H. FREDERICK DYLLA

Scientific Journeys

A Physicist Explores the Culture, History and Personalities of Science

Springer

Scientific Journeys

"What a joy to accompany Fred Dylla on his *Scientific Journeys*! This engaging and insightful collection of essays, drawn from a lifetime in science, takes you through a wide-ranging landscape of research, with fascinating excursions into history, politics, art, and personalities along the way."

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"With an insider's perspective, *Scientific Journeys* ably shows how science and engineering innovations emerge from a complex network of policy deliberations, inspired ideas, dedicated work, adroit management of research, and timely sharing of results."

—Phillip Schewe, *Author of The Grid, a history of how society uses electricity, and Maverick Genius, a biography of the scientist and writer Freeman Dyson*

"We are fortunate that Fred Dylla has devoted the effort to share some of the interesting experiences and perspectives from his distinguished career in physics. They are well written, insightful, and even entertaining, especially for those of us who have also chosen to be physicists."

—Bob Doering, *Director of Exploratory Research, Technology and Manufacturing Group, Texas Instruments*

"Fred's extraordinary career and range as an essayist are nicely summed up in Chap. 26 by his observation: '…physicists like to say they are interested in everything … I was not immune to this.' While greatly enjoying each essay, I was reminded how, as a conference organizer, I used to put Fred at the end to ensure that no delegates drifted away early! Sadly, no such inspirational book existed when I started out, but I am confident that *Scientific Journeys* will do much to motivate the next generation. I shall certainly be buying copies for young friends and grandchildren."

—Robert Campbell, *Former President of Blackwell Publishing*

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With a Foreword by Rush D. Holt

Springer

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Frontispiece: Propagation of the guide laser at the Gemini North Observatory, Hilo, HI. *Credit* Gemini Observatory/AURA

Artwork: The images on the title pages introducing each part of this book are white-line woodcuts by the author

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To Professors John G. King and Rainer Weiss for their inspiring teaching and dedication to scientific research
and to Linda for unfailing encouragement

Foreword

In this volume, we have the wide-ranging thoughts and observations of Fred Dylla, an accomplished physicist with an engineer's fascination for gadgets, a historian's long perspective, an artist's aesthetic eye, and a teacher's passion for sharing ideas. Throughout his varied career as a scientist, builder, administrator, publisher, and craftsman, his curiosity has been his foremost characteristic and his ability to see the connection between apparently disparate things is his greatest skill. Occasionally throughout his career, and especially in recent years when he headed the large scholarly consortium and scientific publisher, the American Institute of Physics, he has recorded his thoughts in remarkably varied essays on personalities, patents, policies, publishing, and artistic productions. Here, he examines the roots and growth of innovation in examples from Bell Laboratories, Edison Electric Light Company, and cubist painter Georges Braque. He considers the essential place of publishing in science, the epochal intellectual technique for learning how the world works. He shows the human enrichment and practical benefits that are derived from wise investments in scientific research, as well as the waste resulting from a failure to embrace appropriate technologies.

As the reader will see in these essays, Fred Dylla's all-consuming drive to extend his understanding of the world began young. When he was only a freshman in high school, scientists from an industrial physics laboratory, recognizing his technical precocity, gave him a large, expensive ruby crystal so that he could build a laser, with which he began biology experiments. He went on to the Massachusetts Institute of Technology (MIT) where, in his undergraduate and doctoral work, he performed experiments in acoustics, low-temperature physics, biophysics, and surface physics. His mentor while studying all of these fields was John G. King, one of MIT's most outstanding and highly acclaimed teachers of physics. Along the way, he worked with Amar Bose, who built a gigantic acoustics corporation, and Rainer Weiss, who received the 2017 Nobel Prize for detecting cosmic gravitational waves. Later, as the head of research groups at national laboratories he worked with gases heated to millions of degrees and with high-energy electron beams driven by super-cold cavity accelerators. As an officer of scientific societies and as Chief Executive Officer of the American Institute of Physics (AIP), he advanced science and science policy. In my own career as a physics researcher, teacher, policy maker, and elected official, I have interacted with Fred frequently over the years, and I admire his scientific skill, his personal consensus-building in research, business, and policy, and his passion to communicate and to educate.

