Letters to a Young Chemist
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This book should be required reading for all faculty members who teach chemistry at the high school, college, and university levels. Addressed primarily to college students, it fills an important gap by offering in conversational language a view into the contributions of chemistry and of chemists who are improving the human condition. Each of the chapters is written in the form of a letter to “Angela,” a hypothetical undergraduate at UCSD, indicating exciting challenges in the fields represented by the authors, all of whom are chemists. Four broad areas are targeted for coverage, namely, applications of chemistry fundamentals, chemistry and the life sciences, functional materials, and chemistry and energy. The styles of the individual contributions are largely informal but vary somewhat across the 17 contributions, reflecting the taste of the individual authors. In order to give the reader a flavor for the offerings of this book, I select here examples to illustrate how some of the authors approached the challenge of stimulating a young mind to appreciate the excitement that chemists find in their subject. But first I offer a few introductory comments based on my own experience as an educator and researcher over more than four decades.

The subject of chemistry may be characterized by the size of the entities it investigates, falling between physics, which studies fundamental particles, and biology, which focuses on macromolecules, cells, and whole organisms. Some therefore refer to chemistry as a “central science,” but this moniker is one that I personally find inadequate. In
many respects, synthesis is the heart of chemistry. In thinking about the synthesis of new substances, there is nothing “central” about what chemists do, nor is it our mantra to serve our sister fields, although our synthetic constructs often do so both intentionally and serendipitously. Our core is to understand the making and breaking of chemical bonds, and in so doing we are able to devise preparative routes to novel molecules and supramolecular constructs as well as solids that are nowadays referred to as nanoparticles. Through synthesis, chemists provide society with new materials that can transform the way in which we go about our daily tasks. Along the way, we apply indirect methods to construct motion picture images of chemical reactions that, for the most part, occur on a spatial or temporal scale too small or too rapid to be visualized. Theoretical contributions can provide insights to support and extend experimental findings. The discoveries are thrilling and deeply satisfying for the knowledge they provide, but to the extent that they also serve society they justify the considerable expenditure of public funds required to build or purchase the reagents, apparatus, and facilities required to carry out chemical research. This service is described in considerable detail in the letters to Angela contained in this book and can also be appreciated through the educational contributions of chemists who share their knowledge of chemistry with students preparing for careers in the related fields of medicine, engineering, materials science, biology, and even patent law, to name but a few.

Letters to a Young Chemist offers significant ammunition for motivating young Angela to consider chemistry as a career. The book displays a variety of personal accounts written by a collection of chemistry faculty representing nearly every branch of the discipline, a full spectrum of ages and experience, and good female gender representation. The lack of participation by faculty at principally undergraduate institutions may perhaps be excused by the focus on research. There are many inspirational passages. Prof. Carl Wamser of Portland State University, assuming the persona of Angela’s “Uncle Carl,” one of many in a large family of chemists that includes his 97-year-old father and who still reads the chemical journals, writes his fictional niece that “Clean Electrons and Molecules Will Save the World.” The topic is energy and the focus is on solar conversion, a highly popular subject among students today. Uncle Carl, reprising a tactic taken by the late Rick Smalley in addressing his audiences during speaking engagements, asks Angela and the reader to list the top ten issues that need to be addressed to improve the quality of life by the middle of the twenty-first century. Energy is one of them of course, which provides the lead-in to the rest of Carl’s letter, but the others are worth repeating here
because, in many instances, one can make a case that chemistry will be required for success. They are, in alphabetical order:

Democracy
Disease
Education
Energy
Environment
Food
Population
Poverty
Terrorism/war
Water

Disease may be interpreted to include the development of new therapeutics, a major focus of synthetic chemistry. Education and energy have already been discussed. Environment, food, population, and water are all closely linked and are being addressed on several levels by chemists. These ten issues are those that Smalley found were the top concerns of his lecture audiences when he queried them, and they closely track the interests of college students whom this book aims to inspire. Faculty teaching chemistry, especially at the introductory levels, should find creative ways to work these issues and their potential solutions into their lectures.

