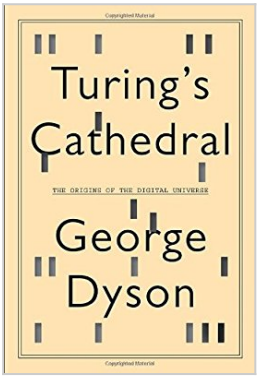

Turing's Cathedral: The Origins of the Digital Universe

By George Dyson

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“It is possible to invent a single machine which can be used to compute any computable sequence,” twenty-four-year-old Alan Turing announced in 1936. In *Turing’s Cathedral*, George Dyson focuses on a small group of men and women, led by John von Neumann at the Institute for Advanced Study in Princeton, New Jersey, who built one of the first computers to realize Alan Turing’s vision of a Universal Machine. Their work would break the distinction between numbers that *mean* things and numbers that *do* things—and our universe would never be the same.

Using five kilobytes of memory (the amount allocated to displaying the cursor on a computer desktop of today), they achieved unprecedented success in both weather prediction and nuclear weapons design, while tackling, in their spare time, problems ranging from the evolution of viruses to the evolution of stars.

Dyson’s account, both historic and prophetic, sheds important new light on how the digital universe exploded in the aftermath of World War II. The proliferation of both codes and machines was paralleled by two historic developments: the decoding of self-replicating sequences in biology and the invention of the hydrogen bomb. It’s no coincidence that the most destructive and the most constructive of human inventions appeared at exactly the same time.

How did code take over the world? In retracing how Alan Turing’s one-dimensional model became John von Neumann’s two-dimensional implementation, *Turing’s Cathedral* offers a series of provocative suggestions as to where the digital universe, now fully three-dimensional, may be heading next.

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Turing's Cathedral: The Origins of the Digital Universe By George Dyson Bibliography

- Sales Rank: #604909 in Books
- Published on: 2012-03-06
- Released on: 2012-03-06
- Format: Deckle Edge
- Original language: English
- Number of items: 1
- Dimensions: 9.50" h x 1.52" w x 6.63" l, 1.80 pounds
- Binding: Hardcover
- 432 pages

Editorial Review

Review
“An expansive narrative . . . The book brims with unexpected detail. Maybe the bomb (or the specter of the machines) affected everyone. Gödel believed his food was poisoned and starved himself to death. Turing, persecuted for his homosexuality, actually did die of poisoning, perhaps by biting a cyanide-laced apple. Less well known is the tragic end of Klári von Neumann, a depressive Jewish socialite who became one of the world’s first machine-language programmers and enacted the grandest suicide of the lot, downing cocktails before walking into the Pacific surf in a black dress with fur cuffs. Dyson’s well made sentences are worthy of these operatic contradictions . . . A groundbreaking history of the Princeton computer.”
—William Poundstone, *The New York Times Book Review*

“Dyson combines his prodigious skills as a historian and writer with his privileged position within the [Institute for Advanced Study’s] history to present a vivid account of the digital computer project . . . A powerful story of the ethical dimension of scientific research, a story whose lessons apply as much today in an era of expanded military R&D as they did in the ENIAC and MANIAC era . . . Dyson closes the book with three absolutely, hair-on-neck-standing-up inspiring chapters on the present and future, a bracing reminder of the distance we have come on some of the paths envisioned by von Neumann, Turing, et al.”
—Cory Doctorow, Boing Boing

“A fascinating combination of the technical and human stories behind the computing breakthroughs of the 1940s and ’50s . . . It demonstrates that the power of human thought often precedes determination and creativity in the birth of world-changing technology . . . An important work.”
—Richard DiDio, *Philadelphia Inquirer*

“Dyson’s book is not only learned, but brilliantly and surprisingly idiosyncratic and strange.”
—Josh Rothman, Braniac blog, *Boston Globe*

“Beyond the importance of this book as a contribution to the history of science, as a generalist I was struck by Dyson’s eye and ear for the delightfully entertaining detail . . . Turing’s Cathedral is suffused . . . with moments of insight, quirk and hilarity rendering it more than just a great book about science. It’s a great book, period.”
—Douglas Bell, *The Globe and Mail*

