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STORY
OF
WESTERN
SCIENCE

ALSO BY SUSAN WISE BAUER

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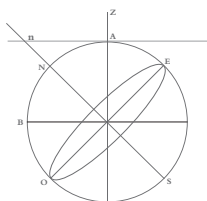
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THE
STORY
OF
WESTERN
SCIENCE

From the WRITINGS *of* ARISTOTLE
to the BIG BANG THEORY



SUSAN WISE BAUER



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The Books

The *Aphorisms* of Hippocrates (ca. 420 BC)

Plato, *Timaeus* (ca. 360 BC)

Aristotle, *Physics* (ca. 330 BC)

Aristotle, *History of Animals* (ca. 330 BC)

Archimedes, “The Sand-Reckoner” (ca. 250 BC)

Lucretius, *On the Nature of Things* (ca. 60 BC)

Ptolemy, *Almagest* (ca. AD 150)

Nicolaus Copernicus, *Commentariolus* (1514)

Francis Bacon, *Novum organum* (1620)

William Harvey, *De motu cordis* (1628)

Galileo Galilei, *Dialogue concerning the Two Chief World Systems*
(1632)

Robert Boyle, *The Sceptical Chymist* (1661)

Robert Hooke, *Micrographia* (1665)

Isaac Newton, *Philosophiae naturalis principia mathematica*
(1687/1713/1726)

Georges-Louis Leclerc, Comte de Buffon, *Natural History:
General and Particular* (1749–88)

James Hutton, *Theory of the Earth* (1785)

Georges Cuvier, “Preliminary Discourse” (1812)

Charles Lyell, *Principles of Geology* (1830)

Arthur Holmes, *The Age of the Earth* (1913)

Alfred Wegener, *The Origin of Continents and Oceans* (1915)

Walter Alvarez, *T. rex and the Crater of Doom* (1997)

Jean-Baptiste Lamarck, *Zoological Philosophy* (1809)

Charles Darwin, *On the Origin of Species* (1859)

Gregor Mendel, *Experiments in Plant Hybridisation* (1865)

Julian Huxley, *Evolution: The Modern Synthesis* (1942)

James D. Watson, *The Double Helix* (1968)

Richard Dawkins, *The Selfish Gene* (1976)

E. O. Wilson, *On Human Nature* (1978)

Stephen Jay Gould, *The Mismeasure of Man* (1981)

Albert Einstein, *Relativity: The Special and General Theory* (1916)

Max Planck, "The Origin and Development of the Quantum Theory" (1922)

Erwin Schrödinger, *What Is Life?* (1944)

[Edwin Hubble, *The Realm of the Nebulae* (1937)]

Fred Hoyle, *The Nature of the Universe* (1950)

Steven Weinberg, *The First Three Minutes: A Modern View of the Origin of the Universe* (1977)

James Gleick, *Chaos* (1987)

Contents

List of Illustrations	xiii
Acknowledgments	xv
Preface	xvii
<i>Or, How to use this book</i>	

PART I: THE BEGINNINGS

ONE The First Science Texts	3
<i>The first written attempt to explain the physical world in physical terms</i>	
TWO Beyond Man	9
<i>The first big-picture accounts of the universe</i>	
THREE Change	16
<i>The first theory of evolution</i>	
FOUR Grains of Sand	21
<i>The first use of mathematics to measure the universe</i>	
FIVE The Void	32
<i>The first treatise on nature to dispense entirely with the divine</i>	

- SIX **The Earth-Centered Universe** 37
The most influential science book in history
- SEVEN **The Last Ancient Astronomer** 46
*An alternate explanation for the universe, with better mathematics,
but no more proof*

PART II: THE BIRTH OF THE METHOD

- EIGHT **A New Proposal** 55
*A challenge to Aristotle, and the earliest articulation of the
scientific method*
- NINE **Demonstration** 63
*The refutation of one of the greatest ancient authorities through
observation and experimentation*
- TEN **The Death of Aristotle** 70
*The overthrow of ancient authority in favor of observations
and proofs*
- ELEVEN **Instruments and Helps** 80
*Improving the experimental method by distorting nature and
extending the senses*
- TWELVE **Rules of Reasoning** 94
Extending the experimental method across the entire universe

PART III: READING THE EARTH

- THIRTEEN **The Genesis of Geology** 105
The creation of the science of the earth