The subject of chemistry and energy is specifically addressed in more than one letter to Angela; and the last three chapters, including the one by Uncle Carl, focus specifically on this topic. Interesting quantitative data are provided about the amount of power from the sunlight that reaches the earth, its relationship to the global energy needs of our planet over the next several decades, and present and future technologies and science devised by the chemistry community to capture and utilize solar energy. A “Powering the Planet” program launched by chemistry faculty at MIT, Caltech, and other institutions to address this issue is described. An especially attractive idea, one that I hear about often from my colleague Dan Nocera, involves the “splitting” of water into hydrogen (H₂) and oxygen (O₂) by sunlight with appropriately designed catalysts. This energetically uphill reaction stores solar energy in the H—H and O—O chemical bonds of these two molecules for subsequent release and utilization when they are recombined in a fuel cell to produce water, an environmentally friendly compound, and electricity. The process bears a striking resemblance to the use of sunlight in nature by green plants, which use water, CO₂, and solar photons
to make hydrocarbons and dioxygen, which are combined in animals to supply energy with the release of CO$_2$ and water back into the environment. Chemists are working intensely to produce new catalysts for the efficient capture of sunlight, to convert solar energy to electrical energy, and to employ the latter to convert water to hydrogen and oxygen as a means of storing that energy for subsequent conversion to water and energy at a time when and/or a place where sunlight is not available. Other strategies described in the letters to Angela reinforce some of the fundamental ideas and the discussions of the life sciences and materials written in earlier chapters of this book. I now turn to these other sections.

The most important decisions in life are often made through an emotional rather than intellectual process; if the choice “feels right” it is usually taken. But the individuals whom one encounters along the way and intensely personal experiences often influence the choice of career and, for scientists, of research direction. Letters by Marye Anne Fox, Abhik Ghosh (Angela was an exchange student in his lab), and Terry Collins nicely illustrate how specific people fueled their interest in fundamental chemistry and, eventually, its applications. A fascinating letter by the Sessler brothers, Jonathan and Daniel, spins a tale in which our fictional Angela had fallen ill and required surgery when she was 7 years old. Dan, an anesthesiologist resident at UCLA at the time, saved Angela from a rare, life-threatening problem that occurred during the procedure. The letter describes how many anesthetics work to induce the unconscious state and mask pain, detailing fundamental principles of chemistry often taught at the freshman level. One can only wonder whether Angela’s own personal experience, recounted in the letter by the Sesslers, might inspire a career in chemistry applied in the medical sciences. A letter by Chaitan Khosla describes how diseases diagnosed in his wife and son led to his interest to investigate an autoimmune disease brought about by eating gluten.

The interface between chemistry and the life sciences is broad and deep. Six of the letters to Angela address specific areas for study at this interface, and several in the other sections of the book contain related information. Letters by Judith Klinman and Marie-Alda Gilles-Gonzalez regale us with the role of dioxygen in biochemistry, specifically how nature has evolved systems to detect and utilize it. Two letters by bioinorganic chemists Liz Nolan (Angela’s cousin) and Kara Bren describe the biological detection of metal ions involved in cell signaling, such as calcium and zinc. They also recount the use of metal ions to probe human health by MRI and gamma radiography and to treat diseases such as arthritis and cancer.
Another important and topical interface is the one between chemistry and materials science including nanotechnology. Three letters involving biomaterials, supramolecules, and nanoparticles comprise this section. An engaging letter from Michael Sailor begins with a reference to physicist Richard Feynman’s lecture entitled “There’s plenty of room at the bottom,” which some view to have heralded the emergence of nanotechnology. Sailor then recounts the Doctor Seuss book *The Cat in the Hat Comes Back!* in which the concept of an indivisible limit is cleverly introduced for children. He then discusses GORE-TEX, the outdoor clothing fabric that repels liquid but not gaseous water as a further entrée into many nanotechnological feats including quantum dots, silicon-based photonic crystals, and “nano-worms” used to find a tumor in the body.

