In other words, no, it cannot think.

After quoting the Enchantress of Numbers, Samuel then wrote,

> *We will start then by considering a digital computer as being merely an information processing device. This is the only thing that the computer does. It cannot create any new information not contained in the original source, although it may transform the input information into a very much more useful form. …The digital computer can and does relieve man of much of the burdensome detail of numerical calculations and of related*

[*] Read his story in Chapter 8.

> *logical operations, but perhaps it is more a matter of definition than of fact as to whether this constitutes thinking.*[63]

Neither the Engine in *Gulliver's Travels* nor Babbage's Analytical Engine were capable of original thought. Both simply combined their respective inputs (words in one case and algebraic logic in the other) to output things that made sense to the humans turning the cranks. In short, the predecessors of AI, both fictional and factual, were great tools. But merely tools.

Then again, can a submarine swim?

The more important question I put to you is this: How different would history be if Ada Lovelace had not been a rebel? She defied not only societal norms but incited her mother's fury. As one writer put it,

> *Ada's education was also designed to mold her moral character. She was made to feel that any natural childish tendency to question, test or rebel was a sign of the immorality of her father. She grew to be supersensitive towards these "faults" as she tried to win her mother's love and approval. …However, if the desire to please failed, there were always "the furies"…a close and loyal band of her mother's friends who dutifully and gleefully reported any hint of Byronic temperament to Lady Byron.*[64]

There's no question Charles Babbage invented the Analytical Engine. But for Ada Lovelace's translation and notes, would their intellectual successors have had the concepts and guiding light to invent computers? I certainly doubt Babbage would have taken the time to document his work. I am fairly certain he would not have taken the time to create a hypothetical punch card program

that showed others how such a machine could do more than crunch numbers. All of that credit goes to his assistant and, if we're being fair, truly his intellectual partner. Imagine a world where Ada Lovelace had lived a conventional life acceptable to polite society. No Lovelace rebel, no computers. No computers, no AI.

Curiously, the next rebel in the story of how we got machines to think is another misunderstood and underappreciated Brit. In 2023, the UK's defense secretary testified in Parliament that our rebel "was probably the greatest hero of the Second World War," and probably the greatest rebel in this book. The parliamentary testimony continued, "His achievements shortened the war, saved thousands of lives, and helped to defeat the Nazis. The story of how society treated him is a sad one."[65]

Referring, of course, to the hero's punishment for the crime of being gay.

5 | The OG of AI

Alan Turing

"Do you know, this morning…I was on a train that went through a city that wouldn't exist if it wasn't for you. I bought a ticket from a man who would likely be dead if it wasn't for you. I read up on my work…a whole field of scientific inquiry that only exists because of you. Now, if you wish you could have been normal…I can promise you I do not. The world is an infinitely better place precisely because you weren't."

—the 2014 movie *The Imitation Game*

Alan Turing was a hero.

He was also an ass.

He did not have time for people incompetent, ignorant, or of inferior intelligence. He was more than brutally honest and blunt. He outright berated his peers, his superiors, and those who worked for him. He had little regard for authority and structure, once bypassing his boss—UK's spymaster, the head of MI6—to

inform Prime Minister Churchill that his project needed more money and manpower. (Churchill immediately approved additional funds and people.)

While eating lunch in the cafeteria at Bell Labs, an eyewitness account once overheard Turing. His account of the incident reads:

> *His high-pitched voice already stood out above the general murmur of well-behaved junior executives grooming themselves for promotion with the Bell corporation. Then he was suddenly heard to say, "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."*[66]

Recall that Bell Labs was owned by AT&T.

The only real reason people put up with Turing is because he was brilliant. An absolute, bona fide genius. An outcast by choice and a misfit by nature who lived at precisely the moment the free world needed him most. As is so often the case in history, the legend of Alan Turing started with serendipity.

In this case, a mix-up in the mail.

Polish Codebreakers

An acquaintance of mine got an odd phone call from her sister-in-law one December. After exchanging some pleasantries, the sister-in-law said, "Julia, I got your Christmas card, and thank you, but…you know Carl and I got divorced this year, right?"

Julia said, "Ruth Ann, what are you talking about? I haven't even sent out my Christmas cards yet. I was planning on mailing them next week."

After a little back and forth and finally reading the postmark, the two women figured it out: Ruth Ann had received the Christmas card Julia mailed from the Christmas before. For nearly twelve months, Julia's card to the then-married couple had laid around somewhere before a postal worker discovered it and quietly slipped it back into the machine that is government efficiency. I get frustrated when UPS messes up my Amazon delivery but thank goodness this type of thing happens.

Otherwise, I'd be speaking German right now.

You see, in 1929, a Polish customs agent got an unusual request from the German embassy. A rather heavy crate sitting in customs had been mistakenly shipped to Poland, and German officials wanted it returned. Posthaste. The embassy's urgency aroused the customs agent's suspicions. Upon opening the crate, he found a complex machine that resembled the lovechild of a grandfather clock and a heavyset typewriter. Rightly suspecting something was up, the agent passed the crate up his chain of command. He had stumbled upon the Enigma machine, the device Nazi Germany used to encode top-secret communications, especially for its military.

Maybe they didn't think the Poles were smart enough to crack it. Maybe they felt confident they could innovate faster than the Poles could keep up. (Or did the Nazis even know the enemy had gotten ahold of their machine? More likely, the guys who screwed up kept it quiet for fear of being sent to the Russian front.) For whatever reason, the Nazis kept using the Enigma codes. If they

knew about the mail mix-up, the Germans had some grounds for their arrogance. Polish intelligence did finally break the code in 1932—thanks to the efforts of Marian Rejewski, Jerzy Różycki, and Henryk Zygalski—but by then, German intelligence had made several advancements to the encryption device.[67]

By 1939 (while Americans were oohing and aahing over Elektro), the Polish government knew Hitler was preparing to invade. About five weeks before exactly that happened, its intelligence agents met with their British and French counterparts in Warsaw and pushed all their Engima research and know-how into grateful hands.[68] They knew their government wouldn't survive the invasion. Perhaps the very agents themselves might not live long enough to see their cryptologists break the new Enigma codes. Hopefully, their allies could.

But the Germans were years ahead.

The Allies did not have years to catch up.

007's HQ

Fortunately, Admiral Sir Hugh Sinclair—the head of MI6* and the very same spymaster Alan Turing would one day circumvent to address Churchill himself—foresaw Germany's aggression and made preparations. In the spring of 1938, Sinclair used his own money to buy a 58-acre, 800-year-old estate about 50 miles northwest of London. Unlike many of London's rich citizens, he didn't intend to flee to his country estate when the Germans inevitably began bombing the city. He didn't buy the property to

* At that time called the Secret Intelligence Service.

escape the war. Quite the opposite. He brought the war to his estate.

The following year when British intelligence got their hands on the Enigma machine and the decryption codes, Sinclair put the estate to its intended use: a secret base for British spies. Seriously, this is James Bond-level stuff. Sinclair was a real-life M* who immediately recruited or assigned cryptologists, intelligence agents, and a small army of support staff all devoted to breaking German codes.

I am, of course, talking about Bletchley Park, perhaps the single most important piece of real estate in the entire Second World War. Were it not for the groundbreaking work accomplished by MI6 in secret there, some historians say the war would have lasted years longer. Other historians doubt the Allies would have won at all.

