INTRODUCTION

ONLY A SCIENTIFIC MEMOIR

I want to explain first of all that this is not a memoir of my full religious conversion. When I tell stories about my scientific experiences, I use them to explain why I have the perspective that I do and how I navigated certain difficult questions after I became Catholic, to give you something concrete to remember as you talk with friends, family, and interlocutors on the topic of faith and science. Catholics are challenged to give answers whenever some controversy over faith and science erupts in our culture. I never knew there was such a controversy until after I converted to Catholicism and began to be challenged by atheists, other Christians, and other Catholics. This is a memoir, if you want to call it that, of how I navigated science in the light of newfound faith. It is meant as a guide for fellow Catholics.

This book is not a scholarly apologetic work either, because there are ample good scholarly works on faith and science already. I could have made the points in a more aseptic style, but it would not reflect either the way I think or the way I communicate with friends and family on the Internet and around my kitchen table. I notice something missing in the faith-and-science dialogue, and that something is the human person. Science involves people. Faith involves people. Whatever challenges and controversies arise, they arise because of people. Therefore, I seek to show how a Catholic *person* works through these questions of faith and science.

My experiences qualify me for commentary on the encounter between faith and science. I worked as a doctoral student in academia and as a research scientist in the global chemical industry for a total of ten years, and I was nonreligious during that entire time.

The whole story is best left for another time. I envision writing those memoirs when I am ninety years old, rocking in my old wooden chair on the porch, martini in hand, finally able to call the story complete. For now, suffice it to say that I searched anew for truth at around age thirty-three, and God granted me a love for life, an appreciation for the gift of children, and a blow of humility. I left my career to better care for my two children and entered the Catholic Church three years later. In my first seven years at home, my husband and I welcomed five more children in quick succession.

Theology studies helped my brain survive the interminable hours of nursing, feeding, changing, washing, and rocking babies. At first I could not fathom how anyone could add any new knowledge in a field that was built on articles of faith. Theology seemed like an exercise in word games. I soon discovered that the study of theology is a convert scientist's dream. The Church hands down the fiduciary knowledge of divine revelation from scripture and tradition. The task of Catholic theologians is to communicate this knowledge to contemporaries and help deepen their understanding of it. I found out that theology is science, the highest science. Any question I could think to ask about the Catholic faith, I could find logically addressed in Church documents, in the same way I once found answers to questions about scientific research in the rows of scientific journals in university libraries.

The science of theology is about ultimate purpose, whereas what we call science today is limited to the physical realm. My studies lifted me, you could say, above the terrain that bound me so that I could finally see the bigger picture, one in which science was properly situated as part of a greater truth, but was not itself the full truth. As this higher vantage of science in the light of faith was coming into focus intellectually, my days as a mother forced me to stay in touch with our humanity. I literally earned a master's degree in dogmatic theology through an Avogadro's number of diaper changes, sippy-cup refills, sister-fight breakups, and piles of unsorted laundry.

Eventually my training as a scientist, my education as a theologian, and my experience as a mother united into a concern for others who are navigating these confusing times—times when science is spoken of as omniscience and faith is regarded as a void for the mushy-minded. What I have to say is not profound; it is rather simple. It is a plea to fellow Catholics to return to that childlike awe and wonder with an unwavering confidence in Christ and his Church when we approach the subject of modern science.

NEVER AN ATHEIST

The second thing I want to make clear is that I never called myself atheist. It is incorrect to say that I am an atheist-to-Catholic convert. I guess I was a "None" before Nones were called Nones: I am a convert from nonreligiousness. I did not want to go to any churches, and I did not want to deal with any questions of any gods because I had no desire to join any of those social clubs. Perhaps I could never deny a belief in God even though I rejected religion. Perhaps I was lazy in not picking a side.

I knew some atheists, and they made atheism seem a sort of strange religion unto itself. There is a big difference between "nonreligious" and "antireligious." The former committed me to nothing. The latter would have committed me to tenets and dogmas I was willing neither to fight for nor to fight against. Outspoken atheists seemed to me like fight pickers, like the boyfriend who breaks up with the girl but will not stop calling her to remind her. Why label yourself with a word derived from something you do not believe in or want to be associated with?

As a research chemist, I knew many people from plenty of different cultural backgrounds and religious convictions. Even in the years I was nonreligious, I did not disrespect or despise the religious people I knew, for that would have been petty and rude, the behavior of an insecure person. In hindsight, I realize it was my scientific training that protected me from such bigotry because scientific training teaches you to withhold judgment until you have gathered empirical evidence. And I converted precisely *because* I gathered enough empirical evidence and arrived at a sound conclusion.

