Introduction

Who is Peter Lax? A famous mathematician. The major player for a half century in the dynamo of American applied mathematics. The last surviving member of the great wave of European mathematicians and physicists in the 1930s and 1940s who helped create the much-heralded “American century.” (It turned out to be just a half-century.)

Back in my grad school days from 1957 to 1962, Professor Peter Lax was my mentor. Now we are both in our eighties and old friends. This book is more than just an account of a career in mathematics, with conjectures and theorems, professorships and prizes. It follows his life’s arc, from childhood in the glamour and tragedy of Horthyite Budapest, to a lifetime of success in New York and Los Alamos, culminating in Oslo with acclamation from the queen of Norway.

His achievement forces one to see the contrasts and similarities between pure mathematics and applied mathematics. For the greatest mathematicians, the pure and the applied have for centuries easily fed and reinforced each other (Newton, Euler, Gauss, Riemann, Poincaré, Hilbert, von Neumann, Gelfand). Yet the value systems of the pure and the applied are opposed. Their prizewinners are almost two disjoint sets. Every day they compete for money from “granting institutions,” including universities. They are a strange kind of twins, simultaneously incompatible and inseparable.

Peter is one of the greatest living applied mathematicians and one of the greatest living pure mathematicians. This book returns repeatedly to this duality.

In telling his life story, I cannot avoid honestly including my own political identity as a lifelong “lefty”, “peacenik”, and all-around dissenter. Peter and I came of age during the great war against Nazi fascism, and matured and lived through a half-century cold war of nuclear threat of mutually assured destruction. We shared many liberal values, and at the same time were separated by profound differences. Our disagreements have been very serious and difficult but always respectful, and in the end, perhaps, really not all that important as they seemed at the time.

Politics entered Peter’s life story repeatedly, first in the form of murderous Hungarian and Nazi anti-Semitism, then in conflicts over accepting refugees and immigrants into the U.S. In the famous Manhattan Project, where a new kind of bomb was being invented and manufactured, Peter was initiated into serious applied mathematics. During the Vietnam War, in a protest at NYU, Peter played a surprising and courageous role.

I, growing up as a New York Jew in the Depression decades, took left-wing sympathies for granted. To him, growing up in the aftermath of a disastrous failed
Hungarian Bolshevik revolution and knowing the dire fate of Hungarian Jewish Bolsheviks who took refuge in Stalin’s Moscow, fear and hatred of Soviet Communism were taken for granted.

In writing this book I first discovered that fifty years earlier, at a time when I as his student felt a great ideological gap between us, Peter was quietly giving essential material support to my school friend Chandler Davis, who had been blacklisted by U.S. academia after serving prison time for contempt of the U.S. House of Representatives Committee on Un-American Activities.

Lax is an ex-prodigy who more than fulfilled his promise. To a distinguished family heritage, Peter brought a brilliant talent, which was recognized early and carefully nurtured both in Budapest and in New York.

Starting in Budapest, we progress through his arrival in New York, his service as a corporal on the Manhattan Project in Los Alamos, his family life, his career, his famous adventure with the bomb scare at NYU in 1970, and on through his writings, his students, and his prizes. I present his remarkable discoveries and creations without requiring advanced technical preparation. On certain pages, there is a brief reversion to the pedagogic or textbook tone, but in the main I present his mathematics as a narrative.

He was recognized early as a likely future master mathematician. In 1941, almost at the last minute, he escaped with his family to comfort and privilege in Manhattan. When they arrived in New York, they brought with them letters from his mentors in Budapest to two Hungarian mathematicians already in the U.S.: John von Neumann in New York and Gabor Szegő at Stanford University in California, whose wife was Peter’s mother’s cousin.

Von Neumann suggested Peter work with his collaborator Francis Murray at Columbia University. But Szegő said that Richard Courant at New York University was “very good with young people.” Peter later said that Szegő’s advice was the best possible. At sixteen he became a student at NYU, starting to grow into his role as a superstar there. He remained there as a professor through his whole career. NYU’s graduate math program in time would be renamed the Courant Institute.

From his first days in the U.S., he was guided, supported, and inspired by Richard Courant and John von Neumann. These two émigrés were different in many ways, but in certain respects they were similar. They both combined deep devotion and commitment to mathematical values (truth, profundity, elegance) with high achievement in the American stratosphere of money and politics.

Von Neumann, one of the supreme mathematical intellects of the twentieth century, would be Peter’s lifelong model of excellence in mathematics.

Included in this book are biographies that Peter wrote of Courant and von Neumann, so it is unnecessary for me to say much about them here.