“The greatest strength of Turing’s Cathedral lies in its luscious wealth of anecdotal details about von Neumann and his band of scientific geniuses at IAS. Dyson himself is the son of Freeman Dyson, one of America’s greatest twentieth-century physicists and an IAS member from 1948 onward, and so Turing’s Cathedral is, in part, Dyson’s attempt to make both moral and intellectual sense of his father’s glittering and yet severely compromised scientific generation.”
—Andrew Keen, B&N Review

“A mesmerizing tale brilliantly told . . . . The use of wonderful quotes and pithy sketches of the brilliant cast of characters further enriches the text . . . . Meticulously researched and packed with not just technological details, but sociopolitical and cultural details as well—the definitive history of the computer.”
—*Kirkus* (starred review)

“The most powerful technology of the last century was not the atomic bomb, but software—and both were invented by the same folks. Even as they were inventing it, the original geniuses imagined almost everything software has become since. At long last, George Dyson delivers the untold story of software’s creation. It is an amazing tale brilliantly deciphered.”
—Kevin Kelly, cofounder of WIRED magazine, author of *What Technology Wants*

“It is a joy to read George Dyson’s revelation of the very human story of the invention of the electronic computer, which he tells with wit, authority, and insight. Read Turing’s Cathedral as both the origin story of our digital universe and as a perceptive glimpse into its future.”
—W. Daniel Hillis, inventor of The Connection Machine, author of *The Pattern on the Stone*

About the Author

George Dyson is a historian of technology whose interests include the development (and redevelopment) of the Aleut kayak (*Baidarka),* the evolution of digital computing and telecommunications *(Darwin Among the Machines),* and the exploration of space *(Project Orion).*

Preface

POINT SOURCE SOLUTION

I am thinking about something much more important than bombs. I am thinking about computers.
—John von Neumann, 1946

There are two kinds of creation myths: those where life arises out of the mud, and those where life falls from the sky. In this creation myth, computers arose from the mud, and code fell from the sky.

In late 1945, at the Institute for Advanced Study in Princeton, New Jersey, Hungarian American mathematician John von Neumann gathered a small group of engineers to begin designing, building, and programming an electronic digital computer, with five kilobytes of storage, whose attention could be switched in 24 microseconds from one memory location to the next. The entire digital universe can be traced directly to this 32-by-32-by-40-bit nucleus: less memory than is allocated to displaying a single icon on a computer screen today.

Von Neumann’s project was the physical realization of Alan Turing’s Universal Machine, a theoretical construct invented in 1936. It was not the first computer. It was not even the second or third computer. It was, however, among the first computers to make full use of a high-speed random-access storage matrix, and became the machine whose coding was most widely replicated and whose logical architecture was most widely reproduced. The stored-program computer, as conceived by Alan Turing and delivered by John von Neumann, broke the distinction between numbers that *mean* things and numbers that *do* things. Our universe would never be the same.

Working outside the bounds of industry, breaking the rules of academia, and relying largely on the U.S. government for support, a dozen engineers in their twenties and thirties designed and built von Neumann’s computer for less than $1 million in under five years. “He was in the right place at the right time with the right connections with the right idea,” remembers Willis Ware, fourth to be hired to join the engineering

team, “setting aside the hassle that will probably never be resolved as to whose ideas they really were.”

As World War II drew to a close, the scientists who had built the atomic bomb at Los Alamos wondered, “What’s next?” Some, including Richard Feynman, vowed never to have anything to do with nuclear weapons or military secrecy again. Others, including Edward Teller and John von Neumann, were eager to develop more advanced nuclear weapons, especially the “Super,” or hydrogen bomb. Just before dawn on the morning of July 16, 1945, the New Mexico desert was illuminated by an explosion “brighter than a thousand suns.” Eight and a half years later, an explosion one thousand times more powerful illuminated the skies over Bikini Atoll. The race to build the hydrogen bomb was accelerated by von Neumann’s desire to build a computer, and the push to build von Neumann’s computer was accelerated by the race to build a hydrogen bomb.