In closing, it seems appropriate to note that the publishing of this book in 2011 coincides with the International Year of Chemistry, a time when the world celebrates the “achievements of chemistry and its contributions to the well-being of humankind,” as articulated on the official IYC 2011 web site. Whereas IYC 2011 looks backward, *Letters to a Young Chemistry* is a forward-looking collection, providing motivation and encouragement to the next generation of chemists on whom society must rely to help solve the problems and provide the breakthrough discoveries required to meet the 10 Smalley issues and many others. The community owes a debt of gratitude to Abhik Ghosh for his inspiration in conceiving this project and his persistence in assuring that the letters be assembled within a reasonable time frame, especially given the busy schedules of all the writers. Surely they, like I, share Abhik’s passion for chemistry and its future. We hope that the community of readers, including students, educators, and the public at large, will find the efforts worthwhile.
Preface

Walk into a major bookstore in your area and wander over to the popular science section, as I have done countless times in the last few years, mostly in the US. You’ll likely find several shelves devoted to physics and to biology. By contrast, the collection on chemistry is likely to be small, almost pathetic, consisting of little more than a book or two about Marie Curie (the centenary of whose chemistry Nobel Prize falls in 2011, the International Year of Chemistry), the periodic table, and the like. Important as these topics are, they hardly convey anything about the excitement that contemporary chemists feel about their subject, and especially about its future. Nor does the popular literature do justice to the massive contributions that chemistry has made and continues to make to human welfare. This book is an early effort to fill a major gap in the popular science literature.

Misperceptions about chemistry’s significance and role abound. Consumer products are often advertised as “chemical-free”, as though healthy products are not made of ordinary matter. Ignorance about chemistry, however, goes beyond public concern (much of it well-justified) about pollution, carcinogens, mutagens, etc. The respected magazine *The Economist* provides a number of examples that would be rather hilarious were it not for their egregious nature. Because the periodic table is essentially complete, except for some fleeting, superheavy elements, the magazine contends that chemistry has “lost its oomph.” Thus, in recent years, whenever the chemistry Nobel Prize has gone to a topic on the chemistry-biology interface, *The Economist* has viewed the matter as the Nobel Committee’s way of awarding two prizes in biology. Imagine the shock felt by the magazine’s science staff when not only the 2010 Nobel Prize in chemistry went to fundamental developments in organic synthesis (palladium-catalyzed...
coupling reactions), but the physics Nobel also went to a chemically oriented theme, namely the discovery of graphene. Well, enough about The Economist; I simply wanted to illustrate one of the more serious misperceptions that are out there. Sadly, there are many more.

Unfortunately, it’s not just science journalists who are sometimes inadequately informed about chemistry. Physicists and biologists often ask us: What are chemistry’s grand challenges? There are many. Some years ago (Chemical and Engineering News, August 7, 2000), Professor Stephen Lippard assembled a list of some twenty such grand challenges (indeed this is part of the reason I requested Steve to write a Foreword for this book), while freely admitting that there were many more. Unlike the physicists, we do not seek theories of everything, but that’s nothing to be ashamed of. It’s a sign that our science is healthy, vibrant, and brimming with exciting problems that will challenge the brightest minds for generations to come. Even practitioners of closely related fields such as biochemistry sometimes fail to see the value of chemistry’s fundamentals. Not long ago, I read an interview of a famous structural biologist in an equally famous journal, where he stated that subjects like inorganic chemistry had simply ceased to exist! Ninety-five percent of the periodic table is no longer worth studying? My first reaction was that the contention was too ridiculous to merit a rebuttal. Yet rebut we must. Several chapters in this book do just that, i.e. show that the study of the fundamentals of chemistry is alive and well.

Why is chemistry so poorly represented in the popular media? This is not an easy question to answer because causation is often difficult to pinpoint. What is clear, however, is that chemists haven’t quite made the effort—on the same scale as physicists and biologists—to bring the excitement of the molecular world to the public. Chemistry’s unique iconic language has been seen as an impediment, as has the subject’s somewhat detail-oriented nature. Finding a transition metal reagent that activates (i.e. reacts with) a normally inert C-H or C-F bond is an utterly fascinating exercise that is no less deserving of a bright young person’s interest than, say, the origin of the universe. Chemists must bite the bullet and take the trouble to better explain what they do and why it’s scientifically worthwhile and personally rewarding. If the public finds it fascinating to read about black holes and string theory—hardly accessible stuff, by anyone’s definition—surely a handful of them will find it of interest to read a popular article (or even a book) about C-H activation, to pick a somewhat random example of an important chemical problem.