Courant is unique in the history of mathematics, the leader of two great mathematical centers—first in Göttingen, Germany, in the 1920s, and then in New York from the 1930s for the next half century. Courant is the author of three great books. The first, affectionately called just “Courant-Hilbert” or, more formally, Methods of Mathematical Physics, is based on David Hilbert’s lectures and became an indispensable handbook for the physicists who created quantum mechanics in the 1920s. Then there is his textbook on differential and integral calculus, which is still the very best of all. And there is What Is Mathematics?, a delectably inviting
work of art that opens modern mathematics to the eyes of any literate intelligent reader. (The co-author was the future famous statistician Herbert Robbins.)

Von Neumann was legendary for sheer mathematical power. Lightning fast computation, encyclopedic memory, uncanny ability to connect seemingly remote mathematical concepts. He first became known for contributions to the “foundations of mathematics”, axiomatic set theory. Then with Oskar Morgenstern he invented game theory, the mathematics which is still today the favorite plaything of high-powered strategists. Then he used a new infinite-dimensional function space, which he named “Hilbert Space,” to unify and establish rigorously the rival quantum mechanics of Heisenberg and Schrödinger. After that he deeply explored the theory of linear operators, introducing “pointless spaces” and continuously varying dimension.

By the time Peter met him in wartime in the 1940s, von Neumann had blossomed as an applied mathematician, a famously powerful one in the Manhattan Project at Los Alamos, New Mexico. There he was joined by eighteen-year-old Corporal Peter Lax. Von Neumann was already one of the inventors of modern digital computers. One of the first, called the MANIAC, was also sometimes the “Johnniac”. He was fascinated by a difficult mathematical-physical problem: shock waves, such as the implosion wave he used to detonate a plutonium bomb or the tremendous pressure wave that springs out of an atomic explosion. These are interesting physical phenomena. Mathematically speaking, they are discontinuous solutions of certain nonlinear partial differential equations. Predicting where and when the discontinuity arises and how it propagates remains to this day a deep, difficult problem.

Peter worked on shock waves alongside John von Neumann and continued and amplified von Neumann’s work after von Neumann’s premature death.

Von Neumann was famously influential at the highest levels of U.S. decision making. When asked about this during a television interview in their native Hungary, his friend Eugene Wigner explained that “after von Neumann analyzed a problem, it was clear what had to be done.”

Courant also was an adviser and consultant in high circles, but most important was his great skill and success in promoting, establishing, and enlarging the institution that later would bear his name. It was no simple or straightforward matter for NYU to become the principal academic center of applied mathematics in the U.S. To the intense competition for federal support Courant brought persistence, guile, and skill at winning the friendship of powerful people.

One of the pleasures of my research for this book was finding in the NYU archives the recommendations that Courant wrote for Peter Lax, including his recommendation for Peter’s election to the National Academy of Sciences.

Peter Lax says that he likes to pick out a striking phenomenon, such as shock waves, and analyze it mathematically. While such work is motivated by physics and produces information valuable to physicists, the analysis itself, as done by Lax, is pure mathematics. It is precisely stated as a mathematical problem, and the claimed result is rigorously proved. Ordinarily, in applied mathematics, in search of a useful result, one may take a shortcut, justified more by hope or by intuition than by rigorous logic. Peter’s work on shock waves, on scattering of light and sound waves, and on the Korteweg-de Vries equation of fluid dynamics is not like that. It is totally and strictly rigorous.
Is Peter Lax a pure mathematician or an applied mathematician? He sees no difference between the two. By choosing problems from physics and solving them as problems in pure analysis, Peter unites the pure and applied seamlessly and inseparably.

In the larger mathematical world, the distinction between the pure and the applied is clear. Applied mathematics values utility and relevance, giving the customer the information needed to get the job done. Rigor and elegance can come later, if at all.

Applied mathematics is likely to be found in an industrial laboratory or in university departments of computing or engineering or applied mathematics. There are journals of applied math, and there are journals of pure math. Some articles could appear in either place, but many could appear only in one or the other. In the pecking order of academic prestige, pure mathematics has a lofty position, looking down from above at any sort of application. But in the practical worlds of money and power, applied mathematics is recognized and important, while the pure in its ivory tower at best receives faint praise.

This de facto separation into two social/academic worlds is mocked by the many very important scientific linkages between them. Applied mathematics often provides great inspiration for work in pure mathematics. Pure mathematics constantly provides essential tools for applied mathematics. At his institute, Courant recognized no separation or distinction between the two. Courant shared this philosophy with his mentor, David Hilbert.

Peter Lax’s career is a singular exception to the usual mutual disrespect between these two inseparable and incompatible twins, the pure and the applied. In phenomena of visible and palpable physics, he found deep mathematical problems whose statement and whose final result or solution can be understood by any interested reader. For other prizewinning mathematicians of recent decades, even the titles of their epochal discoveries are not decipherable by the ordinary practicing mathematician.

Peter Lax is the rare mathematician who is completely at home and masterful in the abstract axiomatic style while still rooted in and always inspired by concrete physical phenomena, such as shock waves, for example.

