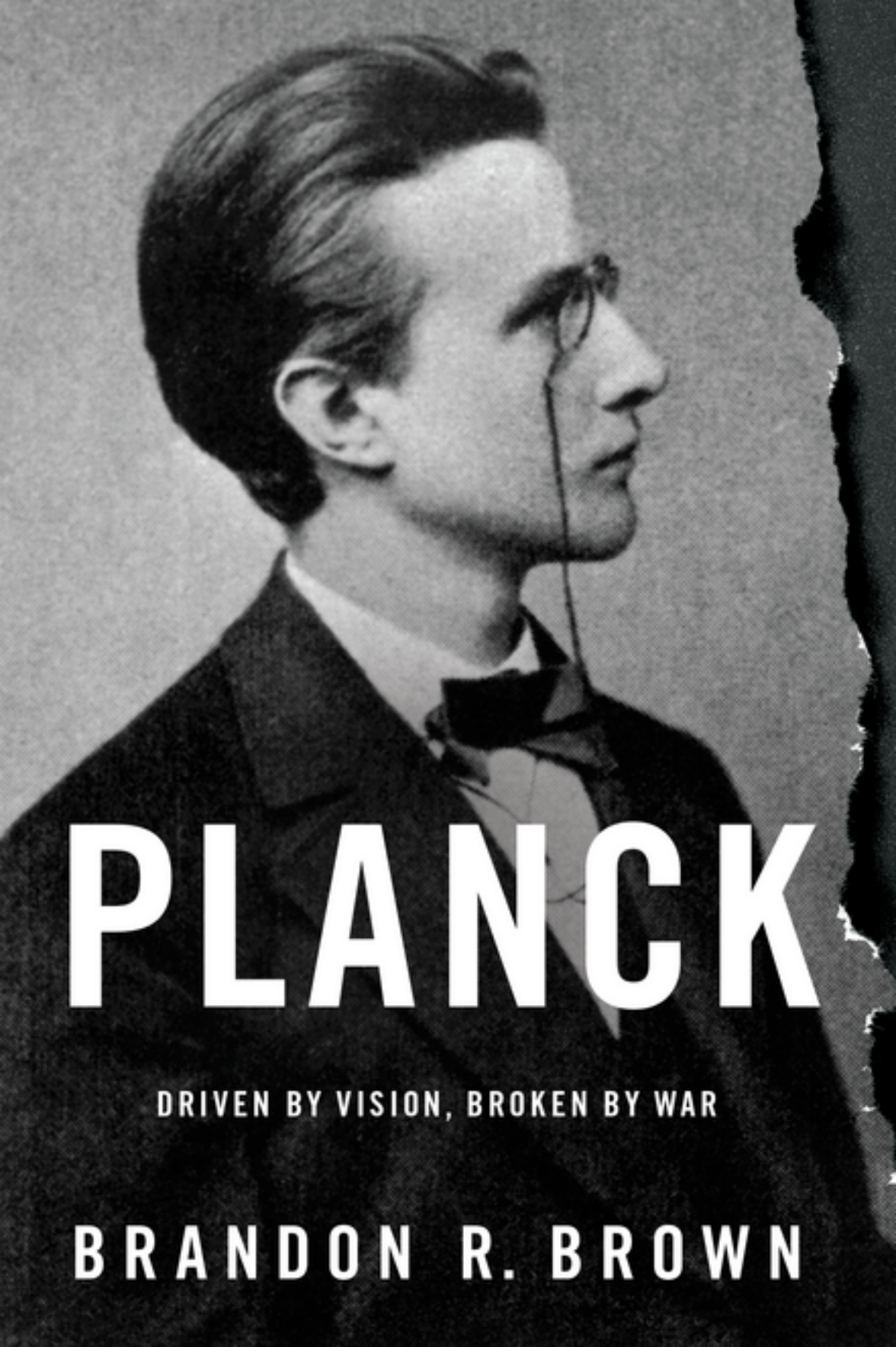
PLANCK
DRIVEN BY VISION, BROKEN BY WAR
BRANDON R. BROWN

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Published in the United States of America by
Oxford University Press
198 Madison Avenue, New York, NY 10016

Cover photo courtesy AIP Emilio Segre Visual Archives.