In the 17 chapters that follow, my fellow contributors and I have tried to fulfill precisely this goal, namely, to explain serious chemistry research
in accessible language. We have done so in the form of letters to a hypothetical young girl, Angela, a UCSD undergraduate who has written to us requesting information on career opportunities in different areas of chemistry. The detailed responses of her correspondents form the body of the book. Steve Lippard’s broad vision and sense of where chemistry is going made him an ideal person to write the Foreword, an invitation he graciously accepted. In his Foreword, he provides a sampler of what the reader can expect to find in this book. Given the excellent job done by Steve, I will refrain from commenting on the individual chapters. Instead I’ll dwell briefly on the origin of the book.

Books with the title *Letters to a Young XYZ* have become a genre of their own. The ur-*Letters* book is of course Rainer Maria Rilke’s *Letters to a Young Poet*, but there are several others that are both instructive and enjoyable. Publication of Ian Stewart’s *Letters to a Young Mathematician* a few years ago made me sorely miss a similar book for chemistry students and led me to envision the present volume. Around the same time appeared Natalie Angier’s *The Canon: A Whirligig Tour of the Beautiful Basics of Science* and Bill Bryson’s *A Short History of Nearly Everything*. I loved these two books, as much for their substance as for their literary styles. I wanted to do for chemistry something akin to what Angier and Bryson had done for all of science. Unfortunately, I was in no position to do so. With a full teaching load and a fair-sized research group, I had little time to write a book, let alone one on popular science. I did the next best thing: I turned to my friends and colleagues, including many on the US West Coast (where I came of age as a chemist and where I still visit on a regular basis), telling them of my idea of a *Letters* book and asking them whether they would consider contributing a chapter. I was humbled by the universally positive response. Elder statesmen and young assistant professors alike, as well as everyone in between, gladly took time out of their busy schedules to contribute to the book. Evidently, the urge to teach and touch the next generation of scientists in a positive way is a strong one. Unlike other *Letters* books, this book is thus a multiauthor effort. We may lack some of Angier’s and Bryson’s literary flair, but as practicing scientists, we bring a first-hand account of science, which should be distinctive and attractive on its own merits.

A few words about Angela, the protagonist of the book. Her character is a pastiche of a number of young students—both young men and women—I have met and taught over the years. As I picture her, she comes from a modest to average social background; her mother is a high-school English teacher, her father a lawn care professional. The
eldest of three siblings, she remembers well some of her family’s financial hardships during her youth and therefore appreciates all the more her current status as a UCSD undergraduate. Enthusiastic and bright, she has been an avid participant in undergraduate research. Outside of school she enjoys spending time with friends and family and the fabulous outdoors of southern California. In many ways, she is like thousands, if not millions, of her generation worldwide. She loves science but also appreciates the importance of a well-rounded life. A number of the authors, myself included, found it natural to claim personal acquaintance with her (in our slightly make-believe world). Her position is not unlike that of a child, a grandchild, a sibling, a cousin, a favorite student, etc. for many of us. When writing my own chapter, I wondered again and again whether I could give the same advice to my fifteen-year-old son, who is now in high school, finds science fascinating but, like Angela, is unsure whether and how it can be a part of his life. I can honestly say that the answer is a resounding yes. I am sure that the same can be said of all my coauthors.

So what exactly makes chemistry a career worth pursuing? Admittedly, it’s not the easiest of careers, but it’s an amazingly exciting and fulfilling one for many people. As mentioned in Steve’s Foreword and in a number of Chapters, chemistry is key to solving many of today’s most pressing problems such as disease, energy, and food supply. At the same time, it would be wrong to view chemistry as simply a kind of central service for the scientific-technical enterprise. Stunning discoveries in the most fundamental aspects of our science are taking place at an ever-accelerating pace. Have a quick browse through a current issue of JACS or Accounts of Chemical Research, or better still (if possible), attend a national meeting of the American Chemical Society and listen to some keynote lectures in different areas. You’ll be left with no doubt that chemists work and live in a world of breathtaking discoveries that are transforming the way we view and deal with the molecular world—and indeed life itself.

