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THE AGE OF SCIENCE

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THE AGE OF SCIENCE

WHAT SCIENTISTS
LEARNED IN THE
20TH CENTURY

GERARD PIEL

WITH ILLUSTRATIONS BY
PETER BRADFORD

A CORNELIA AND
MICHAEL BESSIE BOOK



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Frontispiece: Anatomy of the eukaryotic cell, a nearly empty blob of protoplasm in 1900, [see page 268] organizes its large molecules for the ordered, sequential, interacting cycles of reaction that are the life of the cell. Infolding of the membrane brings the interior of the cell into contact with the surrounding medium, from which it incessantly draws substance. Nucleus, containing chromosomes, is the seat of heredity; centrosomes govern the separation of replicated chromosomes at cell division; mitochondria generate cell's energy [see page 285]; the lysosome is the cell's center for recycling molecular piece parts for reuse.

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About This Book and Myself

In this book, I have undertaken to tell my readers what I have learned about what scientists learned in the 20th century, in sum: The work of science is converging on seamless comprehension of the world around us and the identity of ourselves in it. Not since revelation explained everything so long ago has the picture been so complete. Within and beyond the world around us, the work has opened new immensities to understanding.

This time, understanding is anchored in verifiable human experience. The experience I have to report here transpired principally in the 20th century. In the last decades of the century, work in diverse disciplines converged on the same ultimate questions. Re-framed in the light of objective knowledge, those ancient questions assume immediate relevance to life. The work goes on, ever open to enlargement and amendment by experience.

The objectivity of the new knowledge has had public demonstration in technologies of immense subtlety and reach. They are enabling individuals and society with power to any purpose. The rate, scale and irreversibility of attendant economic, social and environmental change compel re-examination of the received premises from which human purpose has hitherto been drawn.

To such re-examination, the scientific enterprise offers the example of reason, tolerance and individual autonomy.

The picture I have put together here, I must state at the outset, is nowhere assembled in the formal literature of science. The authors of the work say little about relevance. Colleagues in a field have ready appreciation of relevance or they would not be engaged in the work.

Not a scientist, like most people, I have put the picture together myself. My readers, I hope, will find here the material and the encouragement to assemble her and his own picture.

As writer, editor and publisher, I have been a spectator at the inquiry after objective knowledge as it has unfolded in the second half of the 20th century. My employment has been to report on work in each field of science to the wider audience of people who want to follow developments on the whole advancing front of the scientific enterprise.

The challenge set for me and my colleagues by that audience was to meet the interest, in the first place, that almost all scientists have in fields outside their own. They begin their lives wanting to learn all about the world around them—every child is a natural scientist. Not far into the experience, they discover that they must narrow their interests and specialize. Laymen in fields outside their own, they look for ways into those fields with the same innocence and readiness to be surprised as not-elsewhere-classified interested laymen. If we could not measure up to their interest, we had no business talking to anyone else.

I stumbled onto the need of this community in the public-at-large during the 1940s in my service as science editor of the then recently established mass-circulation picture magazine, *Life*. For readers whom I came to know during that apprenticeship, I set out to create a magazine of science. Enlisting partners and staff and rounding up the necessary venture capital, I observed a precedent set by my employer. Time Inc. had purchased the name *Life*, all that was left of a defunct funny magazine. For our enterprise, I bought the 102-year-old name of the then moribund SCIENTIFIC AMERICAN. We published the first issue of the new magazine under the old name in May 1948.

For this lifework, I had the most unlikely preparation. My A.B. in history from Harvard College in 1937 was a certificate, *magna cum*

laude, of illiteracy in science. For me, as for most pupils in U.S. elementary and secondary schools even now, recoil from mathematics and science started in earliest grade school. Arithmetic, taught by drill, had to be learned by rote. That invited resistance. Stubborn mistakes in arithmetic brought humiliation in algebra and mathematics from then on.

