THE SEARCH FOR THE SHAPE OF THE UNIVERSE, ONE BOOK AT A TIME

My family jokes that I was adopted. With two parents, three aunts, and three uncles who all studied English or history, what are the chances of having a child so driven by love of math and science? Even my little sister wonders where I came from: we are both very musical and the physical resemblances are great, but there the similarities end.

I did inherit a bit of the history genes—and certainly the book-loving ones—which may explain why reading is one of my favorite pastimes. We have shelves and shelves of fiction (more than fifty of them) and my great-grandfather's collection of Civil War histories, but the ones I treasure come from the biology class my mother took in 1977, including Lewis Thomas's *Lives of a Cell* and Konrad Lorenz's *King Solomon's Rings*. She also gave me the last book her father requested before he passed away in 1982, Carl Sagan's *Cosmos*. Maybe there are science genes in my makeup after all?

Having parents who are humanities-oriented has its drawbacks—neither of them took calculus or physics, and the biology and chemistry they learned is outdated—but that can be a positive, too. I know the value of working with other students and am completely comfortable teaching myself.

Unlike my peers who grew up hearing stories of their parents' work and saw firsthand academic or industrial workspaces, my image of academia comes almost entirely from books. I learned about the personalities of scientists from biographies, and I learned what type of work awaited me by reading about new discoveries and theories. Slowly, I started to form a picture of what my life could be. Through books, I've integrated a love for literature, history, and science. What started with Matt Ridley's *Genome* has turned into a collection of more than two hundred titles covering topics from quantum mechanics to Fermat's Last Theorem to cryptography. It contains biographies, collections of essays, popular literature, and histories, all with a powerful science theme.

The development of my collection mirrors my intellectual development. Over the past five years, I've graduated from popular science books by authors like Brian Greene and Lisa Randall to classic

textbooks and histories. As my technical knowledge increased, I started picking out texts like Richard Feynman's *Lectures on Physics* and Euclid's *Elements*, and now I can absorb the material from textbooks about classical mechanics, thermodynamics, and quantum mechanics.

But there's more to each of the books than just the text inside. The stories written down aren't the only ones the books tell. Each one brings back its own memory—about a moment in time, a person, a place—that is just as important as the book itself.

It's difficult to pinpoint exactly when I discovered academics as a pastime. Certainly taking higher-level courses in high school helped, but so did a serendipitous discovery of how much fun reading stories about everything from relativity to infinity could be. I think it might have started with Charles Siefe's *Zero: A Biography of a Dangerous Idea*, a book suggested to me by a fellow math-lover, Leo Tolias, who is now an electrical engineering student at Princeton. (We still swap "best book" ideas.) *Zero* took me through the development of a single number, exploring the obstacles and triumphs of one digit and its impact on science, philosophy, history, and more.

Not long after, I came across *Fermat's Enigma* (by Simon Singh) while browsing the mathematics section in a small bookstore in Seattle, Washington. Another customer saw me reading the back of Singh's novel and gave it an enthusiastic review. I had the book read before we returned home later that week. *Fermat's Enigma* and the mystery of the centuries-old, unsolvable proof remains one of my favorite books. Ironically, when exchanging Christmas gifts with Leo, we found that we had both picked out one of Singh's books for the other. I received a copy of *The Code Book*, an account of the dramatic story of cryptography as it has developed throughout hundreds of years, and gave him—what else?—*Fermat's Enigma.*

I began to add scientific books to my Christmas list. The first year, I requested Eli Maor's *e: The Story of a Number* and Paul J. Nahin's *An Imaginary Tale: The Story of* $\sqrt{-1}$, among other titles. My relatives, not believing that any high school student would willingly ask for such weighty books, accused my mother of working me too hard. Nonetheless, I opened the gifts with a beaming smile when Christmas came around, and they were finally convinced that the books had been my heart's desire, not my mom's.