Bletchley Park was a team effort. *The Imitation Game* (the movie starring Benedict Cumberbatch as Alan Turing) covers a handful of the incredible people who contributed to the work there, including Joan Clarke (played by Keira Knightley) and the group from the Women's Royal Navy Service (the WRNS or "Wrens" who did most of the number crunching, functioning much like the women in *Hidden Figures* at NASA twenty years later). But there is no debate the site's wunderkind was Turing.

In fact, the British mathematician had been on Sinclair's radar for years.

* Of course, we all know the only real M is Dame Judi Dench.

Replacing Computers with Computers

Turing's destiny began to take shape in 1935 when he attended a lecture about a supposedly unsolvable algorithm.[69] The twenty-seven-year-old man who already had a reputation as a promising mathematician at Cambridge took it upon himself to prove a point. Not that the lecturer was wrong about its solvability. He set about to prove no such algorithm could even exist. (These types of things did not earn him any friends.) He wrote a paper about it named "Computable Numbers." Forget about the algorithm. It's unimportant. Like Ada Lovelace's "Notes," the paper's true worth came from a detailed thought experiment.

Turing took the reader through the human process of computing. At that time, a "computer" was a person who literally computed numbers, ex. the Wrens at Bletchley Park and the future "hidden figures" at NASA*. Turing showed how stripping a mathematical logic function (à la Boolean algebra) down to its essential elements could almost entirely remove the need for a human being altogether. Computing numbers could be done automatically with a machine.

Not one much for flair, Turing called his proposed device an automatic machine or simply *a*-machines.[70] Later, people would call them Turing or Turing-complete machines. Today, you and I simply call them computers.

In setting out to prove an algorithm unsolvable, he inadvertently gifted the world the "mathematical model of an all-purpose computer."[71] Babbage's first invention (the Difference

* Technically, the women were at the research center in Virginia, but you get the point.

Engine) was a glorified abacus. With the Analytical Engine, Babbage tried to invent a machine that could, for all intents and purposes, perform analytical reasoning. To *think*. Turing's "all-purpose computer" gave us the design for a machine that could do just that.

Turing wasn't the only person to pick up where Babbage left off. Others had tried their hand at creating computing machines over the intervening years. But they all approached the problem the same way Babbage did. They thought computing machines required three distinct elements:

- the machine itself: the mechanical device that turned the gears, rotors, and whatever else it took (what we today call hardware)
- the logical instructions: the punch cards detailing which numbers to use when (what we call software)
- the numerical input: the punch cards representing the numbers needed to be crunched (what we call data)

Turing's design combined all three elements into one machine. Whereas other computing machines could be built for one—and only one—purpose, Turing's *a*-machine could be used for any purpose. For instance, in 1890, the US used a Hollerith Tabulating Machine to run the data for the census. That's the only thing the machine could do: crunch census numbers to output census results. The theoretical Turing machine could run census data on Monday and then tabulate ballistics test results on Tuesday. His

concept was earth-shattering. Or, at least, it would have been if Turing had invented it instead of just writing about it.

But he kept writing. The same year he published "Computable Numbers," he made the unconventional decision (at least, for British mathematicians at the time) to seek his PhD. Even more unusual, Turing decided to do so in the ungrateful former colonies now called the United States.

Princeton University awarded him a two-year fellowship. In his dissertation, Turing took his fictional machine to the next level. The Turing machine 2.0 could perform dynamic problem-solving. His original design treated a computation as a pre-determined problem. You ran the numbers and it spit out the answers. (Again, on paper. He never built it in real life.) His new theoretical design allowed for complexity, a machine that could stop, assess, and adapt. (We now call this a universal computer.) While his first go at *a*-machines was staggering, this kind of ability was mind-boggling.

Pretend you had an autonomous vehicle (AV). You programmed it to drive you to your favorite coffeehouse. Your car uses its pre-programmed map to plot its course and starts rolling. In following its pre-determined route, your car drives you straight through a roadblock and into the raging river that washed the bridge away last night. That's an AV that couldn't stop, assess, and adapt.

Not content with merely hypothesizing about an *a*-machine, Turing got access to Princeton's physics department and proceeded to build several of its working parts. During his time at the university, Turing almost certainly rubbed shoulders with many of the great scientists fleeing Nazi Germany in the 1930s,

including Albert Einstein and John von Neumann (who came to be quite an influence on Turing and vice versa).

But his fellowship ran out in 1938, and he came back across the pond to Cambridge. Around this time, MI6 had put together a list of potential codebreakers to recruit when and if war broke out. Even before the *blitzkrieg*, in 1939 the intelligence service approached Turing and put him through a crash course in the Enigma machine and the Polish decryption device, lovingly called a bomb.[72]

The Bombe

Why had the Poles named their mechanical codebreaking device a bomb (*bombe* in Polish)? Because after doing a run, the machine sounded like an explosion: "When a possible solution was reached a part would fall off the machine onto the floor with a loud noise. Hence the name…"[73] Those at Bletchley Park anglicized the word into "bomba."

On September 1, mere months after Turing's introduction to the *bombe*, Hitler invaded Poland. On September 4, Turing reported to Bletchley Park. His superiors assigned him to submarines.

Germany not only continued to make new and better versions of the Enigma machine after that mail mix-up. It made new and different versions. Either from the Poles or through their own efforts, the Brits had gotten their hands on the version that encoded messages between the German naval high command and the dreaded U-boats (short for underwater boats; seems whoever named them had the same flair Turing did naming his *a*-machine).

You might recall a U-boat sank the British cruise liner the *Lusitania*, the event that began to shift US sentiment from its isolationist stance to bringing us into WWI. The threat was so great that, years later after WWII had been won, Winston Churchill wrote, "The only thing that really frightened me during the war was the U-boat peril." [74] To give you an idea of how complex Turing's task was, U-boats used an Engima version capable of something like 150 quintillion different codes.[75]

In January 1940, just four months after starting, Turing and his team broke it.[76]

In 1942, he sailed across the Atlantic to the US for primarily two reasons.[77] One was to review an invention at Bell Labs called SIGSALY, essentially a top-secret, ultra-secure telephone hotline between the US and UK governments.* Despite being invited by the US military, some bureaucrats were quite zealous in guarding the secret of its existence. It took the British head of the US-UK military task force writing a letter to the US Army's chief of staff to get Turing finally cleared. Turing's second reason was to help the Americans build their own bombas.

At some point on his ocean voyage home in March of 1943, Turing idly leafed through a catalog from the Radio Corporation of America. (Now RCA; you might remember their iconic logo of a terrier dog peering into the speaker of a phonograph.) As you might imagine, even during his work at Bletchley Park, he had continued working on his dream of a universal computer. He went so far as to create a chess program *for a computer that didn't exist* (just like Ada Lovelace did with her notes for the Analytical

* Fun fact: The eventual London terminal of SIGSALY wasn't installed at Downing Street or any of the government offices of Whitehall. It was too big. The Brits put it in the basement of Selfridges, an American department store on Oxford Street.

Engine). Turing called it Turochamp. Without a machine to run his program, he pitted Turochamp against a fellow chess player, simulating running the code by calculating all the commands by hand. (It's funny that this was for a machine designed to eliminate having to do this by hand. But I guess you gotta start somewhere.)