FOURTEEN The Laws of the New Science	115
<i>Two different theories are proposed as explanations for the earth's present form</i>	
FIFTEEN A Long and Steady History	128
<i>Uniformitarianism becomes the norm</i>	
SIXTEEN The Unanswered Question	134
<i>Calculating the age of the earth</i>	
SEVENTEEN The Return of the Grand Theory	141
<i>Continental drift</i>	
EIGHTEEN Catastrophe, Redux	149
<i>Bringing extraordinary events back into earth's history</i>	
 PART IV: READING LIFE (With Special Reference to Us)	
NINETEEN Biology	157
<i>The first systematic attempt to describe the history of life</i>	
TWENTY Natural Selection	164
<i>The first naturalistic explanation for the origin of species</i>	
TWENTY-ONE Inheritance	174
<i>The laws, and mechanisms, of heredity revealed</i>	
TWENTY-TWO Synthesis	179
<i>Bringing cell-level discoveries and the grand story of evolution together</i>	
TWENTY-THREE The Secret of Life	185
<i>Biochemistry tackles the mystery of inheritance</i>	

TWENTY-FOUR	Biology and Destiny	199
	<i>The rise of neo-Darwinist reductionism, and the resistance to it</i>	

PART V: READING THE COSMOS
(Reality)

TWENTY-FIVE	Relativity	215
	<i>The limits of Newtonian physics</i>	
TWENTY-SIX	Damn Quantum Jumps	225
	<i>The discovery of subatomic random swerves</i>	
TWENTY-SEVEN	The Triumph of the Big Bang	238
	<i>Returning to the question of beginnings, and contemplating the end</i>	
TWENTY-EIGHT	The Butterfly Effect	252
	<i>Complex systems, and the (present) limits of our understanding</i>	
	Notes	257
	Works Cited	279
	Index	295

List of Illustrations

4.1	The Pythagorean Theorem: $a^2 + b^2 = c^2$	23
6.1	The Scheme of Hipparchus	39
6.2	The Scheme of Ptolemy	40
7.1	The Copernican Universe	48
8.1	The <i>Novum organum</i>	59
10.1	Galileo's Experiment	72
10.2	Galileo and Jupiter	74
17.1	Pangea and Continental Drift	143
17.2	Convection	147
25.1	Einstein's Railway	222
26.1	Rutherford's Atom	229
26.2	Einstein's Tube	233
26.3	Einstein's Waves	234

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Preface

Or, How to use this book

There is no human knowledge which cannot lose its scientific character when men forget the conditions under which it originated, the questions which it answered, and the functions it was created to serve.

—Benjamin Farrington,
Greek Science: Its Meaning for Us

This is not a history of science.

Histories of science have been written, in great numbers (and at great length), by many other writers. They abound: studies of Greek science, Renaissance science, Enlightenment science, Victorian science, modern science, science and society, science and philosophy, science and religion, science and “the people.”

Of course these histories have value. But somehow, the nature of science itself seems to get lost in the details. Most “people,” regular citizens who have no professional training in the sciences, still have no clear view of what science does—or what it means.

Most of us are fed science in news reports, interactive graphs, and sound bites. These may give us a fuzzy and incomplete glimpse of the facts involved, but the ongoing science battles of the twenty-first century show that the facts aren’t enough. Decisions that affect stem cell research, global warming, the teaching of evolution in elementary schools—these are being made by voters

(or, independently, by their theoretical representatives) who don't actually understand why biologists think stem cells are important, or how environmental scientists came to the conclusion that the earth is warming, or what the Big Bang actually is (neither big nor a bang; see Chapter 27).

So this is a slightly different kind of history. It traces the development of great science *writing*—the essays and books that have most directly affected and changed the course of scientific investigation. It is intended for the interested and intelligent nonspecialist. It shows science to be a very human pursuit: not an infallible guide to truth, but a deeply personal, sometimes flawed, often misleading, frequently brilliant way of understanding the world.

Each part presents a chronological series of “great books” of science, from the most ancient works of Hippocrates, Aristotle, and Plato, all the way up to the modern works of Richard Dawkins, Stephen Jay Gould, James Gleick, and Walter Alvarez. The chapters provide all of the historical, biographical, and technical information you need to understand the books themselves, and conclude with recommended editions. Older works, which don't necessarily need to be read in their entirety, are also excerpted on this book's website; links are provided in the text. (The website also lists available e-book versions, many of which can be difficult to find for pre-twentieth-century volumes.)