The books of my collection come from and have been read all over

the world. I've never visited a college campus without stopping in the bookstore, usually heading immediately to the science and math sections. In England, while I was busy reading William Dunham's *Journey through Genius*, I forced my friends to stop in a tiny bookstore we happened upon while exploring London. It was filled with old books with worn covers. I left with a copy of *Introduction to Statistical Method* by B. C. Brookes, written in 1951. I bought Newton's *Principia* from a bookstore in Washington, and Einstein's *Ideas and Opinions* while studying one summer at Carnegie Mellon. I found the Einstein in a used bookstore I visited after finishing Feynman's *QED* and Singh's *Big Bang*.

I became fascinated by scientific personalities. I devoured Walter Isaacson's *Einstein* and read James Gleick's biography of Feynman, *Genius*, not long after. After being accepted to Princeton, I read *A Beautiful Mind* (Sylvia Nasar) and have since read *Turing's Cathedral* (George Dyson) at the suggestion of a friend from school.

In fact, *Fermat's Enigma* appeared in a draft of my college common application essay. But the essay I wrote wasn't just about the collection of academic books I'd put together through my four years of high school. It was about how the information I gained from these books spilled into and enriched all facets of my life. My math and science books are just components of a collection that embodies pursuit of knowledge.

In 2011, I stumbled across the Museo Galileo in Florence, Italy. It is filled with scientific instruments used throughout history. There were altimeters, telescopes, microscopes, astrolabes, and planetariums—the most extensive collection I'd ever seen. I'd gotten hooked on the history of science and math with *Fermat's Enigma*, *The Code Book*, and Euclid's *Elements*, and now I was able to see the same stories of amazing accomplishment told through instruments rather than text.

I always loved the glamour of Copernicus's heliocentric universe. I loved how one insight could change the model of the universe from a complicated one with the never-ending epicycles of Ptolemy's *Almagest* to an ordered model of circular orbits. Even still, the simple model could be perfected. In the early seventeenth century, Kepler learned that the orbits were actually ellipses, with the sun at one focus. Still, Mercury's orbit was not quite right, so Einstein was able to check the theory of general relativity in the early twentieth century by predicting Mercury's perihelion better than any previous method.

At some point this past year, my mom surprised me with a copy of *Instruments of Science: An Historical Encyclopedia*. She'd found it online and couldn't help but give it to me as a spur to my interest in historical scientific instruments. The first piece I got was a Pickett slide rule, a Christmas present in 2011 and the focal point of my college essay. During an interview for a local scholarship, chatting about my performance at school and my aspirations for the future, one man stopped and said he couldn't help but ask, "Is it a blue slide rule or a yellow one?" The Rotary Club had required that we submit our essays as part of the application, and I was flattered that this man remembered such a small detail in my application. In the essay, I jested at the end that the next year for Christmas I might get something like an abacus. I did. I've now acquired other slide rules, a compass, a scale, a sextant, and a piece to a barometer. One day, I'd like to return to the Museo Galileo to peruse its collections with new appreciation for many of the pieces. It inspired me to expand from simply collecting books to collecting artifacts of the history of scientific pursuit.

The inspiration for pieces to add to my collection can come from almost anywhere. On the same trip to Seattle where I discovered *Fermat's Enigma*, I also was introduced to Encyclopedia Britannica's *Great Books of the Western World*. My Uncle Kevin had all sixty volumes of the second edition, beautifully bound, displayed in one of his bookcases. Later that summer my mother and I tracked down on craigslist the original 1952 edition. We drove eighty miles to Newtown Square, Pennsylvania, to buy it from an older couple who were downsizing—and happy to see their children's books go to another generation. Along with the volumes that fit easily into my slowly developing collection—Galen's *On the Natural Faculties*, Euclid's *Elements*, various works of Archimedes, Copernicus's *On the Revolutions of Heavenly Spheres*, Kepler's *The Harmonies of the World*, Newton's *Optics*, and others—my acquisition criteria, originally strictly scientific, were being reshaped.