I admired the integrity and work ethic of many of my religious colleagues, particularly the Catholic ones. No proselytizing swayed me when I was ready to take the leap of faith. On the contrary, part of my empirical evidence came from observing how they lived their lives. They possessed something special, a deep and pervasive confidence. I let myself hope that I could attain that confidence too.

SYSTEMATIC THINKING

Third, I want to address my mode of thinking and communicating. I am fond of systematic thinking, of placing definitive points of knowledge into the broader picture. For example, if you bake bread, you may focus on exactly the right amount of yeast to use, and you may test different quantities over time to discover how it affects your product, but you work the details out in service of the greater systematic context of sustenance, enjoyment, and communion. Everyone engages in systematic thinking, but not enough emphasis is put on it in education.

I first learned systematic thinking as a scientist. You research the background, narrow in on the questions that need more investigation, conduct your experiments, analyze your data, and then situate your results and conclusions back into the greater context. I was fortunate that my training as a chemist was broad: I did polymer, electro, physical, quantum, bio, analytical, and organic chemistry. That breadth had everything to do with my doctoral advisor, Thomas E. Mallouk at the Pennsylvania State University (Penn State). In my 1999 dissertation, I thanked him for teaching me how to think, and a decade and a half later his instruction continues to serve me well, even though I no longer do chemical research (except in my kitchen).

When I thought systematically as a scientist, however, I still limited my thinking to science. Studying philosophy and theology showed me how to systematize science into the universal picture. When I say "science in the light of faith," I refer to such broad, authentic systematic thinking.

In this book, I steer through these questions: What is the relationship between faith and science? How do you sift through scientific conclusions? Does the Big Bang prove God? Is the atomic world the real world? Does quantum mechanics explain free will? Did we evolve from atoms? Are creationism and intelligent design correct? Can a Christian accept the theory of evolution? When does a human life begin?

Part 1 of the book is devoted to the general relationship between faith and science. Part 2 navigates some of the challenging questions posed by physics to faith and by faith to physics. Part 3 deals with the big questions posed in the biological sciences and how we navigate them without compromising our human dignity or faith.

I cite the works of individuals throughout the book because, as I said, science, faith, and any conflicts between the two involve people. The views of groups or opposing sides are best understood by exploring what individuals mean when they pose arguments. I try to put together what I think a person new to the dialogue needs to get started. If I say, “I think” or “in my opinion,” I do not mean to weaken my point but to indicate that I am aware there are other opinions.

Now, I want to begin by telling part of my story.

PART I

SCIENCE IN THE LIGHT OF FAITH

CHAPTER 1

A STORY ABOUT THE CHASM

FAITH OF A CHILD

Some people say children are born atheists, but I have no recollection of ever making any decision not to believe in a higher power. My earliest memories were naturally of God, of being awed by perfection and vastness beyond me and beyond us all. I grew up in rural Texas during a time when running barefoot in the woods, making mud pies, catching grasshoppers, and hunkering down in a ditch for hours because Bigfoot was surely after us were all as natural to a kid as breathing air.

The skies are bigger than imagination in Texas. Whether in the moonlight or the noonlight, a girl can lie on her back and see into the void of the sky, registering with her eyes the colors and shapes of nature but completely unable to register in her mind what lies between, beyond, and behind the visible things of the world. I remember thinking of the stars as memories because I read that light took years to reach our eyes and that the stars we see may no longer exist.

Like any fortunate kid, I had hope. I regarded each new day as an opportunity to experiment with my surroundings. I knew that no matter how much I played with dirt, handled bugs, examined clouds, and tried to count leaves on trees, even if I did it for the rest of my life, I would never explore everything.

Perhaps nostalgia colors those experiences more joyful than they really were, for I was not an easygoing child, but sometimes I wish it were possible to see memories the way we see stars. The first memory I would see would be my mother's face as I looked up from her embrace.

When she told me God made the trees, the big, round sun, and me, my fascination was fueled by the thought that God made everything. Children start out assuming there is a unifying logic to it all. *To a child, faith and science go hand in hand.*

In high school I learned the chemical reactions of the Krebs cycle (also known as the citric acid cycle or the tricarboxylic acid cycle), and it was a formative event. The Krebs cycle is a series of chemical reactions used by aerobic organisms to generate energy for other metabolic pathways, and it is where most carbohydrates, fatty acids, and amino acids are oxidized to generate molecules to make other biological molecules. In this cycle, eight different enzymes catalyze organic reactions, beginning with citrate synthase catalyzing the condensation of acetyl coenzyme A and oxaloacetate to yield citrate. Students are expected to memorize exacting biosynthesis reactions, and I remember wondering, *Where did this brilliant machinery come from?* Science textbooks do not address that question. Nevertheless, when I looked up at a tree for the first time after coming to understand that these crazy, precise reactions are popping away inside every cell, the realization was overwhelming.