Because of the manner in which this book developed, the majority of the authors of this book are US-based. The broad subject matter, however, should be of international interest. Whether you are reading this book from North America, Europe, Australia, or for that matter Brazil, China, India, Russia or other emerging country, you should be able to identify with the hopes and dreams implicit in this book. But what if you love science but are located in a poorer part of the world, where meaningful scientific research is not possible? Admittedly, that’s tough and I am in no position to offer magic bullets. There are hopeful signs all around, however. By and large, the developing economies are
growing quickly; the Internet is deeply empowering. There are scholarship opportunities abroad. Few things are more satisfying to me than the fact that some of my best students and collaborators have come from Africa, including some from truly disadvantaged backgrounds.

To conclude, I wish to thank again the chapter authors for generously contributing their time and sharing their visions, as well as for their faith in my ability to pull through this project. The book has been carefully but lightly edited so as to preserve the authors’ original viewpoints and styles; indeed, occasionally the authors have expressed opinions that differ considerably from my own. Steve Lippard read every chapter before composing his thoughtful Foreword. The individual chapters have also been checked for grammar and style by three of my collaborators/students, Dr. Adam Chamberlin, Mr. Hans-Kristian Norheim and Mr. Simon Larsen—my sincere thanks to them all. I cannot express my appreciation strongly enough for Anita Lekhwani, a Senior Editor at Wiley. My ideas found fertile ground the moment I mentioned them to her and, since then, her suggestions and words of encouragement have been a morale-booster throughout the editorial process. Wiley’s Senior Production Editor Christine Punzo and Project Manager Janet Hronek, consummate professionals, made the production process painless and even enjoyable!

I hope you find this book useful and enjoyable.

Abhik Ghosh
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Part I

From Fundamentals to Applications
Marye Anne Fox is a distinguished professor of chemistry and the seventh chancellor at the University of California, San Diego (UCSD). She received her Bachelor of Science in Chemistry at Notre Dame College and her PhD, also in Chemistry, at Dartmouth College. After a National Science Foundation (NSF) postdoctoral appointment at the University of Maryland, she joined the faculty at the University of Texas, where she was appointed ultimately to the Waggoner Regents Chair in Chemistry and was named Vice President for Research. She served as Chancellor and Distinguished University Professor at North Carolina State University before assuming her present position. She has been recognized nationally and internationally for her contributions to chemical research, science education, and innovative service to higher education. She is a member of the U.S. National Academy of Sciences, the American Academy of Arts and Sciences, and the American Philosophical Society, and has served on the National Science Board and the President’s Council of Advisors on Science and Technology. She has received 12 honorary degrees.
Dear Angela,

I am delighted to hear that you had a great summer working in a chemistry lab! And combining that experience with study abroad in Norway, which is such a beautiful place, must have been truly wonderful! Quite a change for a Southern California girl.

I assume you had a very positive experience, and I suspect it also means you’ve been bitten by the research bug. By that, I mean that you’ve probably had that indescribable feeling that comes when you’ve synthesized a molecule that never existed before or when you were the first in human history to understand why a particular reaction takes place the way it does. Nothing like it, really. And once you’ve experienced it, you’ll find it hard to live a life that doesn’t include the possibility of discovery. The pursuit of new ways of thinking about nature is addictive, and getting to the goal by proving or disproving your original proposal about what might happen will keep you working long hours for months or years at a time. Your friends may think you’re crazy to work all night on occasion, but you know something they’ll never understand.

I’m also glad to hear that you’ve chosen to pursue your degree. That shows a lot of good sense, given the proximity of your family at UCSD and your determination to make scientific research a big part of your life. Quite aside from the natural beauty of the campus and the fact that San Diego has the world’s best weather all year long, UCSD is a fabulous place to undertake serious scientific studies. Newsweek magazine announced a couple of years ago that UCSD is the “hottest place to do science” in the United States. One indicator of the quality of our scientific research programs is that the 2008 Nobel Prize in Chemistry was awarded to one of our long-time faculty members.

