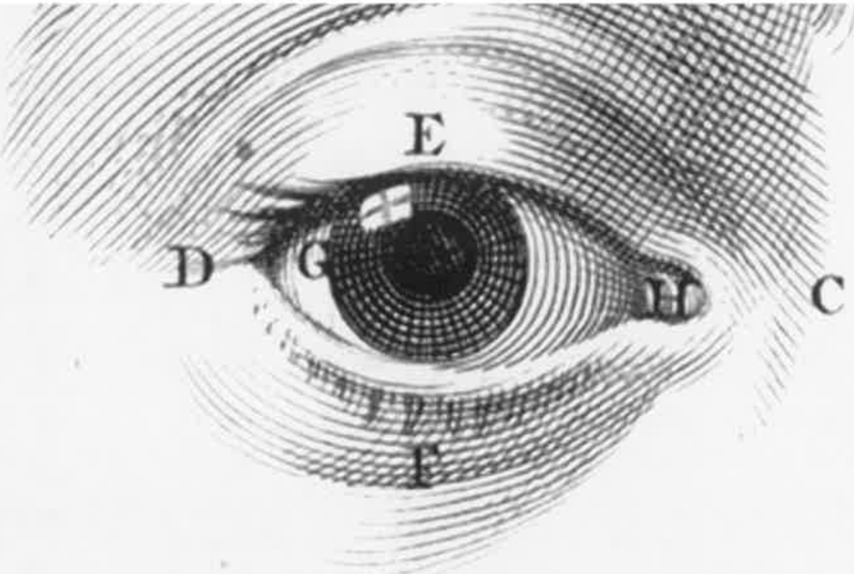

MICHAEL STREVENS

The Knowledge Machine

How an Unreasonable Idea Created Modern Science

‘Riveting ... crystal-clear ... unparalleled’
WALL STREET JOURNAL

PENGUIN BOOKS

UK | USA | Canada | Ireland | Australia
India | New Zealand | South Africa

Penguin Books is part of the Penguin Random House group of companies
whose addresses can be found at global.penguinrandomhouse.com.

Penguin Random House UK

First published in the United States of America by W. W. Norton & Company, Inc. 2020
First published in Great Britain by Allen Lane 2020
Published in Penguin Books 2021
001

Printed and bound in Great Britain by Clays Ltd, Elcograf S.p.A.

The authorized representative in the EEA is Penguin Random House Ireland,
Morrison Chambers, 32 Nassau Street, Dublin D02 YH68

A CIP catalogue record for this book is available from the British Library

ISBN: 978-0-141-98126-0

www.greenpenguin.co.uk

MIX
Paper from
responsible sources
FSC www.fsc.org FSC® C018179

Penguin Random House is committed to a
sustainable future for our business, our readers
and our planet. This book is made from Forest
Stewardship Council® certified paper.

CONTENTS

IV. SCIENCE NOW

INTRODUCTION

THE KNOWLEDGE MACHINE

Why is science so powerful?
Why did it take so long to arrive?

WERE YOU TO BE TRANSPORTED to some randomly chosen place and time in human history, you would likely find yourself gathering pinhead-sized grains, hunting dangerous game with a sharpened stick, and living in a damp, unfurnished hollow.

If you were very lucky, however, you might wake up in the sandals of a wealthy citizen of the Greek world around the time of Alexander the Great. From this position of privilege you could enjoy just about every cultural invention that makes life worth living today. You could delight in the poetry of Homer and Sappho, visit the theater to relish *Oedipus Rex* and other masterpieces of ancient drama, hire a musician to serenade your friends after dinner. You could live in cities regulated by law and a system of courts, shaped by the architects and sculptors who built some of the seven wonders of the world, and governed in accordance with political models that have lasted to this day: monarchy, oligarchy, sweet democracy. If you had the aptitude and the inclination, you could undertake advanced studies in geometry or philosophy.

Yet—you would soon notice a few things missing even from this cultural Elysium. X-rays and MRIs, travel at speeds faster than the swiftest horse, voices and video coverage of world events streaming through the thyme-scented Mediterranean air are nowhere to be found. Most egregiously absent of all is the thing that makes our own advanced medicine, transport, and telecommunication possible: the knowledge-producing machine that we call modern science.