Library of Congress Cataloging-in-Publication Data
Brown, Brandon R.
Planck : driven by vision, broken by war / Brandon R. Brown.
pages cm
Includes bibliographical references and index.
ISBN 978–0–19–021947–5 (hardback : alkaline paper) 1. Planck, Max, 1858–1947.
2. Physicists—Germany—Biography. 3. World War, 1939–1945—Science—Germany.
4. National socialism and science. 5. Planck, Max, 1858–1947—Family. 6. Planck, Max,
1858–1947—Friends and associates. 7. Einstein, Albert, 1879–1955. 8. Physics—Germany—
History—20th century. 9. Science—Germany—History—20th century. 10. Germany—
Intellectual life—20th century. I. Title.
QC16.P6B76 2015
530.092—dc23
[B]
2014042822

Printed in the United States of America
on acid-free paper

To the writer who told me, “Stick to physics, and write from there.”

Contents

Preface

Science has often found unique ways to humiliate its devotees. In 1964, two youngish men crawled inside an enormous metal basket carrying brushes and a bucket of soapy water. The 20-foot-long radio receiver looked like the head of a lacrosse stick, but functioned like an ear horn, opening to the heavens and listening to the cosmos. They scrubbed and scrubbed, hoping the caked layer of pigeon poop might (gloved fingers crossed) be the cause of the mysterious, frustrating, and unwanted signal. Maybe taking a manual Q-tip to the horn antenna's ear would clear up the one note of noise.

They were an unlikely pair in an unlikely place. Robert Woodrow Wilson was a Houston native, and Arno Penzias was a German immigrant who had escaped one of Hitler's camps at age six. And this hill overlooking New York City was not a normal place to pursue astronomy. Bell Labs had designed the antenna to communicate with the new Telstar satellite, but with down time from its primary duties, the owners let astronomers give it a whirl. Wilson and Penzias wanted to probe the sparse outer reaches of the Milky Way galaxy.[1]

They needed the signal to be pristine, and with great effort, they had fine-tuned and calibrated the big basket for their measurements. They found ways to filter out local radio broadcasts, noisy radar echoes, and other extraneous signals arising from their own electronics. After all this, the horn still had some kind of tinnitus—there was a little ringing at the wavelength 7.35 centimeters. No matter where in the cosmos they pointed the antenna, no matter the time of day or night, there was the same ringing, always the same strength. The only thing that all directions and all times of day had in common, they figured, was bird crap. When they ran the big device on chilly nights, pigeons gathered at the warm end and made a mess.

Bird crap removed, they pointed the instrument again away from the thick plane of the Milky Way galaxy and out into the darkest, deepest reaches of space. They wanted to make sure the signal was gone, like listening for an unwanted hum in an excellent audio system. Just sit still in

the dark until the speakers emitted only pristine, quiet beauty. But no, the ghastly noise peak was there again, as strong as ever. The universe appeared to be emitting radiation similar to that from the Amana Corporation's new microwave ovens. With heavy sighs, Wilson and Penzias recorded and annotated the mysterious tone, just in case it wasn't a fingerprint of their own incompetence.

The two had unwittingly made a critical discovery, one for which they would win the Nobel Prize in Physics: The microwave signal is a dim but very real glow emanating uniformly from the universe itself. In further measurements, the "cosmic microwave background" perfectly fit an equation dating to 1900, when the German physicist Max Planck described the natural radiation emitted by *any* object at *any* temperature, be it a bright fiery star, a lukewarm nickel in your pocket, or in the case of the universe's background signal—a faint afterglow of the Big Bang (Figure P.1).[2]