Science was then (and is still) taught from books. High school and college texts were contained in modest octavos, unlike the four-color quartos—some of the best of them published by W. H. Freeman and Company, the science-textbook subsidiary of SCIENTIFIC AMERICAN—that burden the backpacks of students today. Physics, my teacher gave me to understand, was finite. Like Euclid, it was all there in a little green book, and one of its authors was Charles Elwood Dull. A typical laboratory exercise was to measure the boiling point of water, which I knew to be 212 degrees Fahrenheit. I was instructed to find it at 100 degrees Celsius (C). My measurements missed that target and averaged, I recall to my prolonged confusion, 98.6 degrees C.

The sociology of science

At Harvard, my closest approach to science was a tutorial in sociology, to which my attention was riveted by a graduate student named Robert K. Merton. On the principle of total immersion, he set me to reading the works of the giants: R. H. Tawney, Emile Durkheim, Karl Marx, Werner Sombart, Max Weber and even Vilfredo Pareto, who had just then been translated from the Italian. From this humbling experience I turned to history as my field of concentration.

With the ambition to cover the Second World War that history told me was on the verge, I went to work at *Life* in 1938. My illiteracy in science emerged suddenly, however, as a qualification surpassing my preparation in history. John Shaw Billings had been managing editor of *Time*. Drafted to responsibility for the company's considerable investment in *Life*, he determined to make it the photographic edition of the company's flagship, devoted to the same earnest mission of public instruction in all matters. (Admittedly, this has not been to be believed from the appearance now of the magazines bearing those names at the supermarket checkout counter.) He appointed me to cover science with

the thought that ignorance is safer than a little knowledge, which is so very well known to be a dangerous thing.

As I learned from the moment I undertook my assignment, there was no magazine of science. My colleagues—in domestic and foreign news, sports, Hollywood, the arts, the theater—had numerous sources, starting with *The New York Times*, to tell them what to put in the next issue of *Life*. Science, I discovered, is served by its own press, with more publications than any other human enterprise. Its narrowly specialized journals serve internal communication in each narrow line of work and are unintelligible to the outsider, even to scientists in other fields. I found little that I was able to read about science anywhere, not even in *The New York Times*, which covers science so well today.

For good reason, in those days, scientists were wary of the press: they were too often embarrassed by overheated, improbable accounts of their work. It took some doing to persuade my first two collaborator-scientists to go to work with me and a photographer on a story about his and then her work. Once I had succeeded in getting my first few stories into the pages of *Life*, however, I found it happily easier to persuade the next scientist I approached to work with me.

That was because the camera told the story. Displaying the thing itself in its own inherent interest, the photograph relieved the prose of the task of exciting the reader's interest. In other mass publications, it was the carnival barking for the public's attention that occasioned the embarrassment of scientists in their experience with the press. When the photographs were successful, moreover, they were self-explanatory, to the relief of the prose again. The captions and the story that I wrote for the pictures were certified to be accurate, finally, because my scientific collaborators insisted upon vetting my copy. They had to be conceded that right because they put as much trouble into setting up our stories as our photographer and I did.

For the first time, science had responsible, authentic coverage in a mass-circulation magazine. By the summer of 1944, I found myself welcomed by the scientists I called on for help. I was able to enlist even the remote and proud Rockefeller Institute in collaboration on a story. That was the first isolation and chemical disassembly of a virus, a feat for

which Wendell Stanley, a member of the Institute, was to receive the first postwar Nobel prize in chemistry in 1946. With Stanley's help and the loan of a pint of his tobacco mosaic virus, Fritz Goro, my principal collaborating photographer, was able to demonstrate the distinctive geometry of the virus in four colors stirred by a swimming guppy.

By this time, I was aware that my science department had isolated its own warmly interested audience inside the then 4-million circulation of *Life*. The keen interest they took in the pages I filled in the magazine told me that those readers, so well informed in their own fields, had the same need for a magazine of science that I did.

I learn about the "secret"

Meanwhile I had been learning at my work much that I could not report. This was convincing me that a magazine of science would have to stand on its own independent editorial legs. I would not propose the idea to my employer. For all my poor preparation in science, I had learned the "secret" of the Atom Bomb.