This is by no means meant to be a comprehensive list of important books in science, and readers may quibble with my selections. Many worthy books in science are not on my lists (search for any “great books of science” list and you'll find hundreds). I chose these books not merely to highlight particular *discoveries* in science as such, but to illuminate the way we *think* about science. It is an interpretive list, not an exhaustive one.

Part I, “The Beginnings,” covers the origins of science itself. Part II, “The Birth of the Method,” explains how and why the scientific method that we now take for granted arose. The rest of the book is an introduction to major works in three different areas: the science of the earth, the science of life, and the science of the cosmos. The order is deliberate. Geology steered us toward the time frame that modern biology demands, and that time frame then led us to a new contemplation of the entire cosmos.

In Parts III–V, alert readers will notice a shift: sometime after the 1940s, the “classics” listed are most often the books that made new theories or discoveries visible to the world, not the journal articles or conference papers that first introduced them to other scientists. So, to understand catastrophism, you will read Walter Alvarez’s 1997 book *T. rex and the Crater of Doom* rather than the 1980 article “Extraterrestrial Cause for the Cretaceous–Tertiary Extinction” written by Alvarez and three coauthors; to understand the Big Bang, Steven Weinberg’s best-selling *The First Three Minutes* rather than any of the (multiple) scientific papers about cosmic background radiation that preceded it.

After World War II, the practice of science became increasingly specialized.* Scientists gained academic recognition, the interest of their colleagues, and (occasionally) financial reward through the careful investigation of individual puzzle pieces, not through attempts to sketch entire scientific landscapes. Scientific theories were formed, evaluated, and supported or rejected by a scientific community that talked, more and more, to itself—and often in a language incomprehensible to outsiders. *The Double Helix* and *The Selfish Gene* are “great books” of biology in quite a different sense than is William Harvey’s *De motu cordis*; Harvey could lay out his discoveries to his colleagues and the general public simultaneously, but neither James Watson nor Richard Dawkins could count on anyone outside an academic department to read his original paper. (“Parasites, Desiderata Lists and the Paradox of the Organism” reached a relatively small audience.) Instead, they had to popularize: synthesize, simplify, and explain.

Yet *The Double Helix*, *The Selfish Gene*, and *De motu cordis* all performed the same task: they opened up, for all of us, a new way of thinking about the natural world.

*This specialization had multiple causes; massive investment by Western industrialists in research projects that might yield commercial gains and the growing role of the university in nurturing (and paying) scientists are probably central, but other factors played a part as well. The phenomenon is beyond the scope of this book, but interested readers might want to consult John J. Beer and W. David Lewis, “Aspects of the Professionalization of Science,” *Daedalus* 92, no. 4 (Fall 1963): 764–84; or Chapter 8 of I. Bernard Cohen, *Revolution in Science* (Harvard University Press, 1985).

•

You do not actually have to read every text I discuss. Pick the great books you want to start with. If you're most interested in biology, or cosmology, you don't have to read all of my recommended texts from Parts I and II before you jump into the recommended texts in Part IV or Part V.

But at the very least, read my chapters *about* the books and the ideas behind them. Scientists who grapple with biological origins are still affected by Platonic idealism today; Charles Lyell's nineteenth-century geological theories still influence our understanding of human evolution; quantum theory is still wrestling with Francis Bacon's methods.

To interpret science, we have to know something about its past. We have to continually ask not just "What have we discovered?" but also "*Why did we look for it?*" In no other way can we begin to grasp why we prize, or disregard, scientific knowledge in the way we do; or be able to distinguish between the promises that science can fulfill and those we should receive with some careful skepticism.

Only then will we begin to understand science.

•

A note on vocabulary: Throughout, I tend to use the terms "theory" and "hypothesis" interchangeably. A twenty-first-century scientist might point out that a theory is more comprehensive than a hypothesis, or longer-lived, or has stronger mathematical underpinnings. But both words refer to a theoretical structure that makes sense of evidence. Since it isn't always clear when a hypothesis becomes a theory, and since scientists in different centuries and different fields tend to use the words in different contexts, I have declined to struggle over the distinction.

The First Science Texts

*The first written attempt to explain the physical world
in physical terms*

Life is short, and Art long, the crisis fleeting; experience
perilous, and decision difficult.