As is true in most research universities worldwide, you’ll have a chance to get involved in research right from the beginning. Once you demonstrate that you want to do serious research, you’ll likely be able to work with faculty who are well funded by federal granting agencies, and some will be able to offer stipends to students who work half-time or so with the research group on their research projects. As a result, working on a project you love can also help you address the costs of attending a premiere college or university.

One of our highest priorities at UCSD has always been to involve undergraduates in research as soon as they can demonstrate that
they can contribute to a particular research group’s efforts. Having worked in a lab for a summer already, you should be ready as soon as you arrive on campus to connect with one or more professors whose research work interests you.

MY LIFE AS A RESEARCH CHEMIST

I think it’s a great idea that you want to find out a bit more about opportunities in different areas of chemistry so you can make a more informed choice about the direction you’ll ultimately pursue. My area of choice has been physical organic chemistry, with specialization in photochemistry, electrochemistry, and materials chemistry. Virtually all of our work is aimed at understanding how a particular reaction takes place, often in great detail. It includes the scientific question of how changes in structure induce changes in chemical reactivity, in the ground state or the excited state of a molecule or a family of molecules.

Given that reactions take place through a series of bond-making and bond-breaking steps, this work often involves reactive intermediates. A full description of a reaction also defines the rates of reaction (kinetics) and the energy changes encountered as the reaction proceeds (thermodynamics). This is exactly where organic chemistry interfaces with physical chemistry. This description of a chemical reaction, in fact, defines the field of physical organic chemistry. A key step in accomplishing such a description consists of characterizing the electron flow and the reactive intermediates forming along a reaction pathway. In a larger sense, physical organic chemistry defines how a local environment can affect reaction rates by influencing the stability of a key transition state. In many cases, it is also possible to make models of transition states with the help of theoretical calculations and to use theory to predict evolving chemical reactions. It’s extremely rewarding intellectually to work with theorists to establish by inference how a series of chemical bonds are broken and formed, and hence to be able to devise new chemical transformations.

Although I spend a great deal of my time as a chancellor at UCSD, I am still a chemistry professor at heart. In that capacity, I’ve worked with a highly talented group of students to study a variety of physical organic problems. I’m especially proud that we were able to make a major contribution toward defining a new field of organic photoelectrochemistry, which involves a combination of surface chemistry and
excited state chemistry. This work involved syntheses of new molecules, in ground and excited states, and observing how their structure affects subsequent chemical reactivity. We also carried out theoretical calculations in order to test our interpretation of experimental observations. We are often interested in being able to predict physical properties for compounds or materials that don’t even exist until we make them.

I’m happy to say that over 60 students have completed advanced degrees in my research group, and many of them have themselves established well-regarded research programs of their own. Because of their hard work, I was elected at a relatively young age to membership in the National Academy of Sciences, which is a profound honor for any scientist. I really miss the days when I could spend most of my time with students in the lab.

LEARNING TO DO RESEARCH: PHYSICAL ORGANIC PRINCIPLES

Perhaps it would be useful to you to learn how I came to develop an interest in the physical properties of organic molecules. It was basically a series of very positive research experiences that led me to become a research chemist, and thereafter an independent faculty member at a research-focused university.

My first exposure to chemistry research was as a student in a summer program supported by the NSF at the Illinois Institute of Technology in Chicago. As a student in the program called Research Experience for Undergraduates (REU), I was assigned to Professor Jerry Kresge’s research group, thereby working side by side with postdoctoral fellows, visiting faculty members, and graduate and undergraduate students. I was very pleased to be accepted so cheerfully into the group, given my status as an inexperienced REU student. Professor Kresge was interested in determining how acids could effect changes in the hydrolysis of vinyl ethers. We wished to determine whether Bronsted or Lewis acidity was involved, as well as to identify key reaction intermediates encountered as the reaction took place. The work would provide important information about how acids can catalyze (i.e., accelerate) certain reactions.