Within plants, invisibly and faithfully, sunlight is being converted into chemical energy by the process of photosynthesis to fuel their own activities, and glucose is being produced to provide energy for our bodies and oxygen for us to breathe; as if it were all planned out and designed that way. As complicated as it is, the Krebs cycle is but the hub of the overall process in which plants acquire and use energy to carry out the various functions of life. Plants are, in turn, the hub of the overall process in which organisms acquire and use energy to carry out the various functions of their lives. Life on Earth is interconnected in very precise ways at the atomic level.

The huge idea of biological machinery, our bodies included, was breathtaking. I could not fathom how other scientists ever figured all of that out. I could not fathom how the Krebs cycle, photosynthesis at large, even a single living tree, let alone a forest, the globe, or humanity and the universe, ever came to be. I wanted to know more, and my love for science, born in childhood, became manifest in adolescence.

LOSING MY RELIGION

Somewhere in my teen years, I let go of that childhood awe and wonder. Losing my appreciation of the perfection beyond me, I became obsessed with being perfect. When you are young and pondering the big, immediate question of what you might wear that day or what you might do after high school, you tend to care less about big-sky mysteries and more about how you measure up, the right permed hair and big bangs, the right eyeshadow and lipstick, the right miniskirts and leg warmers, the right Jordache designer jeans, and even the right college courses so as to impress.

In college I majored in biology, and for the first time ever I flatly rejected religion, actually in the same year (1991) REM produced the song "Losing My Religion." I know that my interpretation is not what the song was supposed to be about, but words are words, and if you sing them enough, you make their meaning your own. Religion did not fit my style. If religious people wanted to eat yellowish casseroles at potluck socials, highlight their study Bibles, practice for choir concerts, and believe the "Old Rugged Cross" would save them by "Amazing Grace," worms that they were, so be it. Religion was not for me. I wanted to learn how the world works. I wanted to see the world, and I wanted to be somebody.

I reluctantly took a teaching job three years into my undergraduate studies; the university worked out an agreement with a high school that needed a chemistry teacher, and it was hard to argue against graduating early for a job if you were going to college to get a job. So I bought some black suits, got an apartment, and taught high-school chemistry in Athens, Texas. On the first day of class, when I had to say the names of my first students out loud to call roll, I froze like a kid hiding in a ditch again, sure Bigfoot was about to get me. I was twenty-two and mortified that I was not much of an authority figure. I did it, though. I learned how to lead, think on my feet, and explain complex subjects to a variety of people.

There was another benefit: I had to review the basics of chemistry. Looking back, I can see that reviewing and teaching high-school chemistry made me own the material in a fundamental and personal way. The trajectory of a science career usually does not involve a return to high-school fundamentals, but the time I spent teaching chemistry in my early twenties undoubtedly cemented concepts in my mind that otherwise would have remained vague.

In spite of all I gained from teaching, I knew that repeating the basics year after year for the rest of my life would not be enough. My fascination with biological machinery was full-blown by then because I had been reading Ayn Rand's *The Fountainhead* and *Atlas Shrugged*. I also found myself portrayed in Albert Einstein's writings. In a collection of his notes about science and religion titled *The World As I See It*, Einstein wrote that "in this materialistic age of ours the serious scientific workers are the only profoundly religious people."[1] Yes, that was me—a serious scientific worker in a lab coat with an angled face and simple but coiffed hair (like Rand's female protagonists might look). I knew I would not contribute to the field of chemistry or biology if I remained a high-school teacher for the rest of my career. So, two years after starting that role, I wrote a rather hubristic letter of resignation to the high-school superintendent informing her that I was like a machine, a fine automobile in fact, in need of fine-tuning to reach my fullest potential. In order to make that happen, I announced, I was going to leave teaching to pursue a doctorate in chemistry. The superintendent may have been impressed with my resignation. I cannot say. Anyway, I went back to school.

SAVING THE PLANET

I returned to my original university to complete a set of courses in undergraduate chemistry to prepare for graduate school, so I had some time to plan. By then, I had developed the skill of, and fallen in love with, reading scientific literature and scientific papers. I was able to devour them because solidifying my understanding of the fundamentals of chemistry had given me the ability to understand the importance of the papers. I could understand the background of different projects, and it excited me to read how scientists around the world were literally reaching into the unknown to provide humanity with new knowledge about the machinery of the universe. I wanted to be part of the action, and my reading told me I needed to know what I wanted to work on before I applied to graduate schools.