My principal source of intelligence was, naturally, the process of censorship itself. Early in 1942, it became the duty of John Billings to share with me a telegram from the wartime Office of Censorship in Washington. The Office was invoking the voluntary censorship agreement to which the U.S. press had subscribed. The telegram proscribed a long list of topics that started with "atomic energy" and went on, as I recall it now, to put "radium," "uranium," "isotopes," "critical mass" and "atomic fission" on its *Index expurgatorius*.

The recognition of atomic fission by Otto Hahn in Germany, by his collaborator Lise Meitner, in exile from Hitler in Sweden, and then in 1939 at Columbia University had made a minor sensation in the press before I began my assignment. The Office of Censorship telegram made it clear to any reader that this phenomenon now had a place in the war effort. The topics it cited gave me a reading list.

There was already more than enough in the open literature, I found, to give anyone who could read it an idea of how an atomic weapon would work and how it could be made. I could not, of course, be counted as practiced reader of any part of it. With such motivating

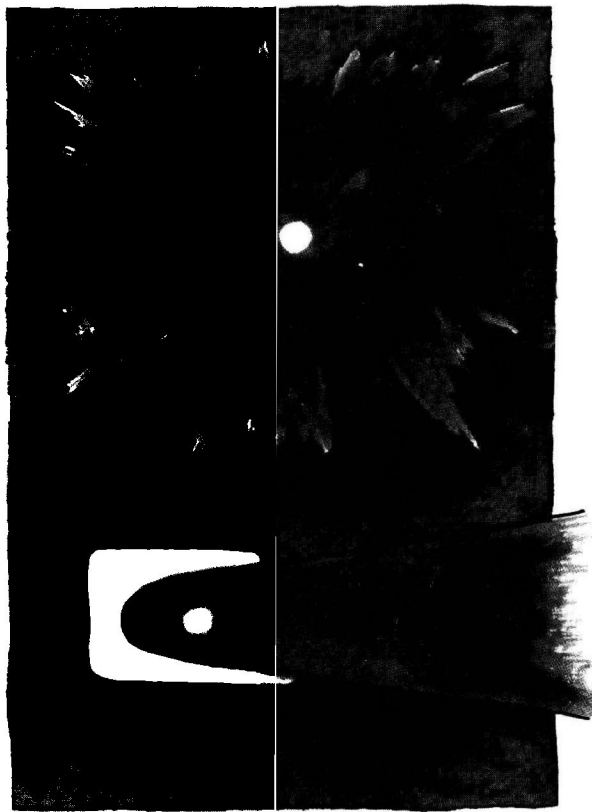
questions in mind, however, I could tease out some meaning even from the paper by E. Fermi and J. A. Wheeler [see page 151]. Outside the primary literature, to my relief, I found a college textbook, published in 1939 before the physicists in the U.S., France and Britain had suppressed publication of their development of the breakthrough. It con-

cluded with a chapter on the promise of energy for free from the nucleus of the atom.

My studies put me on the alert to learn how the atom bomb project was progressing whenever I encountered the censors. Thus, in the midst of our photographing an elegant demonstration of the mass spectrometer at the University of Illinois, Professor A. O. Nier had to call our collaboration to a halt for reasons he could not discuss. With that story, I was eager to show my readers something I had just learned: physicists could tell apart atoms that escape discrimination by chemists. It could be important to tell which was which because, along with differences in weight, "isotopes" of the same chemical identity could

exhibit other significantly different physical properties—such as tendency to fission in a chain reaction. By their interference, the censors told me that mass spectroscopy was being taken seriously as a method for separating the rare and fissionable uranium isotope of atomic weight 235 from the much more abundant and stable isotope 238.

In this context, I learned that the scientists who had been involved in the uranium-fission work at Columbia had all gone to Chicago. Then I was told that I could not interview Professor Nils



Bohr, in exile from Denmark, and admonished that I was not “cleared” even to know that he was in the country. I first heard the name of the Manhattan Project from a procurement agent for the Canadian government when, at night, in the middle of a deserted Manhattan street, he asked in a whisper what I knew about it. The war-effort “priority” of the Canadian government could not compete for supplies with a giant Manhattan Project undertaking in Tennessee. I got an idea of what the enterprise in the hills down there might be about when I overheard at lunch at Eastman Kodak, that one of its bright young physicists was to be saved from the draft by “going to Tennessee.”