The RCA catalog clued him onto the idea of using radio vacuum tubes instead of mechanical gears. Previous research showed that vacuum tubes could perform basic logic switching at something approaching the speed of light. (Think about how quickly your lightbulb turns on when you flip the switch. Electricity was the perfect evolution for calculating zeroes and ones. An electrical circuit is either on or off. Yes or no. True or false.) The metal clinks and clacks of the bomba couldn't touch computing numerical logic functions at that speed. The implications intrigued Turing, since the faster the codebreakers could decrypt German messages, the more quickly they could get intelligence into military hands.

As soon as he got back to Bletchley Park—where he was still cracking new codes two years after breaking the Enigma encryption—he conferred with a mentor of his named Max Newman* and a telecommunications engineer with the British General Post Office named Tommy Flowers. Newman was a fellow codebreaker and Flowers had already experimented with vacuum tubes for telephone switching relays. Together, the three of them created Colossus, the world's first programmable electronic computer later that year.

But it wasn't the universal computer Turing had in mind. While impressive and even revolutionary, the Colossus was a

* Not to be confused with John von Neumann mentioned earlier.

special-purpose machine for decrypting another Nazi code (the Lorenz cipher). Unfortunately, because of Britain's Official Secrets Act, Turing couldn't tell anyone outside a tight circle what they'd invented.

Nevertheless, someone did take Turing's ideas, mixed them with others' work, and rushed to publish "his" invention. Churchill said history is written by the victors. It's certainly true here since Turing's designs are today referred to as von Neumann architecture, the basis for all the computers you and I have ever used.

No matter. Even without getting credit for that, Alan Turing's later work rightfully earned him the title the "father of artificial intelligence." In AI, his legacy is such that, unlike any other rebel in this book, he gets two chapters. But before we tell the rest of his tale, we have to pick up another thread about how Turing's ideas found their way to America and the Yanks' role in what was to come.

The dazzling story of how the US invented AI starts in a swamp.

6| A More Efficient Killing Machine

Pres Eckert & John Mauchly

"When we lived in Maryland, I would periodically hear the name of a place called the Aberdeen Proving Ground. One day as I was driving along near Aberdeen, I heard an explosion. I turned to the person next to me and said, 'Did you hear that?' The person just said, 'Oh, that's just the proving ground. They're testing weaponry there.' That is why Aberdeen Proving Ground exists. It is the place where the military services test-fire all kinds of explosives and where they test-run military machinery. It is a place to find out what works and what does not."

—James Swanson[78]

You have to be a little crazy to do a tech startup. I would know since I've been involved in or a founding partner of thirteen startups (and am currently mulling my fourteenth). My financial gamble paid off six times, more than covering my losses in the

other seven. It takes a certain type of insanity to imagine something that doesn't exist and say, "Yeah, I think I'll roll the dice."

That's how I know Pres Eckert and John Mauchly were my kind of crazy. Not only did they venture out on their own, but they founded the Eckert-Mauchly Computer Corporation in 1946.[79*] Computers had barely been invented. IBM wasn't touching them with a ten-foot pole. Nobody but Uncle Sam, massive corporations, and maybe the Rockefellers could even afford a computer. Venture capital didn't exist.

What were these guys smoking?

Most startups have to be scrappy. In my memoir, *Digital Confidential*†, I tell the story of how my friend Curtis Hill and I began Chainbridge Systems. At one point, we paid a developer in beer. We'd pick him up in the evenings with a twelve-pack of bud and he would code all night. Weirdly enough, the drunker he got, the better he got. He did his best work probably around 4 a.m.

Eckert and Mauchly were scrappy, too. For instance, their computing invention needed thousands of vacuum tubes to function. Smartly, they founded their company in Philadelphia, then known as Vacuum Tube Valley.[80] Even then, no manufacturer had vacuum tubes in the quantities they needed. They wound up using ten different types of tubes, twice as many as their design called for.[81] The pair were constantly scrounging, running from one supplier to another buying up vacuum tubes in lots of one thousand at a time. Manufacturers made enough to supply them, sure. But Eckert and Mauchly had to wait to get

* Technically, they founded the Electronic Control Corporation. The following year, they changed the name to the Eckert-Mauchly Computer Corporation in 1947.
† A couple of people have to die before I publish it.

their orders filled, standing in line behind the US Army. Ironically, the two were part of the very reason Uncle Sam needed thousands of vacuum tubes.

They had to feed the hungry machines at Aberdeen.

"Let's Blow Something Up and See If It Works!"

Sure, the military tested bombs in the deserts of New Mexico and California during WWII. However, the vast majority of weapons testing happened at Aberdeen Proving Ground. And, as of 1947, the site housed Eckert and Mauchly's crowning achievement, the ENIAC: the Electronic Numerical Integrator And Computer.[82] Why? Because the boys wanted to blow stuff up.

Like Bletchley Park, Aberdeen played a crucial role in winning WWII, but the two sites could not have been more different. Bletchley was a centuries-old aristocratic estate. Aberdeen was a mix of farmland, swamps, and marshland. Bletchley was bought by a private citizen, even though the head of MI6 used it exclusively for government intelligence work. Aberdeen was bought by the US government after a literal act of Congress and two presidential proclamations.[83] Bletchley consisted of 58 acres.[84] Aberdeen required the purchase of nearly 70,000 acres.[85] The work at Bletchley was carried out in top secret. The work at Aberdeen could be heard and felt for miles. The Brits' work at Bletchley centered on the "soft" side of war: information, intelligence, secrets, and psychology. The Americans' work at Aberdeen centered on the most obvious aspects of war: bullets and bombs.

After the US entered the First World War (in no small part due to the German U-boats), the US Army's chief of ordnance realized the military needed more room to test-fire tank shells, mortars, rockets, and the like. At that time, for its proving ground, the Army used a spit of land in Sandy Hook, New Jersey, about three miles square. The military needed more space. A *lot* more space. The site selection committee settled on an area over a hundred square miles on the upper part of the Chesapeake Bay, about halfway between Baltimore and Wilmington, Delaware, just outside the town of Aberdeen, Maryland. From the first test-fire on January 2, 1918,[86] the site has seen the testing of just about every type of projectile weapon imaginable, from pistols and rifles to rockets and tank cannons. It continues today as an active military weapons testing site.

Aberdeen did have one major thing in common with Bletchley Park, though. To produce military intelligence essential to winning WWII, both government facilities needed to process staggering amounts of data. The US Army needed to know where the bombs would land.

Going Ballistic with Bullets and Bombs

Think about the mental geometry a professional golfer does with every shot. Over thousands of swings, they trained themselves to account for all the variables. They know in any given situation which club to choose, how much force to apply, to factor in wind and humidity, how to take into account the distance and height differences from the tee to the hole, how their

body feels in that moment, and whether they packed their lucky underwear.

That's ballistics. On the frontlines in Europe and the Pacific seas, G.I. Joe needed a fast way to figure out how to shoot mortars, rockets, and bombs to land where he wanted them to. That's where ballistic firing tables came in. Each weapon had its very own set of tables (printed in a handy booklet for easy travel) with all the mathematical calculations pre-recorded.