To me, reading scientific literature was like reading fashion magazines must have been to some other young women. I dreamed of publishing papers. Scientific papers in refereed journals are where researchers meticulously present their most recent work in so much detail it is almost like being in the laboratory with them. A college library is full of volumes, often dating back decades if not half a century, detailing scientific discovery—the closest thing you can find to the "magisterium of science," so to speak. I spent much time in the university library, and of course I dressed the part. I traded the black suits for something more poetic: an ironed, button-down, white shirt, worn jeans tucked in tall boots, and wild hair, kind of like Julia Roberts in the movie *Flatliners*. I worked myself up about saving the planet, the buzzword "nanotechnology," and not being a cog in the wheel.

In those mid-1990s days, the headlines were full of reports about how the greenhouse effect, acid rain, and holes in the ozone were going to decimate the rain forests and kill off many species of animals, the ever-increasing human population included. In addition to reading scientific literature, I picked up a few popular science books to gain a vision of the future. Jonathan Weiner's 1990 book *The Next One Hundred Years: Shaping the Fate of Our Living Earth* affected me most.[2]

I was never one to get involved in scientific arguments about the fate of our world, as that seemed an unreasonably mammoth-sized problem to solve. It seemed more effective, following some of the suggestions in Weiner's book, to focus on what I could *do* rather than say. I could boycott anything with chlorofluorocarbons, and boy did I try. I even gave up hairspray and tried to grow dreadlocks to make a statement against aerosols, but after two months all I had was one giant knot of hair in the back of my head that had to be cut off. I could recycle, and I did, but back then we did not have the efficient recycling collection systems we have now, so I had to store my recycling until I could drive it to a recycling center (which upset me because driving was bad for the planet) and it caused my apartment to become infested with roaches from all the empty food containers stored in the pantry. I could stop eating meat, and I did so without much pain by substituting more chocolate and cheese into my diet. The unfruitful lifestyle efforts aside, my main takeaway from Weiner's book was that my generation had to do something to develop new energy sources to slow down the emission of carbon dioxide into the atmosphere. I set out to do my part there too.

Weiner's book explains there are three gases that best act like a greenhouse's glass walls and hold heat in our atmosphere. These three "greenhouse gases" are water vapor, carbon dioxide, and ozone, and they share a feature that oxygen gas and nitrogen gas do not have: their molecules are composed of three atoms instead of two. Having three atoms gives these greenhouse gases the special property of trapping heat. When the sun shines on the Earth, high-energy radiation passes through these three-atom molecules to the ground where the radiation is converted into lower energy heat (thermal, also called infrared) radiation. The heat rising back off the ground does not pass back through these molecules. Instead the infrared radiation is absorbed by the bonds in these greenhouse gases. The absorbed energy causes the bonds to vibrate and release more infrared radiation, which is absorbed by other nearby greenhouse gas molecules. Hence, the heat is retained in our atmosphere rather than released back out into space.[3]

This greenhouse effect is related to the cycling of the seasons. Plants take in carbon dioxide during the spring and summer when they are green and the sun is shining on them; via photosynthesis, they convert the sunlight into chemical energy, which synthesizes the carbon dioxide and water into carbohydrates (which store the energy) and oxygen (which we breathe). When the leaves wither and fall to the ground or become food, the carbohydrates decompose back into water and carbon dioxide, so the plants give back some of the carbon they took from the air. This is called respiration. The planet can be thought of as (although we know it is not) an organism inhaling and exhaling (breathing) carbon dioxide throughout the processes of photosynthesis and respiration.

Scientist Charles David Keeling charted the change in concentration of carbon dioxide in Earth's atmosphere starting in 1958, and the data is still gathered today even though Keeling died in 2005. In his book, Weiner explains that these plots are evidence that the buildup of carbon dioxide in the atmosphere would "change the breathing of the world."[4] Technological optimists, he says, interpret changes in the Keeling plots as evidence that the world is breathing more deeply; technological pessimists see the Earth getting out of breath, gasping.

Having grown frustrated with hairdos, rotting pizza boxes stashed in my gas-guzzling Ford Fairmont, and the few pounds I put on as a chocolate-and-cheese-consuming vegetarian, I decided I needed to do something more than spin like a cog in the wheel of a culture strangling the planet, and I knew it had to be something visionary. The chapter in which Weiner discusses the gasping planet and the Keeling curves begins with a quote that is highlighted in yellow in the copy of his book that still sits on my shelf, for I treasure it along with the other books that shaped me: "So it cometh often to pass, that mean and small things discover great, better than great can discover the small: and therefore Aristotle noteth well, 'that the nature of every thing is best seen in its smallest portions.'"[5]

I had no idea who Aristotle or Francis Bacon were, nor did I care, but the words "the nature of every thing is best seen in its smallest portions" resonated with my mechanical worldview. It hit me then that if we humans wanted to *do* something that would save the planet in the long term, we—I—needed to study and simulate what plants do. I needed to simulate photosynthesis, and to do that I needed to learn how to manipulate atoms.