All at once, in the late summer of 1944, I had my gathering surmises confirmed by R. W. Wood, professor emeritus of physics at Johns Hopkins. He was helping us to do a story on the “shaped charge” that had made German antitank shells so lethal in the desert battles of North Africa in 1941–1942. The shaped charge had been belatedly adopted in U.S. ordnance and was no secret because the enemy had it first.

Wood had learned of the phenomenon early in the century, in a technical bulletin published by the U.S. Coast Guard. One of its ordnance experts had discovered that armor plate could be punctured by the proper shaping of an explosive charge set upon its surface; for his report, he had fashioned shaped charges to puncture “USA” into a sample of naval armor plate. From his reading, Wood had been able to explain a safecracking to the Baltimore police. They had found no metal shavings but a clean hole in the door of the safe and congealed droplets of steel inside. Wood had not, however, been able to interest the ordnance officers of the U.S. Army in the phenomenon.

In the battle of North Africa, the Germans had demonstrated that a shaped charge in an antitank shell would deliver most of the energy of its explosion in one direction, forward, instead dissipating it in all directions [opposite]. With Wood’s help, our camera showed that much of the force of the directed-energy beam was supplied by the ultrahigh-velocity vaporized heavy atoms of the metal liner that the German armorers fitted into the conical depression in the charge. The forward-facing conical nose of the shell was a windscreen and fuse carrier; a higher order of physics did the armor piercing.

The atoms of vaporized metal made themselves known in our pictures through Wood's own plastic replica of a Johns Hopkins diffraction grating, said to be the most perfect object made by the human hand [see page 34]. The replica served as a filter on the lens of our camera. A graduate student apprentice to Henry Augustus Rowland, who made the first of those perfect gratings, Wood had succeeded him in his professorship. At the outbreak of the Second World War, with Wood in charge, the laboratory found itself serving a huge new market in the U.S. war effort. Wood had devised his plastic replica of the Rowland diffraction grating to meet the demand. At much lower cost, it reproduced the perfect grating with its own perfection. For *Life's* readers, the plastic grating clearly delineated the lines of light at the wavelengths of the vaporized metals in the skyward detonation of the charge.

One of the customers for which Wood had been manufacturing his replicas in quantity was known to him only as the Manhattan Project. Because the security agents refused him clearance to know what the Manhattan Project was using his gratings for—knowledge by which he might have improved the performance of his replicas—he had given the question a good deal of thought. Until he had my ear, Wood had managed to bottle up his indignation at the censors' affront to his age and eminence. Because they had denied him the mystical security clearance, he was free to talk about what he had deduced. The Manhattan Project wanted his gratings, of course, for use in the precise monitoring by spectroscopy of the purity of all materials involved in the project, including the fissionable U-235, present in nature in minute quantity, to be captured on industrial scale from its more abundant stable isotope U-238. From the timing and the volume of orders for his gratings, he could calculate the progress of the enterprise, which, at that time, he estimated at several critical masses of U-235.

Our shaped-charge story had its own relevance to the Atom Bomb. Wood explained that shaped charges offered the surest way, by implosion, to assemble and hold the critical mass of fissionable material in place for the split instant of its explosion. A hollow sphere of high explosive lined with uranium-235 or plutonium would serve the purpose. In working on the shaped-charge story with me, Wood was play-

ing a high-level joke on the censors. Julius and Ethel Rosenberg were nonetheless to be executed in 1953 for betraying this secret.

The demonstration of the atomic weapon, Wood thought, was imminent. He held its manufacture to be a reckless and criminal enterprise. In particular, he had anxieties about the long-term consequences of radioactive fallout. He wanted me to know about the bomb, he declared, because the press should do something about it as soon as it could, if possible, keep it from being used.