> *Information about projectile trajectories, however accurately computed, had little direct value for the artilleryman in the field. What he needed was a firing table that showed the range to be expected for each gun and howitzer when it fired a specific projectile with a given propelling charge to any selected angle of elevation. The table also had to indicate the corrections to be applied for variations in atmospheric temperature, air density, wind, angle of site, weight of projectile, muzzle velocity, and compensation for drift, and in some cases, for the rotation of the earth.*[87]

Need to shoot a battleship six-and-a-half miles off the port bow? Grab a firing table. *Luftwaffe* pilots bearing down on your anti-aircraft guns? Where's the firing table? German Panzers rolling across the plain toward your fortification? Who's got the firing table!?

As you can imagine, ballistic firing tables required a lot of number crunching, including a lot of calculus. Much of these computations were done by human computers (like the women in *Hidden Figures* since NASA was also in the business of shooting bombs into the sky—except we called NASA's bombs "rocket

ships"). Aberdeen had an entire department devoted to this, the Ballistics Research Laboratory.

In 1934, an MIT researcher named Vannevar Bush designed on paper a mechanical computer that could solve differential equations. The machine could do calculus. In theory. A year later, Aberdeen's commanding officer approved funding its construction.[88] Called the Bush Differential Analyzer, its "success marked the beginning of the development of specialized computers for ballistic computations…"*[89]

As the 1930s progressed, with the looming threat of Nazi Germany, the military poured more money into weapons development and the necessary ballistics research to create the firing tables that would soon be needed on the battlefield. The Bush Differential Analyzer simply couldn't keep up with the demand. "Because this analysis was time-consuming, the [Ballistics Research] Laboratory kept a close eye on the development of new computing machines and obtained new equipment as it was released for use."[90]

Remember in the last chapter my mention of the Hollerith Tabulating Machine the government used for the 1890 national census? Over the next few decades, Mr. Hollerith's company would morph into International Business Machines or IBM. In 1941, Aberdeen bought two electromechanical punch-card machines from IBM.[91]

As the name implies, an electromechanical used some electronics but heavily relied on the same clunky gears and moving metal parts as its mechanical predecessors (like

* For my fellow Deming fans out there, Ed also used the Bush Differential Analyzer during his work with the US Census.

Hollerith's invention and the Bush Differential Analyzer). Over the next three years, researchers from Aberdeen worked closely with IBM designers to invent two electrical relay calculators that could compute numbers in a fraction of the time as the electromechanical calculators. Unfortunately, the

> *two IBM Relay Calculators were used for a short time but they were not successful. Two Bell [Labs] Relay Computers were used. They were accurate, but slow and required expert maintenance. …Once in a while, a dirty relay contact would cause a stoppage, for the Bell Computers would either run without error or not run at all.*

Neither IBM's devices nor those from Bell Labs could keep up. Aberdeen needed faster ways to crunch numbers.

The Computer, Brought to You by John von Neumann. Kind Of.

Vannevar Bush shared his machine's design freely. The University of Pennsylvania's Moore School of Electrical Engineering made its own version, then set about upgrading its components, turning their version of Vannevar's invention from purely mechanical to electromechanical.[92] The Ballistics Research Laboratory used this version so much it came to be called the Aberdeen Analyzer.[93] Later, when Aberdeen wanted a computer superior to those from IBM and Bell Labs, they naturally turned to the Moore School.

A professor of electrical engineering, Pres Eckert had gradually become more involved with the Aberdeen Analyzer early on. In an interview, he said,

> *My practical interest was to improve the analyzer. And I wasn't officially connected with it. I just sort of drifted in and had ideas and the guys in the shop would put them together and finally the professor who was in charge of the differential analyzer—Dr. Weygandt, who had been my teacher so I was on intimate terms with him—kept getting me in more and more until finally I ended up doing more and he was doing less of it.*[94]

In the summer of 1941, Eckert gave a class on defense technology and taught physics professor John Mauchly.[95] The two began to discuss an all-electric computer. In 1943, Aberdeen's military liaison at the Moore School (one Lieutenant Herman Goldstine, an Army reserve officer with a doctorate in mathematics) asked Eckert and Mauchly to put their concepts in a proposal to present to his superiors at the Ballistics Research Laboratory.[96] His boss ran it up the chain and soon the University of Pennsylvania had a check from the US Army for a six-month research project.

Four years later, the Army formally accepted delivery of the ENIAC.

Eckert and Mauchly had done it. They had created the world's first all-electronic, Turing-complete computer. It didn't go into operation until after the war ended but nevertheless fulfilled its purpose to drastically reduce the time necessary to compute ballistics firing solutions. Too bad Lt. Goldstine brought in an

accomplished mathematician toward the end of their project who was an even better glory hound.

The Army liaison had a chance meeting with math prodigy John von Neumann at a train station during the summer of 1944.[97] Von Neumann made quite the impression. (Though as Eckert would later say, "I know Goldstine was very impressed. [But] that was a kind of joke—that Goldstine was impressed with everybody all the time."[98]) The officer invited von Neumann to join the ENIAC project. By that time, though, its design was well on its way to being finished. Eckert and Mauchly had already begun designing its successor, the Electronic Discrete Variable Automatic Computer, or EDVAC.

Von Neumann began taking notes. Copious notes. The next year, he published a paper, *First Draft of a Report on the EDVAC*. In a shrewd bit of self-branding, he omitted Eckert's and Mauchly's names. The paper made von Neumann look as if he were the EDVAC's principal designer, essentially stamping his name on the invention.

Eckert would later remark,

> *I didn't know he was going to go out and more or less claim it as his own. He not only did that, but he did it at the time when the material was classified, and I was not allowed to go out and make speeches about it. And he went out and made them anyway without clearance and got out of it because nobody wanted to come down with the Espionage Act on a prestigious guy. If I had done it, they would have come down on me with a ton of bricks.*

[…] You know, we finally regarded von Neumann as a huckster of other people's ideas with Goldstine as his principal mission salesman.

[…] Von Neumann was stealing ideas and trying to pretend work done at the Moore School was work he had done.[99]

Von Neumann's *First Draft* had few external references but one of those few was mentioned numerous times, a 1943 paper by two MIT researchers named Warren McCulloch and Walter Pitts. In their paper, they provided a mathematical theory of how the human brain works, specifically mentioning neurons. The paper by McCulloch and Pitts had only one reference—Alan Turing's "Computable Numbers."

To give von Neumann credit, he did draw a dotted line back to the two MIT researchers, McCulloch and Pitts. As you'll see in Part III: AI Can Learn!, McCulloch and Pitts are responsible for the concept of neural networks (the kind of AI that led to ChatGPT). As such, you can trace that dotted line all the way to Turing. In our research, we had to turn those dotted lines into solid ones. Ergo, Turing directly influenced Eckert and Mauchly which led to them inventing the EDVAC for which von Neumann architecture is named.

A historical account of Aberdeen (from a book named *Ballisticians of Aberdeen*) said of the MIT researchers' work, "...the article's authors"—McCulloch and Pitts—"take the trouble to demonstrate that a universal Turing machine can be modeled using their idealized neurons and cite this fact as the principal reason for believing that their work is on the right track."[100]

It's curious that von Neumann didn't mention Alan Turing at all seeing as how the two men knew each quite well. I mentioned earlier that when Turing pursued his PhD at Princeton he almost certainly rubbed shoulders with the likes of Albert Einstein and John von Neumann. We know the latter for a fact. Before Turing's second year at Princeton, he applied for a fellowship to supplement his meager stipend from Cambridge. John von Neumann wrote a letter of recommendation on Turing's behalf. It included the lines,

> *I should like to support his application and to inform you that I know Mr. Turing very well from previous years: during the last term of 1935, when I was a visiting professor in Cambridge, and during 1936–1937, which year Mr. Turing has spent in Princeton, I had opportunity to observe his scientific work.*[101]

Now, put that together with the fact that, later in life, Goldstine noted that Eckert and Mauchly focused chiefly on the technological aspects of the EDVAC, whereas for von Neumann: "…after his arrival he took over leadership on the *logical* problems."[102] In so many words, the liaison officer says that the Moore School duo invented the machine while von Neumann was the ideas guy.