I first met Fred Dylla when we both worked at Princeton University's Princeton Plasma Physics Laboratory in the late 1980s and early 1990s. PPPL, as it was known, had grown over the previous few decades from a small group of scientists who wanted to apply the new knowledge about the behavior of hot gases and magnetic fields in stars to the clever idea of making fusion energy on earth. The clever idea proposed to use containers with no walls that is made only of magnetic fields and filled with plasma gas at temperatures of millions of degrees, to fuse hydrogen, deuterium, and tritium and release energy in a process that would be economically and environmentally attractive. By the time we were there, PPPL was a major national laboratory of the U.S. Department of Energy. Both Fred and I, like the thousand or so other scientists, engineers, and technicians who worked at PPPL, were attracted by these large and beautiful research projects, the enormous sophistication of the fusion challenge, and the momentous societal benefit that could be foreseen. Fred worked on techniques to heat the hydrogen gases and to measure their behavior at high temperatures. Along the way, he arranged for national industrial partners to adopt plasma technologies that had been developed at PPPL. This program of technology transfer continues today. Fred also helped develop safety procedures at PPPL to assure the Department of Energy, the university, and the community of the safe handling of tritium gas. He and his advisory committee showed that significant releases of tritium would be very unlikely, and that the risks from tritium, although it is radioactive, would be very small even compared to existing radioactivity in our natural and human-made environment. One amusing and effective moment came when Fred pointed out to inquiring non-scientists that tritium had already been used for years in public places, in sealed tubes in luminous exit signs like the ones in the room where they were sitting.

Most noteworthy for me was Fred's work on science education. For some years before I arrived as assistant director of PPPL, Fred had helped to organize the laboratories' scientists to invite interesting researchers from every kind of science to speak at a weekly *Science on Saturday* program. Intended to acquaint high school students with actual scientific research, the program attracted parents and grandparents, as well. When Fred left the laboratory several years later, I assumed the oversight of that program, which has continued ever since. Some parents have continued to come regularly, long after their children have graduated for school, and now some of the previous high school students are bringing their own children to *Science on Saturday.*

That community program for science education illustrated Fred's continual interest in what science and society owe each other. There is a tendency for scientifically trained and non-scientific communities to separate from each other intellectually, even to think of each other as ignorant or illiterate. The British chemist, novelist, and government official, C. P. Snow, stimulated an international discussion sixty years ago when he wrote *The Two Cultures and the Scientific Revolution* [1], saying that science and the humanities seem to employ separate languages and cultural views. Snow's analysis is oversimplified. There are many fault lines of comprehension and appreciation running through and between the scientific and non-scientific cultures. However, the mutual incomprehension becomes much more than a cultural curiosity when it affects public support for the science the public needs for wise policy decisions, and when scientists fail to show the public the importance of evidence-based thinking in the day-to-day fulfillment of a citizen's democratic responsibility.

Fred left PPPL to help build the Jefferson Lab in Newport News, Virginia, and set up to study nuclear physics with high-energy electron beams, and medical and other applications of high-power lasers. Through it all, he continued to build industrial partnerships and to engage in public education. He built local and international collaborations using the laboratories' technologies.

He participated in education activities for students at all levels, and he spoke widely with policy makers and the public about the need to support scientific research. Many citizens may question the relevance of research such as conducted at an electron beam facility. Fred convincingly showed that, in addition to practical spin-offs, such as medical treatments (from which Fred himself has benefited), such work contributes to the growing web of understanding about our world that is part of civilization's centuries-long progress toward a better, more equitable, and more sustainable quality of life. As I moved into public life as a member of the US Congress, elected by the people of central New Jersey, I occasionally saw Fred and appreciated his views on the state of science and on successful techniques for the education of both scientists and the public.

One important policy matter that Fred and I have worked on together, when I was in Congress and later when I headed the American Association for the Advancement of Science, is scientific publishing. As the former head of the major publishing organization, AIP, Fred understands that good communication of scientific findings is essential for science to thrive and to benefit society—indeed for science to work at all. He also understands that good scientific communication is not frictionless and cost-free, even in the modern digital age when so much information seems free and instantaneous. If science is to generate knowledge that is more and more reliable, researchers must make their findings openly available so that other researchers can critique, build on, refine, or refute those findings. However, well-edited, well-reviewed journals are necessary to minimize inaccurate and accidentally or deliberately misleading reports. In recent years, some people say that making scientific articles free to all readers would facilitate the scientific process and would be fairer to taxpayers and other funders of research. Some governments are proposing to require that research with government funding be published free to all readers, a departure from the principal model for scientific journals. Mandating publishing at zero price does not magically produce publishing with zero cost. Someone must pay in one way or another for the maintenance and enforcement of accuracy and quality. Mandated models of scientific communication, if constructed without a good understanding of how scientific communication can be supported, could have an adverse effect on the progress of science.