—The *Aphorisms* of Hippocrates, ca. 420 BC

Hippocrates, the Greek doctor, lived in a world of solids and gods.

The solids surrounded him. The grey-green leaves of the olive trees, the earth beneath his feet, the brains and bladders of his patients, even the wine that he drank (in moderation); all of these were absolute, uncompounded, simple. How they came to be in their present forms, how those forms might change in the future—these questions occupied Greek scholars for long hours. But what *composed* them, what intricacies might lie beneath their surfaces and *explain* them; asking this was like interrogating a rock.

Twenty-three centuries later, Albert Einstein and the physicist Leopold Infeld jointly offered an analogy for the Greek plight. The ancient investigator of the natural world was like

a man trying to understand the mechanism of a closed watch. He sees the face and the moving hands, even hears its ticking, but he has no way of opening the case. If he is ingenious he may form some picture of a mechanism which could be responsible for all the things he observes, but he . . . will never be able to compare his picture with the real mechanism and he cannot even imagine the possibility or the meaning of such a comparison.¹

Instead of mechanisms, the Greeks had gods.

The gods lived among the solids of the natural world, wandered through the olive groves, resided in their sanctuaries and shrines. They were always watching, judging, and warning men. “The gods . . . notice all my doings,” explains a character in Xenophon’s *Symposium*, “and because they know how every one of these things will turn out, they give me signs, sending as messengers sayings and dreams and omens about what I ought to do.” The divine suffused and guided the natural order. “All things are full of gods,” the mathematician Thales remarked, 150 years before Hippocrates: all things and all places.²

The Greeks studied, and philosophized about, both the presence of the gods and the properties of solid nature. They were curious, not blindly accepting. But their world was not divided into the theological and the material, as ours is. The divine and the natural mingled freely.

In this they were like their contemporaries. The Egyptians, who had honed astronomical observations to an exactness, had already constructed a calendar that accounted for the flooding of the Nile. They could predict when the star Sirius would begin to appear in the predawn sky just before the sun (“heliacal rising”), and they knew that Sirius’s rising meant the inundation was on its way. Yet the certainty of their calculations didn’t destroy their conviction that the Nile rose at Osiris’s pleasure.³

East of Athens, Persian astronomers were tracking lunar and solar eclipses, hard on the trail of a new discovery: the saros cycle, a period of 6,585.32 days during which a regular pattern of eclipses plays itself out and then begins again. Their equations made it possible to forecast the next lunar eclipse with mathematical precision, which meant that the temple priests had enough time to prepare rituals against the evil forces that a lunar eclipse might release. (According to Persian documents from about 550 BC, precautions involved beating a copper kettledrum at the city gates and yelling, “Eclipse!”)⁴

For the Greeks, too, *supernatural* and *natural* existed in the same space. In fact, it was the god-believing mathematician Thales who came up with what may be the first scientific theory: Despite its

solid appearance, the entire universe is made of water. His writings on the subject are long lost, but Aristotle preserved their argument in the *Metaphysics*, 300 years later.

Thales . . . stated [the foundational principle of the universe] to be water. (This is why he declared that the earth rests on water.) Perhaps he got this idea from seeing that the nourishment of all things is moist . . . and also because the seeds of all things have a moist nature; and water is the principle of the nature of most things.⁵

Water (as it turned out) was the wrong explanation. But Thales's theorizing is the earliest known attempt to peer inside the universal watchcase and see what else, independent of divine power, might be causing it to tick.

Thales's attempt to discover an underlying truth about the universe without reference to the gods ("Thales's Leap," biologist Lewis Wolpert calls it) was probably not the first Greek theory of its kind, but it is the first preserved by name. Thales's actual works have disappeared, though. Thales's Leap may be the first known scientific theory, but the Hippocratic *Corpus*—a collection of some sixty medical texts that explain disease without blaming or invoking the gods—is the first surviving book of science.