But as one scholar put it, "John von Neumann was a vain and brilliant man, well used to putting his stamp on a mathematical subject by sheer force of intellect."[103] We've already seen that he had no qualms stealing the limelight from Eckert and Mauchly. It doesn't seem like much of a stretch to me that he would do the same with Turing. Whatever the case, all digital computers today

are based on the designs of the ENIAC and EDVAC…a.k.a. von Neumann architecture.

Later the same year *First Draft* came out, Eckert and Mauchly quit the University of Pennsylvania to found Eckert-Mauchly Computer Corporation. (Fun fact: In 1949, they hired Grace Hopper, the brilliant Navy reservist who invented COBOL, a way to program computers in English instead of Boolean logic symbols.[104]) They sold the company in 1950 and stayed on, overseeing their patented design for the EDVAC II system (later renamed UNIVAC*) which was sold to the US Census Bureau, US Air Force, US Navy, Atomic Energy Commission, US Steel, and Consolidated Edison, among others, lighting the way for all the computer technology advances to follow.[105]

Eckert and Mauchly did much of the work bridging the computer divide between academia and business. If they hadn't been crazy enough to launch a tech startup, would the US and the rest of the world have adopted computers as quickly as we did? Or would it have taken years longer? If so, how much longer would it have taken ChatGPT to launch and bring AI into the mainstream?

With the so-called von Neumann architecture, modern computing (the bedrock on which modern AI rests) would not exist. Few people, however, come across the rebels Pres Eckhart and John Mauchly when tracing AI to its early roots.

* The UNIVAC was primarily intended for government and business use (as opposed to its predecessor expressly designed for the military).

7 | Science: The Final Frontier

Vannevar Bush

> *"Of the men whose death in the Summer of 1940 would have been the greatest calamity for America, the President is first, and Dr. Bush would be second or third."*
>
> —Alfred Loomis, National Defense Research Committee[106]

Fortune favors the bold.

Alan Turing went over his boss's head to contact Churchill directly. The prime minister immediately approved the request and sent a handwritten note to his chief military advisor. Turing got what he asked and would go on to make a dent in the universe.

Just a few years before, a man named Vannevar Bush went over the US Congress's collective heads to meet with President Franklin Roosevelt directly. He presented FDR with a one-page proposal to fund a national research committee to coordinate academic and military research. The president scrawled "OK–FDR" across the piece of paper.[107] Vannevar got what he asked

and made a dent in the universe…although his carried a considerably bigger bang.

OK–FDR. Five letters still echoing across time and space. With it, FDR funded the creation of the National Research Defense Committee which would morph into the Office of Scientific Research and Development (OSRD). The organization provided the funds and direction to invent or advance numerous technologies, including radar, sonar and submarine warfare, rockets and jets, proximity fuses, mass production of penicillin and other life-saving drugs, synthetic rubber, and bombs. Lots and lots of bombs. Including the one created by the OSRD's crown jewel, the Manhattan Project.

If any one person could be credited with creating the military-industrial complex, it's Vannevar Bush. As I mentioned in the chapter on Charles Babbage, the US military played an essential role in developing AI over and over again through what is essentially the Pentagon's investment arm, DARPA (the Defense Advanced Research Projects Agency). It works as a sort of venture capital group to fund "blue sky" (or some might say "pie in the sky") technologies that seem impossible and coordinate the efforts of the military, academia, and private industry. Surely, it's Vannevar's role as the original architect of the military-industrial complex that earned him a place in our pantheon of rebels who gave us AI…right?

No. Vannevar's legacy (as far as our story is concerned) stems from his time not as a shadowy figure lurking in the hallways of power but as a teacher, engineer, and advocate for science and scientists.

Computer Inventor and Visionary

Vannevar Bush was first and foremost an inventor-entrepreneur. At just 29, he spearheaded the creation of Sperry Thermostat Company which soon had over a million dollars in annual revenue. [108] At 32, he founded what would become Raytheon (now a major US defense contractor).[109] Between the two, Vannevar was set for life. Where some people would have put their money in the bank and called it a day, his fortune merely enabled him to pursue science as he saw fit.

You're already familiar with him as the inventor of the Bush Differential Analyzer. The calculus-crunching computing machine processed data in hours what would have taken an army of human computers days. The ballistics firing tables the Allies used in France, Germany, Guam, Iwo Jima, Tunisia, and Burma allowed for who knows how many victories? The Analyzer directly inspired the ENIAC, leading to the advent of modern computers. But like Lovelace, Vannevar saw a vision of what could be…and, as history would one day vindicate, what was to come.

In 1945, *The Atlantic* published an article by Vannevar, "As We May Think." He wrote about an idea of his for a device called the memory expander (or Memex). The man was an absolute genius. In one article, Vannevar outlines what you and I would recognize today as personal computing, the internet, hyperlinks/hypertext, voice-to-text, natural language processing, electronic file storage and archiving, document scanners, mobile image capture, computer screens, computer keyboards, and search indexes/engines.

Vannevar's article influenced one of the fathers of personal computing, Doug Engelbart[110]; the guy who coined "hypertext," Ted Nelson[111]; and MIT professor Tim Berners-Lee (the man who invented the World Wide Web)[112]. Vannevar was a man far ahead of his time—not unlike Charles Babbage. In fact, it was Vannevar Bush's words you read earlier:

> *Babbage, even with remarkably generous support for his time, could not produce his great arithmetical machine. His idea was sound enough, but construction and maintenance costs were then too heavy. Had a Pharaoh been given detailed and explicit designs of an automobile, and had he understood them completely, it would have taxed the resources of his kingdom to have fashioned the thousands of parts for a single car, and that car would have broken down on the first trip to Giza.*[113]

Fortunately for Vannevar, technological progress would continue accelerating, allowing him to see much of his vision come into being before his death in 1974.[114] But don't think we're finished examining his impact on AI.

Vannevar's Gift to AI

After the war, Vannevar joined the other father of the atomic bomb, Robert Oppenheimer, to lobby against further development of weapons of mass destruction, especially the hydrogen bomb. Vannevar was also a strong advocate for the government's continued support of the sciences.

The same month his Memex article came out in *The Atlantic*, Vannevar released a paper he'd written at the request of FDR

called “Science: The Endless Frontier.” In it, he proposed a vision for post-war government support of academic research. He argued the need to fund basic research (and not only the research that had immediate application, like computers to calculate missile trajectories), funding peer review (a hallmark of serious scientific inquiry), and a separation of government direction and meddling in academics. That is, Vannevar was trying to dismantle the military-industrial complex. His efforts culminated in the creation of the National Science Foundation, the independent government agency that funds billions of dollars in academic research and development to this day. As you might already know, the military-industrial complex's integration continued unabated.