The magazine of science

Putting nothing in writing, I reported to John Billings what I had learned, in line of duty, from R. W. Wood. My boss and anyone else with responsibility at Time Inc. would be ready to respond when the time came. Thereupon, I determined that I could lose no time on the start-up of the magazine of science for which responsible citizens, scientists and nonscientists, would now have such urgent need.

The well-timed publication in June 1942 of a "Profile" of Henry J. Kaiser, under my byline, had made him the Paul Bunyan of our country's industrial war effort. He did, in fact, build one-third of all the cargo- and troop-carrying ships launched by our country during the war. Kaiser's 50 convoy-escort carriers, reluctantly accepted by the Navy on orders from the Commander-in-Chief, did critical service as ships of the line in the Battle of the Philippines that saw the destruction of the Japanese navy. Employment as his "personal assistant" through the year 1945 taught me enough about business to secure the launching in May 1948 of the new SCIENTIFIC AMERICAN.

Like my *Life* science department, SCIENTIFIC AMERICAN was the product of the collaboration of scientist and editor. We enlisted the scientists who were authors of work that caught our interest to write the articles about that work. In their concern to reach the wider audience interested in science, they accepted our invitation and then our editing. They collaborated, as well, in producing the illustrations that lifted so much of the burden from our prose.

The magazine did not solve the still outstanding problem of public understanding of science. For the audience to which we addressed it,

we were assured “it fills a real need very satisfactorily.” We had this assurance from our reader and author Albert Einstein, who volunteered it in writing before the end of our second year of publication. Objective evidence from the market confirmed his judgment: the circulation of our magazine in the English language increased steadily over the years to more than 600,000. Uniquely assembled in this circulation was the U.S. community of science, broadly defined to include scientists and the people most interested in what they were doing.

By 1986, SCIENTIFIC AMERICAN had found a worldwide circulation of more than 1 million in English and in nine translated editions—in Italian, Japanese, Spanish, French, German, Chinese, Russian, Hungarian and Arabic, in the order of their launching. In each case, the start-up of the new edition was on the initiative of speakers of that language; they were seeking to fill, so “very satisfactorily,” the need of their fellow citizens. SCIENTIFIC AMERICAN had assembled in its circulation the world community of science.

As my end notes suggest [see page 445], this book is my synthesis of my necessarily close study, then and now, of the articles we published over four decades in SCIENTIFIC AMERICAN. What were accounts of current events, from issue to issue, I have read again as history of a glorious progress in human understanding.

In the first chapter, we will see that scientists do what we all could do if we would clear our heads of preconception and bring our questions in reach of experience. The next three chapters show the world around us reconstructed in continuity with the immensities now opened up within it and outside it. The last three chapters tell the story of life from its beginning, soon after Earth cooled down to hold water in the liquid state, on to the understanding that the people must soon find inside their own heads the purpose of human existence.

CONTENTS AND ILLUSTRATIONS

xi	About This Book and Myself
1	Chapter 1 Science Is What Scientists Do The ground of knowledge. Scientific revolutions. Galileo's inclined plane. Galileo's parabola. No higher authority.
45	Chapter 2 Revolution at the Ground of Knowledge The laws of motion. The law of gravity. Phlogiston and chemistry. Electricity and magnetism. Relativity, Special and General.
109	Chapter 3 Light and Matter Never at rest. Discovery of the electron. No irreducible atom. Not what but whence. Quantum electro- and chromodynamics.
171	Chapter 4 Space and Time The force of gravity. Geometrodynamics. Stellar parallax. Cosmic redshift. Black holes. The inflationary Big Bang.
241	Chapter 5 The Living Cell Mendel's gene. The cell and its nucleus. Constitution of living matter. The origin of life. Symbiosis in evolution.
309	Chapter 6 Earth History and the Evolution of Life Plate tectonics. The first signs of life. Voyage of the Beagle. Natural selection. Increasing diversity. The vertebrate eye.
377	Chapter 7 Tools and Human Evolution The economic problem. Objective knowledge. Arrival of the primates. The Hominoidea. The man-apes. The cultural revolution. <i>Homo erectus</i> . The dawn of purpose. <i>Homo sapiens</i> .
445	End Notes
449	Index
460	Acknowledgments