Civilization stretches back millennia. But the machine has been around only a few hundred years. What took so long?

Among the ancients there was no lack of desire to understand the workings of the world. Around 580 BCE, the Greek philosopher Thales gazed out from the port city of Miletus into the Aegean blue, into the summer haze where sea merges imperceptibly with sky, and proposed that everything is ultimately made of water. His student Anaximenes disagreed: the fundamental stuff, he said, is air. Heraclitus, who lived in Ephesus a few decades later, suggested fire. Back in Miletus, Anaximander—another student of Thales about whom we know equally little—had meanwhile hypothesized that all things are composed of invisible stuff of unlimited potential that he called *apeiron*, or "the boundless."

Though these thinkers, their contemporaries, and their successors—Chinese scholars, Islamic doctors, medieval European monks—argued ingeniously for their points of view, no one of their ideas could gain a foothold over the others. Searching for the deep structure of nature, they contributed immeasurably to humanity's stock of brilliant and original hypotheses, but to its stock of knowledge, scarcely at all.

The reason is straightforward. Although premodern inquirers into nature sometimes hit on the right idea, they had little ability to distinguish it from its rivals. By the time of the collapse of the Western Roman Empire in the fifth century CE, almost every possible hypothesis about the relation between the earth, the planets, and the sun had been proposed: that the planets and the sun revolved around a fixed earth, that the earth and the planets revolved around a fixed sun (as the

Greek philosopher Aristarchus suggested in the third century BCE), and that some or all of the planets revolved around the sun, which in turn revolved around the earth (an idea passed on by Roman writers to the philosophers of the Middle Ages and invented independently in India in the fifteenth century). It was only a thousand years after the fall of Rome, however, that it became generally agreed—and soon after, known for sure—which one of these theories was correct.

That great leap forward was made in the exhilarating period between the years 1600 and 1700, during which empirical inquiry evolved from the freewheeling, speculative frenzy of old into something with powers of discovery on a wholly new level—the knowledge machine. Driving this machine was a regimented process that subjected theories to a pitiless interrogation by observable evidence, raising up some and tearing down others, occasionally changing course or traveling in reverse but making in the long term unmistakable progress. Where Thales once surveyed the horizon and saw water, our radio telescopes look into deep space and see dark matter.

It is to mark this sudden change in the tempo and form of discovery that historians call what happened the "Scientific Revolution," and philosophers and sociologists distinguish what came after the Revolution as a new way of thinking about the world. In so doing, they set "modern science" apart from what preceded it—that is, ancient and medieval science, or what is sometimes called, to emphasize the striking discontinuity, "philosophy of nature" or "natural philosophy." The natural philosophy that came before the Scientific Revolution was not less creative than modern science, and as practiced by thinkers such as Aristotle was no less methodical and no less concerned with the evidence of the senses. Yet something, it seems, was missing.

For that extraordinary something, why the excruciating wait? Why, after philosophy and democracy and mathematics tumbled through the doors of the ancient thinkers' consciousness in quick succession, did science dawdle on the threshold? Why wasn't it the ancient Babylonians putting zero-gravity observatories into orbit around the earth; the Han Chinese building particle accelerators in the flat fields along the Yellow River; the Maya growing genetically modified corn in the Yucatán; the ancient Greeks engineering flu vaccines and transplanting hearts?

Events such as revolutions and elections, declarations and emancipations occur at particular times and in particular places. But a nonevent such as science's non-arrival happens, so to speak, almost everywhere. Modern science did not arrive in democratic Athens. It was not invented by Aristotle. It failed to develop in China a thousand years ago, in spite of that nation's cohesion, scholarly tradition, and technological prowess. Neither Islamic nor European medicine succeeded in becoming truly scientific. The Maya, the Aztecs, the Incas; Goryeo Korea and the Khmer Empire of Cambodia; the India of the Maurya and Mughal Empires: we marvel at their temples and pyramids, their rich traditions of theater and dance. But these cultures, all wealthy, powerful, and sophisticated, are equally non-inventors of science.