Vannevar Bush deserves to be listed as a rebel of reason because of his sheer tenacity. Unlike the sycophants and yes-men who surround DC politicians, Vannevar stood out. He made some shrewd political connections (which is how he got in front of FDR in the first place), but he made loads of enemies along the way. After the president died, Vannevar’s influence waned. But no matter who was with him or against him, he pursued and often persevered in his vision of the role of science before, during, and after WWII.

Without Vannevar, DARPA isn't created. And without DARPA, the history of AI looks quite different than it does today. He played a major role in orchestrating the scientists, inventors, military, government agencies, and private contractors whose efforts created the foundations of AI.

Without discounting any of the man’s accomplishments and achievements, Vannevar's greatest legacy may not have been

anything I've just related. His most important influence (again, as far as how we got to ChatGPT) may have been in his MIT classes on Boolean algebra and circuit theory for one graduate student in particular. He worked alongside Vannevar on the Differential Analyzer and wrote his thesis on using Boolean logic to simplify electrical relay switching.

I'm talking, of course, about the father of the Information Age.

8 | The Whimsical Rebel

Claude Shannon

"I've spent lots of time on totally useless things."

—Dr. Claude Shannon[115]

Picture it. Bell Labs. 1945.

Japan has surrendered. Europe lies in ruin. Men in Oxford wingtip shoes and bland suits fill the rooms and hallways of 463 West Street in Manhattan overlooking the Hudson River. This 13-story building houses the best and brightest America has to offer. The scientists, engineers, and inventors here created the technologies that won the war and forever reshaped the story of humankind.

You are a visitor, following a colleague as he tours you through the facility. The weight and importance of the building's past and present feel almost tangible. The scientific and technological innovations, breakthroughs, and discoveries that have occurred at this very address are legendary, from

telecommunications to anti-aircraft guns. You marvel in its august greatness.

As you turn a corner, your mind tries to comprehend the spectacle before you. In the midst of the beige and gray suits and sea of dark fedoras, a man's head pokes up above the crowd in the corridor. People around him quickly give him a wide berth as he rapidly speeds through them. He passes and you finally get your first full glimpse of the person.

Is that…a unicycle? Is the man pedaling down the halls of Bell Labs on a unicycle…while *juggling!?* Bewildered, you look to your tour guide for some kind of explanation. Does Bell Labs also house a psychiatric facility? Is the circus missing a clown? What just happened!?

Your fellow scientist shrugs his shoulders and provides a one-word explanation as if it contained not only the answer but all the context you would ever need to understand what you've just witnessed.

"Shannon."

The SpaceX of 1940

I silently prayed. *Oh, Lord, hear my cry. Please don't let my son screw this up.*

My thirteen-year-old and I were at a DevOps conference in LA. Talking to us was a friend of mine, Matt Simmons. Matt had loved rockets and orbital trajectories as a kid. When he had the opportunity to become a sysadmin for SpaceX, he jumped at the chance. The moment before my fervent plea, Matt had asked my son, "So, Daniel, what are you guys doing tonight?"

If he's going to ask what I think he's going to ask, please God, let Daniel say we're not doing anything. Please don't let his teenage brain get in the way. I held my breath for a moment.

To my everlasting satisfaction, my son said, "Nothing."

Matt smiled. "Would you like to get a tour of the SpaceX plant?"

Why, yes. Yes, we would.

SpaceX doesn't give tours, but Matt himself acted as our tour guide that night. We walked through the plant as he pointed out the half dozen or so different rockets they were working on. He spent an enormous amount of time explaining literal rocket science to Daniel. You could feel his excitement and passion. He wasn't only a systems administrator—he was part of the team on a mission to colonize Mars. What a place to work!

I imagine that's how it felt for those working throughout the history of Bell Labs. What a storied R&D organization. The former research arm of AT&T gave us Elektro, solar panels, lasers, Unix operating systems, statistical quality control, C programming language, radio astronomy, and too many other inventions to name. It played a key role in the development of so many of the technologies we take for granted today, from transatlantic cables and movies with sound to TV satellite broadcasts and virtually every computer you've ever used. Oh, and the atom bomb: More than a few things from Bell Labs found their way into the Manhattan Project.

It also played a key role in winning World War II. In September of 1940 (when the US was still neutral), the UK sent a secret delegation to the Yanks to exchange research. A British scientist named Henry Tizard had spearheaded the development

of radar. Before this invention, you wouldn't know if a Nazi *Luftwaffe* bomber was flying overhead until you heard the bomb falling. To have even a few minutes' warning saved countless lives.

But Tizard's radar was ground-based. The Allies needed radar they could mount on ships and aircraft. Tizard thought looping the Americans in couldn't hurt. So, he headed what has come to be known as the Tizard Mission. They met with the head of the Office of Scientific Research and Development, none other than Vannevar Bush.

The Brits turned over a complete resonant cavity magnetron, the basis for radar technology. Before this, a researcher at Bell Labs, Arthur Samuel (the computer scientist we quoted in the Ada Lovelace chapter), had designed a magnetron on paper as early as 1934, but the Brits made the important breakthroughs.[116] As Samuel would later say, "How it is possible to be within gunshot, as it were, of a really good idea and yet to quite miss the boat, if you will allow me to mix my metaphors."[117] Bell Labs was tasked with the research and development of smaller radar systems that could be feasibly manufactured for use by the navy and air forces. The lab did not disappoint. The resulting inventions from those researchers (including Arthur Samuel) gave us anti-aircraft and even anti-submarine radars.

But its shining star was the juggling cyclist, Claude Shannon.

Turing Tours Bell Labs

Claude Shannon's name towers above virtually all others in the history of computer science. Like Turing, he made his mark

before even finishing his graduate degree. In his 1937 thesis, *A Symbolic Analysis of Relay and Switching Circuits*, he laid the foundational framework for digital circuits.[118]

We've discussed a couple of times the conceptual symmetry between Boolean algebra (ones and zeroes) and electricity (on or off). Well, it was Shannon who made the connection. He's the one who took a mathematical idea and applied it to the engineering problem of creating a better computer. If Turing invented the alphabet, Shannon invented the printing press. It was a stroke of genius.

After simultaneously earning his master's and doctorate at MIT in 1940[119], he went to work at Bell Labs. The nation's premier R&D facility hired the electrical engineer and mathematician to work on—drum roll, please…codebreaking. His brilliance there earned him eternal recognition in another field, being dubbed the founding father of cryptography.[120] One among the many projects Shannon worked on included SIGSALY, the hotline between FDR and Churchill I mentioned earlier. (Technically, the US terminal was in the Pentagon with an extension to the Oval Office. Technically, the UK terminal was in the basement of Selfridges department store. Technically, details generally muddy otherwise pretty cool stories.)

Now, recall that in 1942, Alan Turing steamed across the Atlantic Ocean to review the encrypted hotline setup (ultimately giving it his endorsement) and to help the Americans construct our own bombas to decipher Nazi military communications. He

specifically sailed to New York City and reported to Bell Labs at 463 West Street.*

While it seems implausible that Shannon's superiors had not planned for the two mathematicians and leading cryptanalysts to work together, I cannot find any information to support what would otherwise be an intuitive assumption. I would bet my life on the fact that they knew of each other, not only because they were leading mathematicians of the time but also because they danced around some of the very same concepts. As crazy as it sounds, the two only met because they took tea at the same time in the Bell Labs cafeteria.[121] If one of them had taken their tea at a different time, these two intellectual legends would have never met.