ILLUSTRATIONS

ii	Frontispiece: <i>Anatomy of the eukaryotic cell</i>
	Chapter 1 Science Is What Scientists Do
6–7	<i>In orders of magnitude or powers of ten</i>
14–15	<i>Copernican revolution</i>
18	<i>Galileo's inclined plane</i>
19	<i>Newton's first law of motion</i>
30	<i>Prism separates colors in visible "white" light</i>
31	<i>Redshift measures expansion of universe</i>
	Chapter 2 Revolution at the Ground of Knowledge
57	<i>Discovery of oxygen</i>
58	<i>Law of definite proportions</i>
59	<i>A "valence" joined atoms in compounds</i>
60	<i>Laws of electrolysis</i>
61	<i>Periodic table of the elements</i>
65	<i>Heat is motion</i>
66	<i>Distribution of heat energy</i>
67	<i>"Ultraviolet catastrophe"</i>
74	<i>Electricity and magnetism</i>
75	<i>Induction of electric current</i>
76	<i>Faraday's "field" of electromagnetic force</i>
77	<i>Electromagnetic wave</i>
90	<i>Velocity of light</i>
91	<i>Attempt to measure aether "wind"</i>
92–93	<i>Effective mass of the photon</i>
	Chapter 3 Light and Matter
113	<i>Wave-particle duality</i>
114	<i>Wave nature of light</i>
115	<i>Particulate nature of light</i>
121	<i>Charge-mass ratio of the electron</i>

122	<i>Wave nature of the electron</i>
132	<i>Atom as solar system</i>
133	<i>Circumference of electron orbits</i>
134–135	<i>Electron-wave-cloud atom</i>
146	<i>Nucleus of the atom</i>
147	<i>Particle accelerators</i>
156	<i>Overthrow of parity</i>
166	<i>Four particles and four forces</i>
167	<i>Matter and energy</i>

Chapter 4 Space and Time

185	<i>Measurement of parallax</i>
190	<i>Cavendish experiment</i>
191	<i>Curvature of spacetime</i>
192	<i>Visualization of spacetime</i>
195	<i>Hertzsprung-Russell diagram</i>
200–201	<i>Thermonuclear synthesis of elements</i>
216	<i>Accretion disk</i>
217	<i>Accretion disk jets</i>
218–219	<i>Collapse of a star into a black hole</i>
224–225	<i>The nucleus of the Galaxy</i>
226	<i>Spherical “corona”</i>
234–235	<i>Big Bang genesis of the universe</i>

Chapter 5 The Living Cell

244	<i>Inheritance is by combination, not blending</i>
262–263	<i>Highly structured large molecules</i>
264–265	<i>Transcription, translation and replication</i>
272–273	<i>Replication of eukaryotic and prokaryotic cells</i>
276–277	<i>Mechanical function in eukaryotic cells</i>
282	<i>Photosynthesis transforms solar energy</i>

283	<i>Respiration transforms chemical energy</i>
300–301	<i>Eukaryotes originated in symbiosis of prokaryotes</i>
305	<i>Eukaryote genes are conveyed</i>
	Chapter 6 Earth History and the Evolution of Life
312–313	<i>Submarine mountainous ridge and tectonic plates</i>
314–315	<i>Upwelling of convection cells at mid-Atlantic ridge</i>
327	<i>Earth's structured interior</i>
346–347	<i>Cyclic turnover of atmosphere and hydrosphere</i>
354–355	<i>Supercontinents of 800 and 200 million years ago</i>
370–371	<i>Ever-increasing diversity of life</i>
372	<i>Evolution in stages of increasing complexity</i>
	Chapter 7 Tools and Human Evolution
387	<i>The primate family tree</i>
388	<i>Evolution of pelvis and skull</i>
418–419	<i>Three agricultural revolutions</i>
420	<i>High-yielding chinampas gardens</i>
434	<i>Three population explosions</i>
435	<i>Demographic transition</i>