The long absence of science is therefore not to be explained by some particular train of events or some specific mix of custom and circumstance. It spans democracies and theocracies, east and west, pantheists and People of the Book. It seems, to all the world, that there is something about the nature of science itself that the human race finds hard to take on board.

That, I believe, is the answer: science is an alien thought form. To understand its late arrival on the human scene, we need to appreciate the inherent strangeness of the scientific method.

The first step is to take a close look at the method, at the rules that drive modern science and explain its fact-finding power. An easy task, you might think. The principles in question regulate science wherever it is found. Every university, every research facility, every industrial laboratory follows them. Go there; make a few queries. Scientists themselves will tell you what science is and how it functions.

Yet it has turned out to be anything but straightforward to obtain a satisfactory answer. Some scientists say that the essence of science is controlled or repeatable experiment, forgetting that experiments are of relatively little importance in cosmology or evolutionary biology. Some say advanced mathematical techniques are crucial, forgetting that the discoverers of genetics, for example, had no use for sophisticated math. Some say what matters is observation. That is a big-hearted answer—it does not exclude whole branches of science like the other responses—but it is too generous. The ancient Greek natural philosophers sought to explain what they saw around them, yet for all their yearning to make sense of the observable world, they had not yet laid their hands on the secret of modern science.

Carry out a poll of the scientific profession, then, and you will soon discover that although scientists know very well how to implement their methods, they don't know what it is about those methods that really matters, and why.

What about other scholars who study the nature of science—the historians of science, the sociologists of science, the philosophers of science? You'll find no more agreement among them than you do among working scientists. Indeed, the question of the scientific method is one of the most difficult, most contentious, most puzzling problems in modern thought.

The consequence is an argument that has sometimes smoldered, sometimes blazed for well over a hundred years—the Great Method Debate. Subtle, powerful thinkers have attempted to describe the scientific method and come to quite opposing conclusions.

More perplexing still, many who have inspected science closely have concluded that there is no such thing as the scientific method. To the question of what is new about modern science, of what changed in the Scientific Revolution, they answer "Nothing much"—or as the sociologist Steven Shapin has declared, "There was no such thing as the Scientific Revolution." Three centuries after Newton explained why the planets orbit the sun, the nature of science is, as the philosopher of science Paul Feyerabend has written, "still shrouded in darkness."

Into that darkness *The Knowledge Machine* will plunge, searching for illumination among the tangle of competing visions of and skepticism about the scientific method. It will wrangle with philosophers such as Karl Popper, who believed that the method hinges on a certain kind of logic applied by thinkers with the right sort of temperament, and Thomas Kuhn, who thought that it is rather a special kind of social organization that is responsible for science's power. It will confront sociologists such as Steven Shapin who hold that no method exists. And it will put forward its own proposal about the nature of the method.

There are many reasons to join the Great Method Debate. Science is so vital to the quality of our modern life that even if the scientific method turned out to be something rather boring and unremarkable—a superior kind of experimental technique, say—it would be imperative to find it and to frame it in a book.

I would have no interest, however, in writing that book. What fascinates me is that science's rules of engagement are so unexpected, so unintuitive, so odd. It is this peculiarity, I believe, that accounts for science's late arrival. Even putting aside the fascinating question of science's delay, the weirdness of the scientific method is an intellectual spectacle in itself. It is to share and delight in that spectacle, as much as anything else, that I put these pages before you.

Once I have taken my turn as the P. T. Barnum of the laboratory, unveiling the monstrosity that lies at the heart of modern science, you will begin to understand why it has been so difficult to chase down.

Those who have searched for a scientific method—the *methodists*—have been looking for a logical and behavioral directive that expunges human whim from scientific thought, replacing it with a standardized rule or procedure for judging theories in the light of evidence that explains science's stupendous knowledge-producing capacity. The rule that governs science and explains its success is far weaker, however, than the methodists have supposed: it tells you what counts as evidence but offers no system for interpreting that evidence. Indeed, it says nothing about the significance of evidence at all.

Further, the rule does not reside where the methodists have expected to find it, in scientists' heads. It does not tell scientists what to think privately; it merely regulates how they argue publicly. It is not a method of reasoning but a kind of speech code, a set of ground rules for debate, compelling scientists to conduct all disputes with reference to empirical evidence alone.