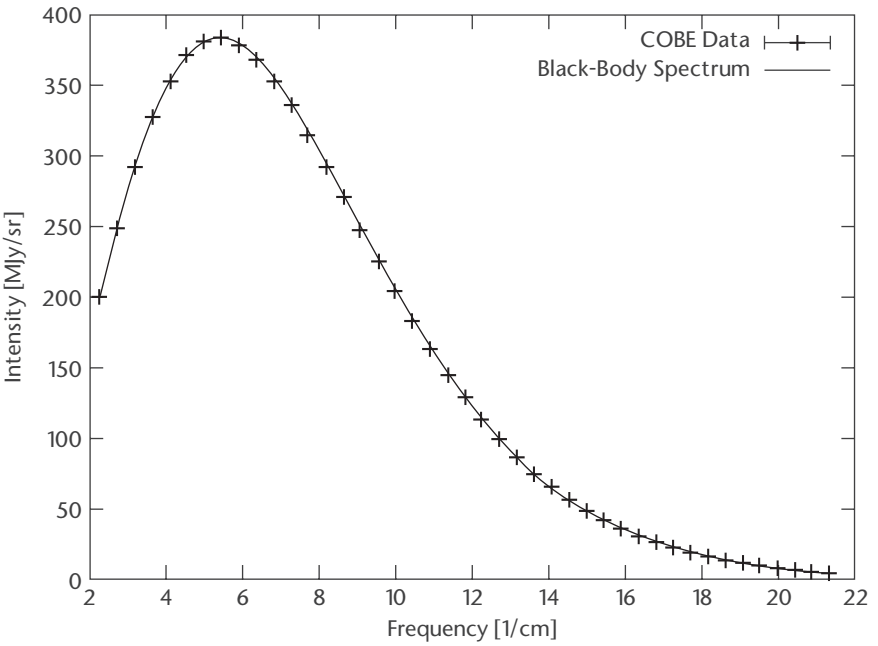


Figure P.1. Spectrum of the cosmic background radiation, or the residual glow of the universe, when all galaxies, dust, and so on are removed from the signal. When these data from the COBE satellite were presented in 1990, they precipitated a spontaneous standing ovation. Planck's law (*the line labeled Black-Body Spectrum*) fits the universe's signal (*crosses*) so precisely that the uncertainties in the data points are much smaller than the line thickness used here.

As of this writing, humanity now has a cosmic ear horn in orbit, and it listens with the best clarity yet to these low-frequency signals from the universe. Similar in size and shape to the instrument used by Wilson and Penzias, it rotates its narrow view about once every minute, sweeping out a ring of measurements like a second hand. In the cosmic background's blemishes and tiny inconsistencies, the Planck satellite can see residual clues describing the universe's initial fireball—a fingerprint of the *first* physics, or the very hands of God, depending on whom you ask. The satellite's namesake, the late German physicist Max Planck, did not think much about astronomy, and when his younger friend Albert Einstein turned his own gaze to the cosmos, Planck told him it was probably a waste of time. Yet, when the European Space Agency decided it needed a catchier project title than the acronym COBRAS/SAMBA, the name "Planck" was an easy sell to all parties.

It had been just as easy to sell his name after World War II, as the Allies looked to rebrand all German research programs. Albert Einstein, estranged from Planck and bitterly divorced from Germany, composed a tribute to the man on behalf of American scientists. "Even in these times of ours," he wrote in 1948, "when political passion and brute force hang like swords over the anguished heads of men, that even in such times there is being held high and undimmed the standard of our ideal search for truth. This ideal, a bond forever uniting scientists in all times and in all places, was realized with rare completeness in Max Planck." And according to Einstein, Planck's 1900 discovery, "became the basis of all 20th century research in physics and has almost entirely conditioned its development ever since. Without this discovery it would not have been possible to establish a workable theory of atoms and molecules and the energetic processes which govern their transformations."[3] This was not a hyperbolic statement then, and it holds today.

Our understanding of the building blocks and the structure of matter trace directly to Planck's work. And our understanding of how separate chunks of matter then exchange energy—how they chat and inform one another—also starts with Planck's primary discovery. He expertly described the radiation that leaks from any and every object in the universe. No matter what object, and no matter its temperature, we need just one equation—Planck's—to describe every single case. At the time he penned his formula, scientists were years from discovering galaxies beyond our own, never mind looking for remnants of the Big Bang. Planck, just

like Wilson and Penzias, had been trying to diagnose one thing when he stubbed his toe on something much different and even more important. In trying to once and for all describe this baffling glow from all things—called "black-body radiation"—Planck found the key that unlocked the modern age of physics. Even though he contemplated the physics governing the light *inside* of a small, dark cavity within a brick, his satellite now gazes in the opposite direction—the ultimate outward—and finds the same fundamental physical law reigning supreme.

Planck is known as the father of quantum theory, and most textbooks give students little more than that. He was German. He was a theoretical physicist (versus an experimental, or laboratory-based one), with a firm grasp of mathematics. In the typical side-column photo, we see him later in life: bald, and stern. He discovered quantum theory. He had a mustache. And that's about it (Figure P.2).

But there is so much more to Planck the scientist and Planck the person.

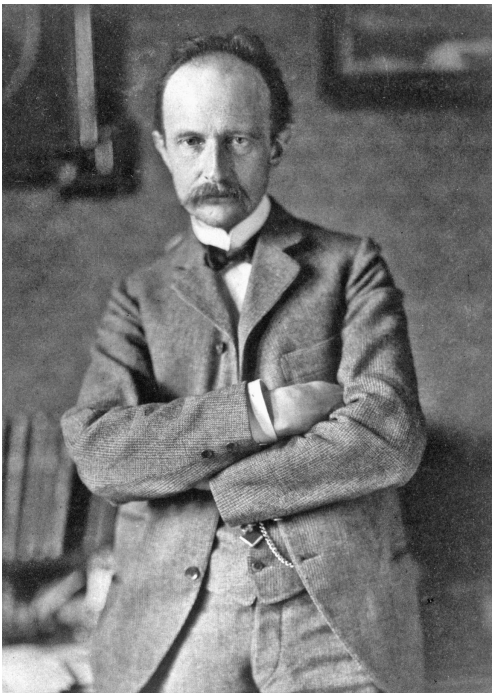


Figure P.2. Max Planck in 1906, at age 48.