Students sometimes come to the university anticipated and well known, having shown brilliant promise to qualified judges. Such great promise is not always followed by the hoped-for great performance. The aspiring mathematical genius usually has years of struggle ahead. First, struggle to get into the best graduate program, then struggle to beat out other aspiring grad students for the best thesis adviser, then struggle to make enough of a dent in the right problem to impress the adviser and the broader research community, then struggle for tenure at a top-notch math department, then struggle to make more great discoveries—arduous years to make it to the top and stay there.

Peter is one of the few who rose to the top and stayed there, from childhood through the rest of his life. Great promise in childhood was fulfilled by great achievement as a professional. Among the international mathematical giants of our time, Peter Lax is almost unique. He has one foot in each of two camps: one side is the deeply abstract and theoretical, the other side is the computational, practical, scientifically useful.
Louis Nirenberg is one of the most honored living mathematicians, the uncontested world expert on inequalities and estimates. He says,

Peter always knew a lot more math than I did. When he was explaining something to me he sometimes said he was willing to explain the same thing more than once but not more than 10 times. Peter has been like a brother to me.

Peter’s life was not free from misfortune or suffering. With his family he had to flee the murderous Nazi persecution. Later he suffered very painful losses of his closest loved ones. But he doesn’t show scars or wounds. He’s remarkable for kindness and gentleness.

I chatted with Peter’s grown-up grandsons, Tommy and Timmy, and asked Tommy, “What do you think of Peter as a grandfather?” He answered, “My earliest memory of him is that Peter was the only person that could really get me out of bed.”

“How did he do it?”

“He would sit right next to me and sing Irving Berlin’s ‘You gotta get up, you gotta get up, you gotta get up in the morning!’ with a Hungarian accent.”

My friend Mutiara Buys, a mathematician whose Ph.D. is from NYU, writes, “For two years I made sure I attended at least one of Peter’s classes, and continued sitting in his classes and seminars after orals. I was attracted to his extremely lucid and clear mind, as well as his charming and witty personality.

“The proverbial prof just goes on ad infinitum writing math computations on the blackboard. Little time is devoted to thinking about what a formula means. Peter Lax devotes considerable attention to speaking about and conceptualizing a computation, so valuable insights are imparted to the student.
"One day Peter was stuck in one of his computations and was rather annoyed with himself. He stared at the blackboard for a long stretch. All of a sudden he hit his head dramatically and exuberantly shouted, “Oh my God, I could have had a V-8!” (famous commercial for the vegetable juice V-8 of a guy hitting his head; I hope you know it). He energetically and happily erased the board and provided a succinct, elegant proof while apologizing for not having had a good proof to start with. I don’t think I have ever not laughed in his class; he is an engaging and fun lecturer. Outgoing, amiable, and fun-loving.

“At a wedding attended by many shy people, Peter was on the dance floor showing off his dance steps and egging people on to participate.

“At my thesis defense he was dozing off. To get his attention, I had to loudly mention the Lax Pair, at which he immediately perked up and listened attentively.”

This last experience of Mutiara’s was not unique. Less famous than his mathematical brilliance and his personal kindness and friendliness is Peter’s narcolepsy (falling asleep inappropriately). As a fellow sufferer from this disability, I know that it is a misfortune, amusing though it is to onlookers.

At a time during my student days when I didn’t have an office, Peter offered me a desk in his office. He was visited by Seymour Parter, a respected numerical
analyst at the University of Wisconsin, who was eager to talk about his great new idea (to use graph theory to study matrices for numerical calculation). Peter’s head would nod off as he lapsed into slumber, but Seymour just shouted, “Wake up! Wake up! Peter, wake up!” Peter would shake his head, open his eyes, smile slightly, and resume listening to Seymour’s lecture.

Peter’s telephone was constantly ringing. He was always willing to interrupt his work and help the caller with his problem. Once I actually was able to help Peter Lax. He received a phone call from the ground floor, “Mr. So-and-so is here to take his real variables exam.” In our course on real variables, Peter had made the final exam optional, and now here was a student actually asking to take a final! The last thing Peter wanted was an interruption to write a real variables exam. He moaned, “What can I do?” “It’s easy,” I answered. “So-and-so doesn’t want to settle for a B, he wants an A. So just give him an A.” “Brilliant!” cried Peter. He picked up the phone and told the waiting receptionist, “Tell Mr. So-and-so that his grade for the course is A.” Problem solved.

Alex Chorin, a professor at Berkeley, is an original, influential contributor to fluid dynamics, but as a graduate student, he had to struggle. “It is very clear to me that Peter had some idea that I was having difficulties not necessarily related to mathematics and was very patient with my absences and my not always turning up when summoned. I was grateful then for Peter’s patience and humanity, and am even more grateful to him now that I have had grad students of my own. Without his kindness I doubt I would have received a Ph.D. It is not easy to see the need for kindness when the usual view of one’s duty is to insist on steady progress.”