(This would have been the same cafeteria† where Turing was overheard to say, "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."[122] I wonder if this was during a conversation with Shannon?)

I don't think it's a coincidence that once Turing got home, he was inspired to build the Colossus computer with Max Newman and telephone engineer Tommy Flowers. I am reasonably sure some part of it was catalyzed by his discussions with his American counterpart.

In 1948, Shannon published the Magna Carta of the information age, as *Scientific American* dubbed his paper "A

* See my blog post about 463 West Street here: https://www.profound-deming.com/blog-1/463-west-street-a-place-of-modern-technological-innovation

† And the same cafeteria Deming passed through on his many trips to collaborate with another fabled Bell Labs employee, Walter Shewhart.

Mathematical Theory of Communication."[123] As I sit here in front of my laptop screen connected to the global telecommunication network that is the internet, while my iPhone is constantly pinging and ringing, I cannot overstate the profound importance of his paper. It is the reason the world looks like it does today.

No book tracing ChatGPT back to its ancestry could do justice without recognizing Claude Shannon. He was the midwife of the Information Age, the Digital Age, or whatever else historians want to call the incredible period of time that spanned the second half of the last century. The man deserves volumes written about him.

But for the purposes of AI, I'd like to call your attention to his toys.

The Magic Mouse in a Metal Maze

The man invented a trumpet flamethrower and a Frisbee rocket.[124] A motorized pogo stick and a juggling machine.[125] The Ultimate Machine: a box with a switch to activate a hand that reached out and turned itself off.[126]

For Christmas in 1949, his wife gave him an Erectors toy set.* "In short order he had built a mechanical turtle with an antenna, which would run around a room and back away after encountering obstacles."[127] If he could have attached a vacuum cleaner, maybe we could have had Roombas back in the 1950s!

Charles Babbage wasn't the only inventor inspired by the Mechanical Turk. Claude Shannon's wife said he was, too. Between the Turk and his turtle, Shannon conceived an idea in

* Technically, a Meccano toy set but marketed in the US as Erectors.

1950 to build Theseus, a metal mouse in a maze.[128] On the surface, the metal mouse on wheels would wander around a reconfigurable metal maze. Like modern Roombas, the mouse would learn the layout. Eventually, you could turn it on and watch as it went right to the bronze cheese. Underneath the table were a series of telephone relay switches. Using Boolean logic, Shannon designed a logic system that could "remember" the layout of each new maze.

He could pick up the mouse at any point, put it anywhere in the maze, and it would unerringly navigate back to the magnetic cheese. If he reconfigured part of the maze, the mouse would map the new sections against the old, essentially updating itself on the changes. If he changed the maze entirely, the mouse would teach itself the whole new layout. Of course, it wasn't really the mouse itself. That was just a magnetic prop. The "brains" resided in the telephone switches powering the whole show. Historians point to Theseus as one of the world's first real AIs. But Shannon's point wasn't that he could teach what looked like a wind-up toy.

He had created an artificial machine that could think for itself.

As you might imagine, the world was floored. What a time to be alive. But yet again, we have the Elektro Effect. To the observer, Theseus looked like magic. A marvel of modern science. But the technology wasn't all that impressive. When one of the mouse's copper whiskers touched a metal wall, it completed an electrical circuit. The electrical current would flip the corresponding relay switch to the "off" position. The mouse would reorient itself and move forward again. At some point, it bumped into enough walls to turn off enough switches. The only switches left were, by default, the paths that didn't have any walls. It kept going

forward until it hit something, then said to itself, "Oh, I can't go that way. Guess I'll try another." Once again, not magic. Just a bunch of on-off switches. And yet…it *was* artificial intelligence.

Shannon embodies the ethos of our rebels of reason. Emphasis on *reason*. He wasn't a rebel without a cause. He was an intellectual giant who put his mind to good use designing and inventing machines that approximated human (or at least mammalian) reasoning.

Funnily enough, the same year Shannon invented his AI mouse, Alan Turing published a thought experiment in a paper that has since earned him the title "father of AI." That's right. We're going back across the Atlantic again to pick up almost where we left off on Alan Turing's story from Chapter 5. Let's skip the rest of the story where Turing saved the free world (watch *The Imitation Game* for that) and start with his colleague bringing Turing an exciting original paper recently published by an old friend, John von Neumann.

Knowing what you do now, can you imagine how Turing felt reading it?

9 | Prove You're Not a Robot

Alan Turing (again)

> *"Neither do men light a candle, and put it under a bushel, but on a candlestick; and it giveth light unto all that are in the house."*
>
> —Matthew 5:15 (KJV)

In *Back to the Future*, Doc Brown talks about sending Marty McFly "back to the future." It doesn't take a genius to figure out how they came up with the movie titles for *Titanic* and *The Godfather*. While I loved *The Imitation Game* (Benedict Cumberbatch did a superb job portraying Alan Turing), the movie never did explain its name.

Turing's 1950 paper "Computing Machinery and Intelligence" earned him the title Father of Artificial Intelligence. In the paper (which references not only Babbage but addresses "Lady Lovelace's Objection" about machines incapable of original thought), Turing introduces the Victorian-era parlor game which inspired the title for the movie. It involves three people: one is the

liar, one is the helper, and the third is the guesser. The liar and helper are hidden or even sitting in another room. One is male and the other is female, though it doesn't matter which is which. The point of the game is for the guesser to figure out which person is the male and which is the female by asking questions and reading the written responses. One of the hidden players lies to throw the guesser off. The other player tries to help the guesser win.

It's like a scene from a movie where a shapeshifter is fighting their mirror image. A third person picks up the gun. One of the doppelgangers says, "I'm the real so-and-so! Shoot him!" The other one says, "No, *I'm* the real so-and-so! Shoot the other guy!" Just like the person with the gun, the guesser in the imitation game has to figure out which one is telling the truth.

Turing thought the question "Can machines think?" was dumb. What exactly did we mean by "machine?" How do you define "think?" Knowing that, you can kind of see that Edsger Dijkstra's comment about Turing shows that Dijkstra was either being obtuse or that he didn't get the joke—Turing himself thought it was a stupid question. He said Turing asked whether machines could think, which was about like asking whether a submarine could swim. But Turing didn't ask whether machines could think. Like Dijkstra, he thought it was a stupid question and made that quite clear in his 1950 paper when he wrote: "The original question 'Can machines think?' I believe to be too meaningless to deserve discussion." [129] The question was too subjective. According to Turing, it could only be answered by something like "a Gallup poll" to survey how people used the words "machine" and "think." [130]

There had to be a better way.

The Turing Test

He thought the better question was whether we could build computers smart enough to pass as human. Instead of hiding a man and woman and passing answers back and forth, hide a human and a computer. The human would be the honest helper while the computer served as the lying trickster trying to fool the guesser. Though he didn't name it, the world has since come to call this the Turing Test.

You know what would have been a better movie to name after the imitation game? The original *Blade Runner*. In a dystopian future, androids are so advanced that you can't tell them apart from real humans. One (the android that Harrison Ford falls in love with) is so advanced that she even believes she's human. Like Frankenstein, the artificial humans rebel and become a threat to humanity. Harrison Ford has to hunt them down and "retire" them.