Photograph by Rudolf Dührkoop, courtesy AIP Emilio Segre Visual Archives, W. F. Meggers Gallery of Nobel Laureates.

Max Planck had elevated and refined the formerly obscure notion of "entropy" in the universe—he made it not only a useful tool, but also a central topic. Relevant for diagnostics ranging from car engines to black holes, entropy has even provided a template for the study of information itself. Planck also made great contributions to chemistry, to the then-infant field of statistical mechanics, and to Albert Einstein's new ideas of relativity.

His human story is equally rich: musical ability, a cherished family, and a sterling reputation; a devotion to his homeland, come what may; a delicate and poignant relationship with Albert Einstein. Planck was first and last a communicator. He assembled prose in the manner of a master watchmaker, and he launched his mind at much more than physics. Planck was also a person in the right place at all the wrong times, watching ridiculous advances in technology reformat his world and then tear it apart. In 1933, just as little Arno Penzias was born into a nervous German Jewish family, Planck was trying to reason with the new German Chancellor Adolf Hitler.

After Planck's death, the Royal Society sent Charles Darwin's grandson, Charles George Darwin, to Berlin. Even though the Britain of 1948 had no love lost for Germany, one name transcended the garish wounds of two wars. "But if Planck the originator in scientific achievement commands the homage of our heads," Darwin said, "no less does Planck the man deserve the approbation of our hearts. His character was modest, kindly and blameless, and amid the trials of distressful times and through many personal sorrows he preserved his integrity and his quiet courage."

There are many sensible reasons that Planck's story is not better known, particularly in the English language. His library, personal journals, notebooks, and letters were destroyed with his home in World War II. What exists of his correspondence with other German scientists is often handwritten in an antiquated form of German shorthand, *Sütterlin*, understood by ever-fewer scholars. And he was certainly eclipsed by the younger, bolder, and more brilliant Albert Einstein. Whereas Planck was very much a nineteenth-century Prussian gentleman walking into a wholly new twentieth century, Einstein saw himself as a modern man of the world, and he benefited from the dawn of global media. He also enjoyed a long presence in America as it took the mantle of worldwide scientific leadership from Planck's vanquished Germany.

Humbly, I now try to tell some of Max Planck's rich story. I admit from the start that I can't approach his life as a science historian, but I come to Planck as a physicist long fascinated by his breakthrough and haunted by

those sad eyes. I have for many years wanted to know who he was, what shaped him, and how we might best understand his circumstances—or, as we might say in physics, his fundamental principles, his initial conditions, and his boundary conditions. What follows are my best attempts to discover this German physicist and share the results—not just with scientists, but with any interested reader, since we are bathed one and all, from every direction, in the glow of his law.

Brandon R. Brown, Summer, 2014.

Acknowledgments

I humbly offer my gratitude to Dr. Dieter Hoffmann for his helpful advice and communication. May American academics learn something not only from his decades of scholarship on German science, but also from his hospitality to a nonspecialist.

For enormous language and cultural translation help, I thank Dr. Imke Listerman and Candice Novak. (Any residual translation errors are without a doubt mine alone.)

For generous, enjoyable, and immensely helpful discussions on many technical topics in this book, I thank Dr. Horacio Camblong.

For the sabbatical of 2012–2013, I thank my Dean's office, as well as my faculty union, the USFFA. I thank the University of San Francisco's faculty development fund for supporting international travel, and translation fees. I also thank my home department for great support and camaraderie throughout this project.

I acknowledge the cooperation and assistance of the following archives and institutes: Archiv der Max-Planck-Gesellschaft in Berlin-Dahlem, with special thanks to Dr. Kristina Starkloff, Dirk Ullmann, Susanne Uebele, and Bernd Hoffmann; the Deutsches Museum Archiv in Munich, with special thanks to Dr. Matthias Röschner; the Archives of the American Philosophical Society in Philadelphia, with special thanks to Earle Spamer; the American Institute of Physics, with special thanks to Melanie Mueller; the Emilio Segre Visual Archives, with special thanks to Savannah Gignac; the Niels Bohr Library, with special thanks to Felicity Pors; Brookhaven National Laboratory, with special thanks to Jane Koropsak; Stadtmuseum Kassel, with special thanks to Dr. Alexander Link; and finally Germany's Bundesarchiv, with special thanks to Sabrina Bader.