I read K. Eric Drexler and Chris Peterson's 1991 book *Unbounding the Future: The Nanotechnology Revolution*, and my visionary path uncoiled before me.[6] This book is a tour of all the ways nanotechnology—the ability to manipulate matter at the atomic level—can improve our lives and save our planet. Particularly, Drexler discusses how molecular manufacturing can provide clean solar energy by mimicking photosynthesis. Materials could be used more sparingly than in human-scale technologies, and pollutants could be minimal and more controllable since the machines would be molecular. As machines grew more perfect at the molecular level, their motors, bearings, insulation, and computers could become less wasteful. Molecular machines could, like plants and the chemical cycles that sustain them, produce waste products that are the reactants for the next cycle of production. Nanotechnology, he says, could be the "ultimate recycling technology."[7] I knew that if I could get into a research lab that simulated photosynthesis on nanomaterials for the purpose of providing new energy sources, I could become more than just someone who lived in her time and place and did what the wheel of her culture made her do. I could become a mover. I could help save the planet.

So I put down the popular science books and headed to the library to sift through science journals for the latest research on using nanotechnology to create artificial photosynthesis. The subject spans several disciplines: physics, biochemistry, materials chemistry, and polymer chemistry. I learned of a research team that had just recently moved from the University of Texas at Austin to Penn State and was researching, among other things, artificial photosynthesis on nanometer-scale inorganic particles with a long-term goal of producing new materials that could, like plants, take energy from the sun and convert it into chemical energy. In 1993, I wrote to Dr. Thomas E. Mallouk's Chemistry of Nanoscale Inorganic Material Research Group at Penn State. He invited me to visit the university; I was accepted into the graduate school with the customary full scholarship plus stipend, and the following fall I moved 1,200 miles northeast, away from my family and the big skies of Texas, to pursue my dream of becoming a serious scientist.

WRESTLING WITH NATURE

My first assignment in the Mallouk lab at Penn State was to work with Dr. Steven Keller, the postdoctoral fellow who was conducting the research on artificial photosynthesis on inorganic-organic nanometer-scale composite assemblies. It is an understatement to say that I thought my life was complete, but I had in my mind only my *scientific* life, while I knew my personal life was a disaster and did not know how to unify both lives. By then, I had given birth to two children, but I was so beholden to my career that I was an absent mother. Scientific research makes it easy to put personal problems on the shelf because you have to block everything else out in order to do your work.

In my arrogant mind, I was the rare Randian, Einsteinian heroine doing necessary work. Everything else was secondary, including the two inorganic-organic highly complex multicomposite assemblies who called me mother. I actually referred to my children as "inorganic-organic highly complex multicomposite assemblies" on the day they sat in the front row at my doctoral dissertation defense; it is painful to recall how insensitive, full of myself, and lost I was.

My task was to learn from Dr. Keller, publish with him, and then continue the project with the team after he left the group to start his own career. For the most part, daily life in the lab was not about success. A chemistry professor told me early on in my scientific endeavors that if I wanted to become a research chemist, I had better be able to handle failure, by which he meant that the vast majority of my experiments would fail to do what I wanted them to do. He was right. We had enough good results with artificial photosynthesis to get articles published in the *Journal of the American Chemical Society*; the *Proceedings of the Robert A. Welch Conference on Chemical Research in Nanophase Chemistry*; an advanced textbook, *Photochemistry and Radiation Chemistry: Complementary Methods for the Study of Electron Transfer*; and the *Coordination Chemistry Reviews*.[8] I do not list those accomplishments so much to impress (although they were impressive to me) but to set the stage for my comeuppance.

What we did, while noteworthy enough to merit publication, was small—not small as in nanoscale, but small as in insignificant compared to what leaves actually do. In spite of all I was accomplishing, I still could not quite forget what I had known as a child to be true: our knowledge is a speck compared to our ignorance. I have a knack for missing the obvious, so I kept on wrestling.

We were trying to simulate a single electron excitation and transfer along the electron transport chain in the light reactions in the photosynthetic cycle. Let me back out from those reactions to put the process into the bigger perspective. Photosynthesis begins, of course, with sunlight; it occurs within a plant cell in organelles called chloroplasts.