The main tool the detective uses is called a Voight-Kampff test. Ford asks a series of innocuous questions, but some are peppered with horrific details. The idea is that a real human would be revulsed by the gruesome details while androids wouldn't see the problem. In the movie, the interrogator walks a suspected android through a set of questions, such as, "You've got a little boy. He shows you his butterfly collection…plus the killing jar." The interrogator watches the machines attached to the suspect to see if there's any type of reaction. Later, he says another provoking statement: "You're watching a stage play. A banquet is

in progress. The guests are enjoying an appetizer of raw oysters. The entree consists of boiled dog."

A normal human would have a visceral reaction. Their heart might beat faster, their pupils dilate, or their skin begin to sweat. An android would not. If the suspect failed the test, it meant they weren't human and were immediately executed.

Blade Runner's androids passed the Turing test with flying colors. In the book the movie's based on, *Do Androids Dream of Electric Sheep?* [*], the detective begins to feel like the androids possess more humanity than many of the people he deals with on a daily basis.[†131]

(By the way, we've come a long way in creating AI that can fool humans since Turing's days. In 2014, a chatbot named Eugene Goostman acted as if it were a thirteen-year-old boy from Ukraine and successfully convinced one-third of the human judges that it was, in fact, a kid whose first language wasn't English.)

In an ironic twist, you have almost certainly dealt with the mirror image of the Turing Test. Ever been on a webpage and had to "Click this box to prove you're not a robot"? Ever had to "Select all images that contain a bicycle" or squint to read the letters and numbers in a smeared, pixelated image? These are called CAPTCHAs, short for **C**ompletely **A**utomated **P**ublic **T**uring Test to Tell **C**omputers and **H**umans **A**part. A "public Turing test." We're living in a day and age where we have to prove to computers that we're *not* one of them. What a world.

* By Philip K. Dick. The book *Do Androids Dream of Electric Sheep?* explores what it means to be human.

† He came to feel like Captain Kirk did giving Spock's eulogy: "Of all the souls I have encountered in my travels, his was the most…human."

But I've gotten ahead of myself. Turing published this paper in 1950. I still haven't told you about the British scientist John Womersley bringing a copy of *First Draft of a Report on the EDVAC* home in 1945.

Hiding Turing Under a Bushel

In the 1930s, Womersley served at Britain's counterpart to Aberdeen Proving Ground, the Royal Arsenal in Woolwich, where he worked on ballistics research. [132] He was promoted to the Ministry of Supply in 1942 and, like Dr. Deming at Aberdeen, was in charge of statistical quality control for weapons matériel during the war.[133] In 1945, he became the head of the Mathematics Division at the National Physical Laboratory (the UK equivalent of the US National Institute of Standards and Technology). [134] With his background in mathematics and ballistics testing, he naturally had a deep interest in the development of mechanical and electromechanical computers.

Based on Alan Turing's 1936 paper "Computable Numbers," Womersley attempted to design a universal machine using electrical relays.[135] When he toured the US in 1945 to witness the ENIAC in action and read von Neumann's *First Draft*, he immediately grasped the significance. [136] He returned to the National Physical Laboratory and immediately hired Turing to design an electrical computer for the British government. By the end of the year, the wunderkind of Bletchley Park had written a report detailing the design of his Automatic Computing Engine, the ACE.[137]

Unlike John von Neumann's paper, Turing's was "a complete description of a computer, right down to the logical circuit diagrams," even including "a cost estimate of £11,200."[138] He also listed ten different types of problems or executable commands the ACE could handle, including playing chess and solving simple jigsaw puzzles.

As early as 1947, Turing was examining the question of "how far it is in principle possible for a computing machine to simulate human activities" in a presentation to the London Mathematical Society about the ACE.[139]When someone suggested he modify the ACE to be more like the EDVAC, Turing wrote, "[It] is…very contrary to the line of development here, and much more in the American tradition of solving one's difficulties by means of much equipment rather than by thought."[140] (After working with banks and software companies all over North America, I have to say Turing was right. The American approach to solving problems is often to throw more money at it rather than analyze underlying systemic issues.)

Due in no small part to a falling out between Turing and Womersley, the father of artificial intelligence left the National Physical Laboratory to follow his colleague and mentor Max Newman to the University of Manchester in 1948.[141] With the team there, Turing was instrumental in building the Ferranti Mark I. At the same time, down at Cambridge, another team developed and built the EDSAC, drawing directly from the EDVAC report. Whereas Eckert and Mauchly's EDVAC II/UNIVAC paved the way for the wholesale adoption of computers in the US, the Ferranti Mark I did this for Europe and Canada. The EDSAC would shape the field of computer science to come. While von

Neumann stole the spotlight, the credit for inventing modern computers on both sides of the Atlantic belongs to Alan Turing. Again, because of Britain's Official Secrets Act, Turing legally couldn't dispute von Neumann's claims. (As Eckert noted, the Espionage Act in the US forbade von Neumann from publishing anything associated with the ENIAC and EDVAC, though he did it anyway.)

For all the lives he saved and for shaping the world to come—from gifting us the design for modern computers and laying the foundational thinking for AI—Turing's legacy languished in red tape and obscurity for decades.

Unfortunately, no good deed goes unpunished.

The Sleeping Death of an Emasculated Man

Turing did not hide the fact he was gay. Even here well into the third millennium, it still takes courage to come out to the world. Back in the 1950s, homosexuality was not only decidedly against accepted cultural norms but was still illegal.

In 1952, Turing returned home one day to find his apartment ransacked. He strongly believed it was an acquaintance of his lover's. Instead of focusing on the burglary, the investigating police charged him with the crime of gross acts of indecency. The sentencing judge offered him an alternative to imprisonment: chemical castration. At the time, pseudoscience still believed homosexuality was a mental illness that could be cured with injections of female hormones to lower libido.

The ignominy of his impotence was multiplied when Turing began to grow breasts. In addition to the public and private humiliation, his sentencing also stripped him of his government security clearance, effectively ending his career in computer research and development. He found himself squarely in Her Majesty's crosshairs. The government curtailed his ability to travel abroad and even deported a Norwegian (also purportedly gay) on his way to visit Turing.[142]

It's easy to understand why Turing's death was ruled a suicide.

It seems he had taken a particular liking to the cutting-edge cinematography of the time in the form of *Snow White and the Seven Dwarves*, chanting a particular rhyming line over and over again from the scene where the evil queen dips an apple into poison[143]:

Dip the apple in the brew,
Let the sleeping death seep through.

In 1954, Turing's landlady found him dead in his apartment, a half-eaten apple nearby with the unmistakable fumes of cyanide in the air.[144] The investigator concluded the forty-one-year-old scientist had injected the apple with the chemical and ate it, ending his own life. One historian wrote, "Alas, it seems all too possible that Alan Turing was hounded to his death by the governing authorities of a nation he had—unsung—done so much to save."[145]

Years later, others would assert there was more evidence to support ruling it an accidental death, as Turing regularly performed chemistry experiments in his room. Either way, the world lost one of the most remarkable men in modern history.

In *The Tempest*, Shakespeare wrote, "What's past is prologue." Everything we've covered in these last nine chapters merely gives us the basics we need to start learning how artificial intelligence began to come about.

AI got its start with kindly ol' Uncle John trying to wrangle some cats.