For helpful conversations and good ideas along the way, I thank Morgen Daniels, Dr. Bob Eason, Dr. Michael Eckert, Arden Hendrie, Peter Hennings, Victor Lin, Dr. Elliot Neaman, Spin City Coffee, Dr. Dean

Rader, Rachel Reed, Dr. Jennifer Turpin, Dr. Aparna Venkatesan, Pete Zuraw, and Terry Zuraw.

I thank my agent Jennifer Lyons for her advice and advocacy.

I thank my editor Jeremy Lewis and his great team at Oxford University Press for guidance, enthusiasm, and clarity.

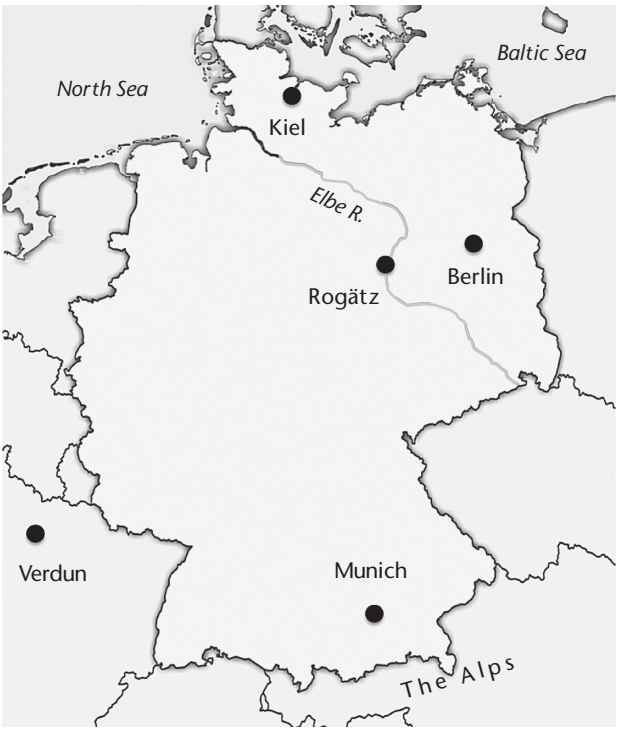
I thank my dozens of teachers, professors, and colleagues who sparked and honed interest. For writing training, I thank in chronological order: Mom, Dad, Mrs. Gohmert, Ms. Miller, Max Apple, Glen Blake, Ehud Havezelet, and Rich Daniels. For years of writing instruction and special advice for this project, I also thank Marjorie Sandor and Tracy Daugherty. For reporting training, I want to thank Johnny Mac and all my fellow Santa Cruz slugs.

Finally, I thank my wife, Dana Smith, for years of brainstorming, months of proofreading, and endless patience with my Planck obsessions.

Max Planck Timeline

1858	Karl Ernst Ludwig Marx Planck (M.P.) born in Kiel, Denmark.
1867	Planck family moves from Kiel to Munich, Bavaria.
1870	M.P.'s older brother Hermann dies in the Franco-Prussian War.
1871	Wilhelm I of Prussia proclaimed Emperor of newly formed Germany.
1874	M.P. begins studies at the University of Munich.
1879	M.P. defends dissertation and notes entropy as the arrow of time.
1880	M.P. defends habilitation thesis.
1885	M.P. appointed associate professor of theoretical physics, University of Kiel.
1887	M.P. weds Marie Merck in Munich.
1888	Karl Planck, first child of M.P. and Marie, is born.
1889	M.P. accepts position at the University of Berlin. Twins Emma and Greta Planck are born.
1893	Erwin Planck is born, as the last child of M.P. and Marie.
1894	M.P. elected to Berlin Academy of Sciences turns attention to black-body radiation.
1900	M.P.'s father Wilhelm dies in Munich. M.P. effectively launches quantum theory during brief presentation in Berlin.
1903	Max Laue obtains PhD under thesis advisor M.P.
1905	The Plancks move to house in Grunewald suburb of Berlin. M.P. elected president of Prussian Physical Society. "Miracle year" for Albert Einstein, with five groundbreaking publications.
1906–1908	M.P. publishes relativistic dynamics, building on Einstein's initial work.
1907	Austrian student Lise Meitner comes to Berlin to attend M.P. lectures.
1909	M.P. visits the United States and gives eight lectures at Columbia University. On his return, M.P.'s first wife Marie dies. At a conference in Salzburg, M.P. meets Albert Einstein for the first time.
1911	M.P. marries Marga von Hoesslin. First meeting on quantum theory at the Solvay conference, in Brussels. M.P. provides clear