The collection is a tangible representation of my pursuit of knowledge. It is learning for the sake of understanding. The authors represented in the *Great Books* wrote because they had innate curiosity and an irrepressible desire to learn. The authors of literature wrote because they had stories to tell, stories that would stay relevant for hundreds of years. One of my goals is to read every volume of the *Great Books*. On the plane ride home from Italy, I read Machiavelli's

The Prince (vol. 23); I read *Don Quixote* (vol. 29) in its original language during my junior year of high school; I read *Paradise Lost* (vol. 32) with the same English teacher who took us to London after sophomore year; we read the *Federalist Papers* (vol. 43) in U.S. History during my junior year and selections from Freud (vol. 54) in Psychology. This past semester, I've read most of volumes 3 and 4 (Homer and the Greek tragedies of Aeschylus, Euripides, and Sophocles), as well as part of volume 13 (Virgil's *Aeneid*). Admittedly, my collection consists primarily of physics books, because that's where my passion lies, but more and more, it represents my fascination with the development of knowledge and a spur to my intellectual curiosity.

Course work inspired or led directly to the purchase of many of the books in my library. At the senior awards ceremony in high school, I was presented with Stephen Hawking's *A Stubbornly Persistent Illusion* after receiving the Physics Award. Undoubtedly, my physics teacher remembered that I had given him a copy of *Einstein* as a thank-you for writing my college recommendation. After spending a year in the Integrated Science Curriculum at Princeton, I've added classic textbooks to the collection, such as David J. Griffiths's *Introduction to Electrodynamics* and an old first edition of his *Introduction to Quantum Mechanics*. Even though I'll need to replace the latter next semester with a newer edition, this old copy will always be emblematic of my first rigorous introduction to quantum mechanics. What I'd known only on a purely conceptual level during high school could now be represented with mathematical models that made quantum mechanics even more fascinating. During one lecture on quantum mechanics, Professor Joshua W. Shaevitz mentioned that George Gamow's *Thirty Years That Shook Physics* was a good, quick read about the history of quantum mechanics. I ordered it immediately and sat down in Rocky common room to read it as soon as the semester ended. Early in fall semester, we had done a lab on Brownian motion. At the end of the year, Professor William Bialek gave each student a copy of Einstein's *Investigations on the Theory of the Brownian Movement* as a gift, and it now sits between *Information* and *Isaac Newton*, both by James Gleick.

My family members are no longer surprised by any of my requests for books. Over the summer, my aunt sent me a copy of *The Boy Who Loved Math: The Improbable Life of Paul Erdos*, a children's book by Deborah Heiligman. She attached a note: "I saw this and thought of

you." For my birthday, my sister the artist got me the *New York Times Book of Mathematics*, a collection of mathematical stories from the past hundred years. She remembered that I'd loved reading Steven Strogatz's "Elements of Math" column in the *Times*.

My mother now has a search alert on several of my favorite authors, including James Gleick, whose *Chaos*, *Genius*, *Information*, and *Isaac Newton* are among my favorites, and Simon Singh (*Big Bang*, *The Code Book*, and *Fermat's Enigma*). Uncle Kevin also finished my set of Brian Greene's books after I'd read *The Elegant Universe*. He watched NOVA's *Fabric of the Cosmos* and sent me a copy of the foundational book, enthusiastic about the subjects covered. Uncle Kevin is not a scientist, but he shares my curiosity (and love of music). Recently, he sent me a copy of Leonard Shlain's *Art and Physics*, a book that manages to integrate our two passions.

My father, though not a librarian like my mother, has also been instrumental in the development of my collection. His apartment is filled with antiques and art, and over the years he's given my mom many beautiful first editions of books by Robertson Davies and Ivan Doig, two of her favorite contemporary authors. Along with the baseball books he's given me over the years, I've also gotten Feynman's *Lectures on Physics* and the Philadelphia Public Ledger's *Unrivaled Atlas of the World* from 1899. For my past birthday, he surprised me with an original copy of *Scientific American* from October 24, 1896, featuring the sesquicentennial celebration of Princeton University on the cover. (To celebrate my admission to Princeton, he also tracked down a copy of *Sports Illustrated* from October 17, 1955, with a picture of the Princeton University Band on the cover.)