In 2009, Representative Bart Gordon, Chair of the U.S. House Committee on Science and Technology, asked Fred to convene a Scholarly Publishing Roundtable of publishers, librarians, and university research administrators to consider the issue of public access to government-funded research. The recommendations of Fred's group became the basis for legislation enacted to facilitate accessible publishing of federally funded research. Fred then worked to form a nonprofit corporation supported by the publishing community to implement the legislation now known as CHORUS.

In this collection of essays, Fred Dylla touches on these areas where our careers have intersected and many more. He has been to many places and has gotten to know some of the world's scientific greats, both through personal contact as a student and as an international scientific leader, and through archival sojourns and museum study. The reader will find much food for thought.

Washington, DC, USA
October 2019

Rush D. Holt
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Washington, DC, USA

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Introduction

I consider myself very fortunate to have been born shortly after the cessation of World War II and to have grown up in 1950's America. The nation and world were changed considerably by that terrible cataclysm that cost tens of millions of lives and left huge swaths of Europe, Russia, and the Far East in ruins. The American continent escaped the devastation of the battlefields, but the gargantuan war effort had transformed American industry and American social life in just four years. Millions of returning American soldiers took advantage of the offer from the US Congress to attend college and vocational schools with the tuition cost paid by the government. This legislation, the so-called GI Bill, led to the most educated generation in the nation's history with more than 2 million obtaining their college degrees within 10 years of the war's end. Over its first decade, the legislation cost the nation more than 4 billion dollars, but the estimated return on this investment over the next generation was a 100-fold [1]. I was one of the so-called baby boomer generations that benefited from the postwar infusion of an educated workforce and expanding economy that appeared unchallenged and unlimited at the time. The largess in the American continent was generously shared for rebuilding the devastated economies of the European continent and Japan—which led to both Germany and Japan becoming major industrial powers of the world within three decades after the war.

The warring nations' investment in science and technology during the war had obvious consequences. It is often said that the allied effort to develop and deploy radar won the war and the Manhattan Project's successful development of the first atomic weapons ended the war, with Japan's surrender in the Pacific theater. The German efforts to develop rocket and jet-powered weapons at Peenemünde led to the successful development of missiles that guarded the stalemate peace of the Cold War, and to the race for the first moon landing in 1969.

The small committee of very talented scientist–statesmen that steered the research effort in the USA during and immediately after the war (led by MIT's Vannevar Bush and Harvard's James Conant) laid the groundwork for considerable and sustained funding of basic science by the US government after the war starting with the founding of the Office of Naval Research in 1946 and the National Science Foundation in 1950. These agencies became models for funding scientific research in the USA (and other countries) and have since seen near-continuous growth year after year, despite fluctuations due to downturns in the national economy and political support that varied with how well incoming political factions understood the long-term value of government investment in science.

I grew up in 1950's America with the second national awakening of the value of science. After the Soviets launched the world's first artificial satellite in 1957, there was considerable angst about the nation being dangerously behind in the "space race." The angst was converted into the passage of the National Defense Education Act in 1958. This enabled significant new investments, not only in space technology but in nearly all forms of scientific research and scientific and engineering education. I became what was known as a "Sputnik Kid," convinced that I was going to be scientist and with never a thought about another career path—despite being eight years old at the time of Sputnik's launch. I was joined by many other Sputnik Kids in my generation. We built and launched small rockets, took apart and re-assembled radio receivers and transmitters, and collected all kinds of rocks and minerals—hoping for some spectacular crystals or perhaps some radioactive ores that would phosphoresce on a bookshelf at night. I devoured any sort of science magazines I could get my hands on, such as *Popular Science* and *Scientific American.* (Millennial readers will find this latter form of information transfer archaic given the advent of the Web and Google.)

Despite this limited exposure to the scientific literature, I knew I was going to be a scientist. I did not know what kind of scientist but did not particularly care. All of that changed with the invention of the laser in 1960. I read and re-read an article in *Popular Science* called "*The Incredible Ruby Ray*." From the time I finished the article, I was convinced of two things: I needed to build my own laser, and I was going to be a physicist. Both came true.

This book is a collection of essays that were written after I had spent four decades in various capacities as a working physicist. My trajectory of training to be a physicist and then working as a physicist was never easy, but it was always satisfying. I shared my career with hundreds of unforgettable colleagues and occasional less collegial beings who I felt were impediments to my view of a sensible path forward. I learned from both types of encounters.