	statement of Third Law of Thermodynamics. Hermann Planck born to Max and Marga Planck.
1911–1913	M.P. introduces a "zero point" energy of the vacuum in his second theory of thermal radiation.
1912	M.P. appoints Lise Meitner as his new assistant. Karl Planck is admitted to a sanatorium in Kassel.
1913	M.P. becomes rector for the University of Berlin and joins the Kaiser Wilhelm Society (KWG). Albert Einstein officially accepts academic post in Berlin. Grete Planck is admitted to a sanatorium.
1914	World War I begins. M.P.'s mother Emma dies in Munich at age 93. M.P. signs "Manifesto of the 93 Intellectuals" defending Germany. Erwin Planck is taken prisoner by French forces.
1916	Karl Planck dies in the battle of Verdun.
1917	Grete Planck dies shortly after childbirth; her daughter Grete Marie survives. Erwin Planck is released from captivity in France and returns to Berlin.
1918	Kaiser Wilhelm II abdicates his throne, leading to end of World War I.
1919	M.P. awarded 1918 Nobel Prize in Physics. Emma Planck dies in childbirth; her daughter Emmerle survives.
1920	M.P. and colleagues launch *Notgemeinschaft* to fund German science.
1923	Attempted Nazi coup fails in Munich. Erwin Planck marries Nelly Schoeller.
1926	M.P. officially retires as a professor (duties continue for some time).
1930	M.P. becomes president of the KWG.
1933	Adolf Hitler is appointed Chancellor, and Erwin Planck resigns from government. M.P. has face-to-face meeting with Hitler.
1937	M.P. steps down from presidency of the KWG.
1938	M.P. is forced from presidency of the Prussian Academy of Science.
1939	Germany invades Poland, officially starting World War II.
1943	M.P. and Marga move to Rogätz due to ongoing bombing in Berlin.
1944	Adolf Hitler survives assassination attempt. Erwin Planck is arrested in connection and found guilty of treason.
1945	Erwin Planck is executed at Plötzensee Prison. M.P. and Marga are rescued by the American Alsos Mission.
1947	Karl Ernst Ludwig Marx Planck dies at age 89 in Göttingen.



This map of modern Germany highlights key locations and features for the life of Max Planck (1858–1947), while omitting many other features. The modern nations bordering Germany are, moving clockwise from the top: Denmark, Poland, Czech Republic, Austria, Switzerland, France, Luxembourg, Belgium, and the Netherlands.

PLANCK

I

October 1944

When Max Planck heard his son's verdict, he addressed a letter to Adolf Hitler. He wrote with calm respect and a surgeon's precision, as always, but he conveyed his shock. And the man of physics bartered as follows: If I am a national treasure, as you say, then show mercy. Reward this 87-year-old man's lifetime of work for the Fatherland by sparing my son's life.

Before this unique letter, Planck had spent decades methodically separating the worlds of work and family. He was a dignified Prussian gentleman, after all, so he didn't mention personal heartbreaks in his scientific correspondence. Eventually, some close friends believed he relied on work to escape the weight of family tragedy. But by 1944, as an avid mountain climber long past his summit, Planck had lost his footing, and the letter was like a pick to the mountainside, his best shot to halt a steep slide.

At the time, he stood as one of the most decorated physicists on the planet. The name Planck was well on its way to physics immortality, and he attracted nearly reverential respect and praise from scientists everywhere. He had won a Nobel Prize for unleashing the revolution of quantum theory. As he put his physics calculations to the side late in life, he emerged as a scientific philosopher and spokesman, with frequent public talks and radio interviews in peacetime and in war.

But during World War II, Planck's beloved homeland had also come to tarnish him. As an old friend of Albert Einstein (the despicable king of "Jewish Physics" to some), Planck faced decorated enemies now in science, like fellow Nobel laureates Johannes Stark and Philipp Lenard, and within the Reich leadership, like Reich Minister of Propaganda Joseph Goebbels. The Gestapo investigated his heritage, and newspaper columns referred to him as a "white Jew," one of the pied pipers who had supposedly led German science astray, taking

students and colleagues into the barren field of more mathematical and less meaningful science.[1] His questionable associations didn't end with Einstein either; Planck had befriended other Jews, like the chemist Fritz Haber and the nuclear physicist Lise Meitner, both of whom had fled Nazi Germany. Worst of all, he'd requested a face-to-face meeting with Hitler in the spring of 1933, during the new Chancellor's first months of power. Planck's perceived criticism sparked a notoriously angry and one-sided confrontation.[2]