Lectures on Physics appeared on my "book wish list" after I read Lecture 19 as I was studying the variational principles of mechanics over the summer. Feynman's quirkiness made him one of my favorite physicists, but I'd yet to read any of his renowned lectures. After reading about the principle of least action in Herbert Goldstein's *Classical Mechanics* (yet another recent addition to my collection), I tackled Feynman's lecture. He had a unique way of teaching physics that made it almost entirely conceptual. In *Feynman's Rainbow*, Leonard Mlodinow remembers that "Feynman used to say there were two kinds of physicists, the Babylonians and the Greeks.... The Babylonians made western civilization's first great strides in understanding numbers and equations.... Yet it is the later Greeks ... who we credit

with inventing mathematics. To put it simply, the Babylonians focused on the phenomena, the Greeks on the underlying order.[1] I'm struck by how truly distinct—yet necessary—the two approaches are. Einstein was a Babylonian: he developed his theories of relativity with *Gedankenexperiments*, or thought-experiments. But after hitting a wall while developing a general theory, he turned back to mathematical foundations to help guide his thoughts. From Feynman, I began to learn what type of physicist I wanted to be.

I also started to focus on certain physicists as role models. I'd idolized Einstein as a child, the same way young baseball fans always choose the star of the team as their favorite player. Now I've graduated from Mark McGwire/Einstein to a broader appreciation for all members of a team and more of the great minds of "giants." I learned to root for Yadier Molina of the St. Louis Cardinals after the seventh game of the 2006 National League Championship Series against the New York Mets, and I learned to appreciate Feynman after discovering that his style of studying physics was one I strived to emulate. Now that I've reached college, I'm finally learning the math behind all the physical concepts that I'd read about. I can sit down and watch mathematical formulism unfold on the page of a textbook the same way I discovered the history of zero from Charles Seife. As I read through something like the decoupling of Maxwell's Equations, I wait in anticipation for the point when you discover that the speed of light is inversely proportional to the square root of the products of the permittivity of free space and the permeability of free space. Or you can watch magnetic forces develop so fluidly from relativistic principles. You can derive the wave equation for the hydrogen atom, then (because you're a curious science student) graph your equations with different quantum numbers to find that they create the same orbitals that you've been learning about since intro chemistry during high school.

Before I can make new discoveries, I need to learn what my predecessors have spent hundreds of years working on. But this doesn't mean we can't make discoveries of our own. Science is best learned through tinkering. We make connections between seemingly unrelated principles that improve our understanding of the physical world.

1. Leonard Mlodinow, *Feynman's Rainbow: A Search for Beauty in Physics and Life* (New York: Vintage, 2003), 24.

Every time I read a book—a history, a memoir, a textbook—I make discoveries that help connect the web of scientific formulism and concepts that I've developed as a student. In seventh grade, I could discover something as simple as the fact that the vertex of a parabola represented a maximized physical quantity. In eighth grade I learned that the same parabola could represent the motion of a projectile.

My understanding of the connections between pure mathematics and the physical world is certainly more sophisticated than it was back in middle school. Classes teach more complex topics, but in high school, this was only enough to whet my appetite. Books were my portal to the world of science, past and present, and the authors and scientific personalities that I came to be familiar with were my teachers as much as the teachers at Westfield High School. Even after reading *Fermat's Enigma* back during my freshman year of high school, I'd gotten used to the idea that science textbooks could be novels of a sort. There's character development as we define principles and axioms, then the plot rises as you start to make calculations, hoping they are taking you in the right direction. Sometimes, you begin to see where the plot is headed—maybe you've seen a similar derivation before—but at other times the result can sneak up on you, like a plot twist you were never expecting, and suddenly your picture of the world is a little more complete.

I'm addicted to this feeling the same way you can get addicted to a good novel, unable to put it down until you've reach the resolution. It's driven me to study the world through as many ways as possible, and there's no better way than through books.

—RORY FITZPATRICK
Class of 2016