My contribution to the project was to synthesize cyclohexenylethyl ether and to monitor the kinetics of its hydrolysis to cyclohexanone. The rate of hydrolysis could be followed by monitoring the appear-
The absorbance of the ultraviolet absorption of the ketone product. We then established reaction rates for other vinyl ethers, for example, those with smaller rings or appended functional groups, and with enhanced or reduced sensitivity toward various acids. The question was whether a general acid (H+) or a specific acid (HX, where X− is a counterion that is involved in the key transition state) induces the catalytic acceleration of the observed rates. In turn, this allowed us to find out exactly how this reaction proceeds. Ultimately, the work led to my first paper in the Journal of the American Chemical Society.

Having had a very positive experience in a physical organic group, I loved the idea of undertaking simple syntheses to make new compounds in which fundamental changes in reactivity could be brought about by changes in structure. So, when I had the chance to work with Professor Roger Binkley on problems involving photochemical excitation, I jumped at it. Photochemical reactions are those that take place after the absorption of light. Photochemical excitation is perhaps the easiest way of inducing a reactivity change with minimal structural change. Photochemistry is therefore an exceptionally important subarea of physical organic chemistry.

Although Dr. Binkley was interested in carbohydrate photochemistry, I chose to work on a structurally simpler compound, benzalazine. We wanted to measure the relative rates of cleavage of the C–N bond by monitoring the quantum yields for consumption of the starting material and for the appearance of product. The underlying goal of this work was to determine the multiplicity of the excited state leading to each product; that is, we wanted to know whether a singlet or triplet state was involved. The insight afforded by establishing the reaction kinetics has profoundly influenced my research for the rest of my career.

Perhaps even more important, the Binkley research group met each Wednesday night at his home to have a simple dinner in which the dessert consisted of working together to solve a tantalizing mechanistic problem. Sometimes, the problems involved reactive intermediates, often radicals or diradicals produced by photochemical excitation. As a beginner, it was hard to imagine how a molecule could be twisted so much to yield highly strained or rearranged compounds. In general, we practiced arrow pushing to determine the electron flow that defines a reaction mechanism.

Moving to Hanover, New Hampshire, to attend graduate school at Dartmouth College was one of the most important decisions of my life. Not only did I find a brilliant mentor, Professor David Lemal, a person who cared equally about teaching excellence in research and
about his students, but because the program was small, I was also able to work frequently with other faculty working on quite different projects. I recall fondly working with Professors Walter Stockmeyer (a polymer chemist), Chuck Braun (a physical spectroscopist), Tom Spencer (a biochemical kineticist), and Gordon Gribble (a synthetic organic chemist). Because of their invaluable insights, I was able to finish my doctoral work quickly, in 3 years, so I could join my husband in Washington where he was assigned after having been drafted into the U.S. Air Force.

The project I began in graduate school was to prepare perfluorotetrahedrane, a highly strained compound in which four carbon atoms were arranged so as to resemble a pyramid with a fluorine atom at each corner. The molecule was bound to be highly strained and to have interesting physical properties. I worked for nearly a year preparing various precursors and applying what I had already learned about photochemistry. I discovered some interesting routes to strained compounds, but the goal remained elusive. This was the first time I had to deal with failure in the lab. But even in this failure I learned an important lesson: when a project is worthwhile, there will be challenges, and sometimes it will be useful to fail quickly and get on to another project. I did have the chance several years later to collaborate with a German friend who had synthesized tetrakis(t-butyl)tetrahedrane, so the project continued to be close to my heart.

In my case, my failing to synthesize my target meant shifting to studying the valence isomerization of several families of halogenated arenes. I discovered a new reactive biradical derived from chlorobenzene and several interesting interconversions among halogenated pyrazine, pyridazine, and pyrimidines, along with fully defined mechanisms by which the conversions took place.

Besides learning about broad areas of science, I used my graduate school experience to learn time management and how to balance various competing demands from my personal and professional life. The norms of graduate life in chemistry also reinforced a strong core work ethic that I’ve had throughout my life. To this day, administration colleagues marvel at my work capacity, which is simply normal by chemists’ standards.

I will always be indebted to my research advisor David Lemal for encouraging me to realize that children should not be forgone as part of the life of an academic, whether male or female. He was gracious in letting me work odd hours and still keep my stipend when my first son was born, in order to stay on track to achieve my 3-year completion goal. In doing so, he taught me invaluable life lessons. (These