Erwin Planck was Max's long-time hiking partner and his favorite child. As a high-ranking member of the German government preceding Hitler's ascent, Erwin was no fan of the Nazi regime. They had in some cases murdered his friends and former colleagues. Erwin resigned from government in 1933 and accepted a job with a leading German manufacturer, staying away from politics. But in the summer of 1944, a briefcase exploded in Hitler's inner sanctum, barely missing its mark. The wounded Führer took to the radio swearing vengeance, and the Gestapo arrested hundreds in the days that followed. They took Erwin on July 23, accusing him of high treason against the Fatherland. They linked him to the conspirators, and for three months, Erwin awaited trial in prison. His captors denied the visit requests of Erwin's wife Nelly and his father. As with most prisoners so accused, he suffered intense interrogation sessions and, most probably, torture.[3]

Though Erwin apparently had no direct involvement in the bombing, he had helped draft a secret constitution for a post-Nazi government. Under interrogation, he admitted knowing the conspirators but claimed to have ended communication with them years earlier. In truth, he had provided them contacts and recruited supporters.[4]

The trials spawned by the assassination attempt began in August. Max Planck would have followed the few that were publicized, via radio and newspaper—the regime never wanted the public to know the conspiracy's full measure.[5] In the first weeks after the July bombing, 110 death sentences—*Tod!*—fell on suspects.[6] In bridging Germany's proudest moments to the horror of its Nazi present, Max Planck would only need to place his father Wilhelm Planck at one end and his helpless son Erwin at the other. His father, a nineteenth-century judicial scholar, helped refine Germany's civil code, proudly building upon the rewards of the enlightenment. But a fascist regime now paraded Erwin into the notorious People's Court, with an all-powerful judge sneering at due process.

We have a photo of Erwin standing at trial (Figure 1.1). His look, with a slack face and eyes unfocused, says he knows the verdict before hearing it. Max and Nelly referred to Erwin affectionately as "Mops," a German term for pug dog. Despite a family built on hope, Erwin had little in that moment. It was October 23 when Roland Freisler, president and presiding judge of the People's Court, spit another guilty verdict and another sentence to death by hanging, this time for Erwin Planck, son of the nation's figurehead of science. And so the father's race to save the son began. As he later confided to a friend, he would set "Heaven and Hell in motion" to that end.[7] If the sentence could be commuted to life imprisonment, Erwin might survive to the war's end, and they might see one another again.

For now, if Erwin was treated like others with a death sentence, he was escorted into Plötzensee Prison, a large three-story cross of a building. Built northwest of Berlin in the late nineteenth century, the site now houses a memorial to the thousands murdered there. The majority of executions took place in the last years of World War II. Most victims at Plötzensee

Figure 1.1. Erwin Planck on trial in the People's Court, October 1944.
Courtesy Archiv der Max-Planck-Gesellschaft, Berlin-Dahlem.

were either foreign nationals or Germans, like Erwin and his boyhood friend and neighbor Ernst von Harnack, also implicated in the resistance.

Convicts typically entered House III, the cellblock adjacent to the execution chamber. For many years, a guillotine served as the primary instrument, but in 1942, the Reich installed a large steel beam against one wall of the eerily blank cubic space, and there they mounted a set of iron hooks. In this way, they could carry out eight executions at a time, sometimes using piano wire. Over 250 executions took place in September of 1944 alone, including suspected members of the German resistance, as well as many from the Czech resistance. And as with the court sessions, the executions were filmed for Hitler's later viewing, particularly for anyone suspected in the bomb plot.[8]

By 1944, Planck's inner circle had either fled Germany, or, not sharing Planck's incredible vigor, had passed away. Erwin was now his father's closest confidant and best friend. He was also the last survivor of Max's four children with his beloved first wife, Marie. Erwin represented the last glimpse of incredible days in the early century, when optimism wasn't just a guiding principle—it was an obvious conclusion.

In 1905, the Planck family, the Kaiser's empire, and Max's well-nurtured garden of German physics all looked poised for decades of health and growth. New ideas and technology bristled in Berlin like a spring burst of wildflowers: electricity, automobiles, radio waves, moving pictures, and on and on.