The first phase of my science education occurred in a middle school and high school in New Jersey where I was fortunate to be exposed to teachers that let me plow ahead with self-studies on almost scientific subject that interested me. One of the essays in this book (Chap. 16) provides a window for that period in my life and illustrates the value of generous mentors for nourishing enquiring minds. I filled my toolbox for doing science with the good fortune of spending eight years at MIT, gaining three diplomas in physics in three separate subjects. I was fortunate to have a thesis advisor for that entire period who felt strongly that scientists should change their field of study every five years so that they do not get into a scientific rut. You will have an opportunity to read about this remarkable mentor in the essay written about Prof. John G. King (Chap. 17).

I added something to my college education that few scientists indulge but should, given the importance of good communications and analytic skills to any vocation. During my undergraduate years, I included literature as my second area of study. For the rest of my career, this investment paid off immensely. At the time I just needed a night off from physics or math problem sets, but more importantly, the plays and novels I read taught me to understand that science and engineering need the humanities for these endeavors to be most useful for our survival and sustenance.

After obtaining my Ph.D. in biophysics, I spent the next 33 years in two U.S. National Laboratories, first as a plasma physicist and machine builder at Princeton University's Princeton Plasma Physics Laboratory and then as an accelerator physicist and another machine builder at Jefferson Lab, in Newport News, VA. You will find several essays in this book where I have woven life lessons from these laboratories into the narrative.

In 2007, I embarked on my last formal career stop. From 2007 to 2015, I was Executive Director of the American Institute of Physics. AIP is a federation of ten physics-based societies serving more than 125,000 scientists with scientific publications, and related education, government, and public outreach services. For me, it was the job of a lifetime. It gave me an astounding opportunity to view science worldwide and meet and interact with thousands of scientists. I had left the laboratory and direct employment as a scientist, but I found the trade-off worthwhile.

Most of the essays in this book were written while I was at the helm of AIP. On the day I started working there, I launched a weekly essay for AIP members and staff to note important developments that could affect the progress of science or commemorate an historical or cultural event that would cross-connect with science and enrich both endeavors. I have grouped these essays in five parts. The opening Part I entitled "*Signposts*" is vignettes for a number of personalities or events in science that affected my world view of science and culture. In Part II, "*Mentors and Milestones,*" I highlight the science and engaging personalities that intersected my career from building lasers, to magnetic fusion research, to particle accelerators, to materials science.

Part III, "*Science Policy Matters,*" describes my forays in explaining the importance of science to a whole range of audiences: from my children and fellow students, to the general public, to informed decision makers, and to legislators who handle the purse strings for scientific research. Part IV, "*Communicating Science,*" explores a particular form of science communication to which I devoted much time in my professional life—the scientific journal. Such journals are needed for scientists to present their work to their peers. Journal publication is a complicated and expensive business that is undergoing significant stress due to the burgeoning volume of content and the need for rapid incorporation of new technology to deliver the content. I describe pragmatic solutions for stress relievers that I helped put in place to keep the scientific journal sustainable, while other forms of initially print communications (i.e., newspapers and news periodicals) are largely ghosts of their original incarnations.

In Part V "*Art and Science,*" I hope you find pure fun. I have always enjoyed the interplay between art and science. My two daughters (Kim and Sarah) are accomplished artists who would have made fine scientists, but they thought their father was a little too crazy and instead sought out (successful) careers in the arts. They taught me to appreciate the arts, they are wonderful critics of my attempts to generate art, and they continue to show me the value of integrating the appreciation of art and science. The collection of essays in this last part illustrates these points.

Please dear reader, do not feel that you have to read this collection in any order. Pick and choose essays that may entice you at the moment. For those interested, I have offered footnotes and references for further reading on many of the included topics.

During my entire career, I was also fortunate to be exposed to many talented scientists and humanists who enriched my life. I mention and thank just a few in the *Acknowledgements* section at the end of the book.

Author with an inspiring bronze for all scientists at the Einstein Museum in Bern, SW *Credit* Courtesy of Linda B. Dylla

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1. Glenn C. Altschuler and Stuart M. Blumin, *The GI Bill: A new deal for veterans*, Oxford University Press, Oxford, UK, 2009.

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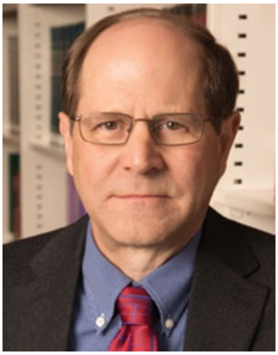
About the Author



H. Frederick Dylla is Executive Director Emeritus of the American Institute of Physics. He has spent 50 years as an enquiring physicist helping to design and build scientific facilities for astronomy, fusion energy, particle and nuclear physics, and medical and materials research. Along the way, he enjoyed sharing his love of science and the arts with students, colleagues, family, and friends.

He lives in Lewes, Delaware, with his wife Linda.