Computers were essential to the initiation of nuclear explosions, and to understanding what happens next. In “Point Source Solution,” a 1947 Los Alamos report on the shock waves produced by nuclear explosions, von Neumann explained that “for very violent explosions . . . it may be justified to treat the original, central, high pressure area as a point.” This approximated the physical reality of a nuclear explosion closely enough to enable some of the first useful predictions of weapons effects.

Numerical simulation of chain reactions within computers initiated a chain reaction among computers, with machines and codes proliferating as explosively as the phenomena they were designed to help us understand. It is no coincidence that the most destructive and the most constructive of human inventions appeared at exactly the same time. Only the collective intelligence of computers could save us from the destructive powers of the weapons they had allowed us to invent.

Turing’s model of universal computation was one-dimensional: a string of symbols encoded on a tape. Von Neumann’s implementation of Turing’s model was two-dimensional: the address matrix underlying all computers in use today. The landscape is now three-dimensional, yet the entire Internet can still be viewed as a common tape shared by a multitude of Turing’s Universal Machines.

Where does time fit in? Time in the digital universe and time in our universe are governed by entirely different clocks. In our universe, time is a continuum. In a digital universe, time (T) is a countable number of discrete, sequential steps. A digital universe is bounded at the beginning, when T = 0, and at the end, if T comes to a stop. Even in a perfectly deterministic universe, there is no consistent method to predict the ending in advance. To an observer in our universe, the digital universe appears to be speeding up. To an observer in the digital universe, our universe appears to be slowing down.

Universal codes and universal machines, introduced by Alan Turing in his “On Computable Numbers, with an Application to the Entscheidungsproblem” of 1936, have prospered to such an extent that Turing’s underlying interest in the “decision problem” is easily overlooked. In answering the *Entscheidungsproblem*, Turing proved that there is no systematic way to tell, by looking at a code, what that code will do. That’s what makes the digital universe so interesting, and that’s what brings us here.

It is impossible to predict where the digital universe is going, but it is possible to understand how it began. The origin of the first fully electronic random-access storage matrix, and the propagation of the codes that it engendered, is as close to a point source as any approximation can get.

Users Review

From reader reviews:

Marc Gaul:

Now a day people that Living in the era exactly where everything reachable by connect with the internet and the resources inside it can be true or not require people to be aware of each data they get. How many people to be smart in acquiring any information nowadays? Of course the correct answer is reading a book. Studying a book can help persons out of this uncertainty Information particularly this Turing's Cathedral: The Origins of the Digital Universe book because this book offers you rich data and knowledge. Of course the info in this book hundred % guarantees there is no doubt in it you probably know this.

Hayden Roberts:

Spent a free time to be fun activity to accomplish! A lot of people spent their down time with their family, or their friends. Usually they performing activity like watching television, likely to beach, or picnic inside park. They actually doing same task every week. Do you feel it? Do you want to something different to fill your current free time/ holiday? Might be reading a book could be option to fill your free time/ holiday. The first thing you will ask may be what kinds of publication that you should read. If you want to test look for book, may be the publication untitled Turing's Cathedral: The Origins of the Digital Universe can be excellent book to read. May be it can be best activity to you.

Willard Griffin:

Reading can called brain hangout, why? Because if you find yourself reading a book mainly book entitled Turing's Cathedral: The Origins of the Digital Universe your mind will drift away trough every dimension, wandering in every single aspect that maybe unfamiliar for but surely might be your mind friends. Imaging each word written in a reserve then become one form conclusion and explanation this maybe you never get previous to. The Turing's Cathedral: The Origins of the Digital Universe giving you yet another experience more than blown away your head but also giving you useful data for your better life in this era. So now let us explain to you the relaxing pattern is your body and mind will likely be pleased when you are finished studying it, like winning a. Do you want to try this extraordinary investing spare time activity?

Allison Phelps:

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