By that year, Planck had made his most critical contribution to science, though very few recognized it at the time, including Planck himself. He'd been drawn to hints of transcendent and universal principles underlying a mysterious and little-studied phenomenon known as "black-body radiation," a type of energy that emerges from within matter. If one removes the reflected light bouncing from an object and measures only that emerging from its interior, every object, regardless of shape, size, or material, throws off the same exact type of radiation. A train car, a puppy, and a straw hat, if all the same temperature, give off the same faint signature: the same exact outline of frequencies, mostly in the infrared. Max Planck wanted to know *why*, rightly intuiting that the answer would dwarf the question. To see the experimental data from this realm of thermal physics was like walking into a world where a breeze would set every object ringing with the tone of a single wind chime—buildings, street signs, and ham sandwiches all giving the same exact tone. After years of toil, Planck uncovered a new

fundamental constant, *h*, the "quantum of action" as he came to call it. This constant unlocked the radiation's underlying mathematical machinery, and when Planck first tried to describe what he saw, he unknowingly sparked the quantum revolution.

But most exciting to Max himself, and of great relevance to physics still, he had proposed the idea of "natural units": a system of measurements based only on fundamental universal constants, with no bias from human preference, convenience, or experience. The length of an arm or the span of a heartbeat would have no say in this system. Natural units would be so objective, Max Planck said, that any group of scientists, not merely humans but even extraterrestrials, would necessarily arrive at these units and agree on their values. To this day, we still refer to the Planck time (5.39106×10^{-44} second) and the Planck length (1.616199×10^{-35} meter). These are absolute measures derived directly from the fabric of the cosmos, via fundamental constants. We compute them by multiplying and dividing different combinations of the speed of light *c*, the universal constant of gravitation *G*, and Planck's own *h*, until we respectively obtain measures of length or time.[9] (The Planck length and Planck time are unfathomably tiny and short. As the city of San Francisco dwarfs a single proton, so that proton then dwarfs the Planck length by the same factor.)

In fact, since Planck unearthed the values of multiple fundamental constants with unprecedented precision and accuracy, he propelled the entire field of physics into a more numerically precise age. Quantum field theory, the grandchild of Planck's quantum notion, is now the most physically accurate theory in the history of science; its precision is such that a quantum doctor would be able to predict the lifespan of a patient to within a fraction of one second, or a quantum economist would be able to predict next year's U.S. gross domestic product to within $50.

Planck had also helped cement Germany, if not Berlin itself, as the absolute center of physics on Earth. German was *the* required language for any student of the increasingly respected subject of physics, and the journal *Annalen der Physik*, where Max served as editor, was its leading voice. As electric power innervated the cities of Europe and radio messages took their maiden voyages across oceans in an instant, interest in physics soared, classrooms filled, and the brightest students from Europe (and America) queued to get in.

The center of Planck's personal universe in 1905 was a new suburban address: Wangenheimstrasse 21 in Grunewald (literally "green forest"), a

Berlin suburb. Neighbors reported a dark-paneled interior with down-to-earth furnishings—every detail spoke to a sober and strict atmosphere.[10] At this address, Max enjoyed his ideal study and library, a chamber for intensive mornings of thinking and writing. He established a focused routine of study, writing, and correspondence in the mornings, with walks and music in the afternoons, and time for family in the evenings. Though projecting an austere public presence, sometimes interpreted as aloof or arrogant, Planck could also be very playful within the walls of his villa on Wangenheimstrasse, enjoying card games and even horseplay in the lawn, well into his advanced years.[11]

And here, in 1905, he reviewed and decided to publish the miraculous and fog-cutting voice of a young outsider, Albert Einstein, a man with neither a PhD nor a university position. At the same desk, Planck enthusiastically penned his first lectures on Einstein's groundbreaking Invariance Theory—or as Max called it, "Relative Theory." At the scientifically ripe age of 47, when many minds no longer bend, Max embraced Einstein's radical new notions of motion, in which rulers changed their length and events changed their order depending on the observer's own motion. It is no exaggeration to say that Planck discovered Einstein, and he helped shepherd the squarest peg of Einstein's genius into the round hole of the science establishment. Max stood with young Einstein and said they had to stick together against waves of skeptics. In time, Planck persuaded Einstein to join his physics powerhouse in Berlin.

In 1905, Wangenheimstrasse 21 nurtured the next generation of Plancks. The worrisome Karl was approaching the end of his secondary studies and thinking of pursuing geography in college—surely, his parents thought, that would finally provide some direction for him. The identical twins Grete and Emma were now 16 and prone to soothing the home with their singing and the expert bowing of their violins. Whether or not he could always distinguish their voices from one another, Max could probably hear their mother's songbird timbre in both. And finally there was 12-year-old Erwin, his father's favorite. The young politician already mediated the thorny dialogue between his father and older brother, Karl. Their father had just given Erwin a cello and fully welcomed him into the family's music.

Max and Marie hosted parties for a mix of professors and musicians. Max, an exacting and practiced pianist, often performed with other guests in duets, trios, or quartets. He loved especially the work of Schumann and Schubert, German romantics, and he counted the renowned violinist