The entire *Corpus* was once attributed to the shadowy Hippocrates himself, a fifth-century doctor who grew up on the tiny Greek island of Kos, just off the coast of Asia Minor. Plato tells us that Hippocrates taught aspiring doctors for a fee; the *Corpus*, now generally accepted as a collective project of his students and followers, preserves his lessons.⁶

Many of Hippocrates's contemporaries were priest-physicians, devotees of Aesculapius (son of Apollo, god of healing). To be cured by Aesculapius, a patient would travel to one of the temples of the god and spend the night in the *abatón*, the temple's sacred dormitory, surrounded by the free-slithering snakes that represented the god's presence. Sometime during the night, healing would take place. The serpents would lick the patient's wounds and mend them, or the god would send a dream explaining how the illness

should be treated. Or perhaps Aesculapius himself would appear to carry out the cure. “Gorgias of Heraclea had been wounded with an arrow in one of his lungs,” writes the Greek chronicler Pausanius:

Within eighteen months the wound generated so much pus that sixty-seven cups were filled with it. He slept in the dormitory, and in a dream it seemed to him that the god removed the barb of the arrow with his lung. In the morning he went forth whole, with the barb of the arrow in his hands.⁷

Hippocrates didn’t necessarily disbelieve in Aesculapius’s existence, but he was skeptical about the god’s role in illness. Instead, he looked to the visible world, the ordered cosmos, for explanations. Diseases were not caused by angry deities, and they did not need to be cured by a benevolent one. Even epilepsy, long held to be a sacred condition inflicted by demons or divine possession, was “no more divine nor more sacred than other diseases, but has a natural cause.” The only reason to chalk up illness to the will of a god is ignorance: “This notion of its divinity,” Hippocrates says tartly, “is kept up by men’s inability to comprehend it.”⁸

Hippocrates blamed stomach upsets, fevers, epilepsy, plagues, and illnesses of all kinds on imbalance—too much or too little of one of the four fluids, or “humors,” that course through the human body. When these four fluids (bile, black bile, phlegm, and blood) exist in their proper proportions, the body is healthy. But any number of natural factors might throw them out of whack. For Hippocrates, the chief causes of unbalanced humors were winds (hot winds, for example, caused the body to produce far too much phlegm) and water (drinking stagnant water could lead to an overabundance of black bile). The recommended treatment: restore the body’s balance. Purges and bleeds were prescribed to get rid of excess humors. Herbs (rue, mustard, fennel, stinging nettle) helped to draw out some humors and renew others. Sick men and women were often sent to different climates, away from the winds and waters that were deranging their natural harmonies.⁹

Like Thales’s theories, Hippocrates’s explanations were wrong.

But half the time, entirely by accident, his methods worked. Avoiding marshy, stagnant water *did* improve health. Shifting from a crowded, epidemic-afflicted city to a breezy coastal town *could* bring recovery from an illness. Light nutritious meals *were* helpful to feverish patients—much more helpful than a long onerous journey to the nearest *abaton* and an uncomfortable night spent with snakes.

While the temples of Aesculapius didn't immediately go out of business, Hippocratic methods slowly gained traction—so much traction that in the eighteenth century, physicians were still purging, bleeding, and sending their patients to the seaside. The Hippocratic worldview even lingers today. I know perfectly well that a cold is a viral infection, but I still find myself yelling, “Don't go outside without a coat or you'll catch cold!” as my sons bound into a windy winter morning clad only in T-shirts and shorts.

Thus the Hippocratic *Corpus* stands not only as the first surviving scientific writing, but the first recorded triumph of natural methods over the unearthly.

To read relevant excerpts from The Corpus, visit <http://susanwisebauer.com/story-of-science>.

HIPPOCRATES

(ca. 460–370 BC)

On Airs, Waters, and Places

The nineteenth-century Francis Adams translation, one of the first done for English-speaking lay readers, is still readable and is available both in print and as an e-book. The Adams translation includes *On Airs, Waters, and Places*, along with the *Aphorisms*, *The Oath of Hippocrates*, and several other works, collected together as *The Corpus*. Editions include

The Corpus, Kessinger Legacy Reprint (paperback, 2004, ISBN 978-1419107290).

The Corpus, Library of Alexandria (e-book).

The Corpus, with foreword by Conrad Fischer, Kaplan Classics of Medicine (e-book and paperback).

The Adams translation of *On Airs, Waters, and Places* alone is available online in multiple places.

A more modern translation is included in the Penguin Classics paperback *Hippocratic Writings*, translated by John Chadwick and W. N. Mann, with an introduction by G. E. R. Lloyd (paperback, 1983, ISBN 978-0140444513). The sentence structure is slightly easier to follow, but the two translations are very similar.