That explains why the methodists failed to find their method. They were looking for the wrong kind of rule. And they were looking in the wrong place.

How can a rule so scant in content and so limited in scope account for science's powers of discovery? It may dictate what gets called evidence, but it makes no attempt to forge agreement among scientists as to what the evidence says. It simply lays down the rule that all arguments must be carried out with reference to empirical evidence and then steps back, relinquishing control. Scientists are free to think almost anything they like about the connection between evidence and theory. But if they are to participate in the scientific enterprise, they must uncover or generate new evidence to argue with. And so they do, with unfettered enthusiasm.

The resulting productivity is what makes all the difference: science is a machine for motivating disputatious humans to carry out tedious measurements and perform costly and time-consuming experiments that they would otherwise not care to undertake. It is these empirical minutiae, so painful to collect, that single out the truth among the plausible falsehoods. Eventually, enough such evidence accumulates that just about every scientist, whatever their quirks, biases, and prejudices, agrees on its significance: one theory stands well above the rest as the best explainer and predictor of it all.

The apparently unassuming code of public behavior, the evidence-only constraint on scientific argument that constitutes all the method science needs to set humanity marching inexorably toward truth, deserves a grand name; I call it the *iron rule of explanation*. Much of *The Knowledge Machine* is given over to understanding where the iron rule came from, what it amounts to, and by what means it leads science toward enlightenment. That will be my attempt to settle the Great Method Debate. If I am correct, then in this book you will discover how science really works.

You will also find the answer to my opening question, learning why it took so long for the human race to discover the power of the iron rule. I won't explain science's late arrival by composing a history of the origins of the Scientific Revolution. My interest is in all the apparently propitious places and times that science *failed* to appear. That nonappearance is to be explained by something timeless: that the iron rule, the key to science's success, is unreasonably closed-minded. It works superbly well, but from the outside, it looks to be, quite simply, an irrational way to inquire into the underlying structure of things. The ancient Greeks had poetry, music, drama, philosophy, democracy, mathematics—each an expression and an elevation of human nature. Science, by contrast, requires of its practitioners the strategic suppression of human nature, indeed, the suppression of the highest element of human nature, the rational mind. What Greek philosopher could have supposed that this was the route to unbounded knowledge of the world? The mystery is not that science arrived so late, but that as a technique for discovery it was ever hit upon at all.

By the end of *The Knowledge Machine*, then, I will have answered two big questions, one philosophical and the other historical:

1. How does science work, and why is it so effective?
2. Why did science arrive so late?

To the first, philosophical question, I say: what matters is the iron rule. To the second, historical question, I say: it is the irrationality of the rule that barred it from human consciousness for so long.

The investigation of the intellectual, moral, and social structure of science that answers both the philosophical and historical questions will constitute by far the greater part of *The Knowledge Machine*, but near the end I will yield to the temptation to do something more like conventional history, explaining why science finally turned up when and where it did, in the European seventeenth century. I then comment on the impact of the iron rule's irrationality on the shape of science today and ask how we can best maintain, even improve, the knowledge machine so as to continue to profit from its penetration and power—and not least, so as to save ourselves from some of the havoc it has helped us to wreak on our planet.

The Knowledge Machine has much to say in favor of science. It sets out to defend scientific inquiry against those who doubt its legendary ability to find the truth—against fundamentalists, postmodernists, romantics, spiritualists, philosophical skeptics. The legend, I show, is firmly founded in fact.

Yet these same arguments and explanations show how peculiar and often inhuman in its workings the knowledge machine can be. It gets the job done not in spite of but in virtue of its proprietary blend of inarticulacy, closed-mindedness, and systematic irrationality. No wonder humanity was so reluctant for so long to pull the lever that brought it buzzing and spluttering to life.

My story begins at the height of the Great Method Debate, as the twentieth century's two foremost philosophers of science—Karl Popper and Thomas Kuhn—lay out opposing visions of the mechanism behind science's knowledge-making capacity. Neither effort will succeed. But sifting through the philosophical wreckage, I will find the foundation on which to construct a better theory of science.