Tales of Our Forefathers

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Introduction

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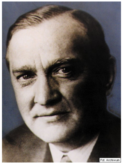

Mittag-Leffler refers to one.

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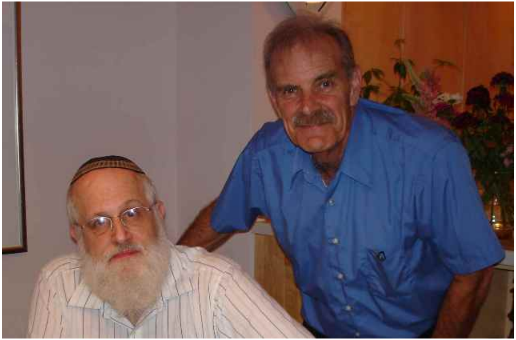

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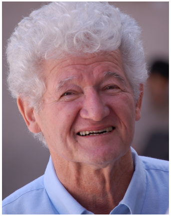

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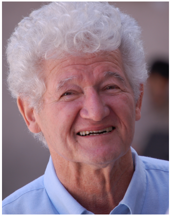

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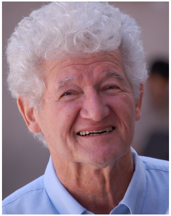

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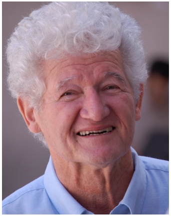

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But I digress—and not for the first time.

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Second, I regret that this is only about forefathers and not foremothers also, although two female mathematicians have cameos later. It is an unfortunate aspect of history that we used to ignore half our mathematical talent—I'm glad we no longer do quite that badly.

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Of course, prior to the twentieth century, mathematicians were more universal and so "analysts" means most mathematicians.

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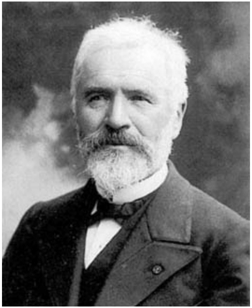
For example, consider Camille Jordan (1838–1922),



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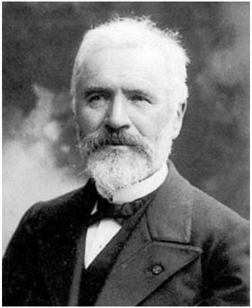

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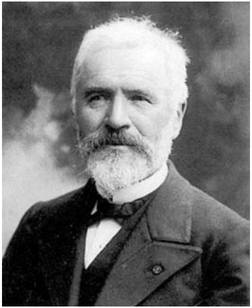

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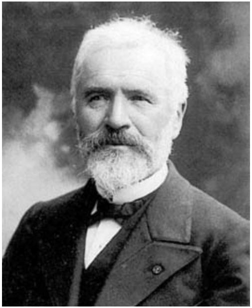

who made significant contributions to algebra (Jordan normal form, Jordan–Hölder sequences), geometry (Jordan curves), and analysis (Jordan content and Jordan decomposition of functions of bounded variation).

Some Caveats

By the way, this is not the Jordan of Jordan algebras and the Jordan–von Neumann theorem—that was the physicist Pascual Jordan (1902–80), best known as one of the authors of the “three-man paper,” which was one of the foundational papers of quantum mechanics.

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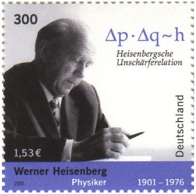

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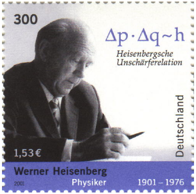

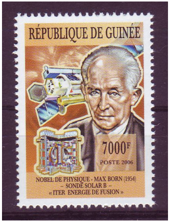

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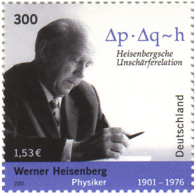

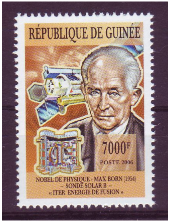

Some have speculated that this Jordan might have shared in Born's Nobel prize if it weren't for his strong support of the Nazis and pro-Nazi views during the Hitler era.

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The Arnold Principle. "If a notion bears a personal name, then this name is not the name of the discoverer."

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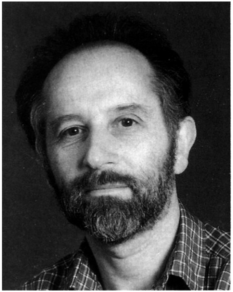
The Berry Principle. "The Arnold Principle is applicable to itself."



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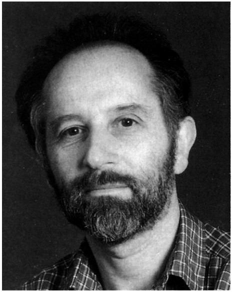

Berry’s Principle is certainly true. You won’t find “Arnold’s Principle” on Wikipedia, but you will find “Stigler’s law of eponomy,” which Stigler stated in 1980 as

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Stigler remarked that since it was a discovery of Merton, it was appropriate to name it Stigler's law to validate the law!

Family Matters

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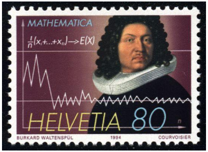
We start with the largest of the mathematical families.

The Bernoullis

The family originally fled Belgium for religious reasons and wound up in Basel some time before the birth of mathematicians. The senior mathematician was Jacob (1654–1705).



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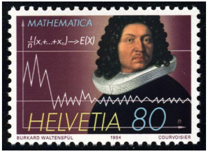

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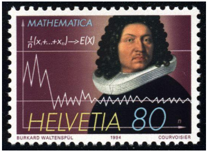

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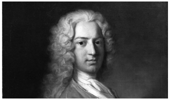
and Johann's son Daniel (1700–82)



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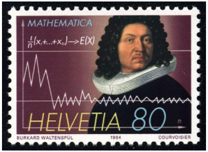

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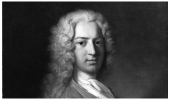

and Johann’s son Daniel (1700–82)

who was born in Holland where his father was teaching (at the time). There were also several lesser cousins.

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Jacob was the most significant mathematically with the discovery of e as the limit of $(1 + n^{-1})^n$, Bernoulli trials and the law of large numbers, and Bernoulli numbers. Much of his most famous work appeared posthumously (1713) in *Ars Conjectandi*.

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Daniel is most noted for Bernoulli's principle in hydrodynamics and Johann for contributions to differential equations, for early work in the calculus of variations, and, as we'll see, for l'Hôpital's rule.

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There was tremendous jealousy between the two brothers. Once Johann got recognition, Jacob declared Johann his student and Johann objected. There was a huge priority fight between them over the isoperimetric problem and a total break in 1697. Jacob was convinced that Johann wanted his chair in Basel, which Johann got after Jacob's death.

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The Bernoullis

Guillaume François Antoine, Marquis de l'Hôpital (1661–1704) was a French nobleman who over many years paid Johann Bernoulli a large annual retainer, initially for lectures on the new calculus of Leibnitz and Newton and for continuing advice.

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Ironically, given Johann's other priority disputes, this claim was dismissed by historians of mathematics of the nineteenth century, until in the 1920s when notes were found in the University of Basel which supported Johann's claim!

Euler

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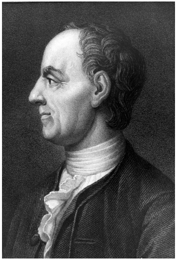

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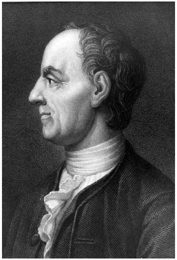

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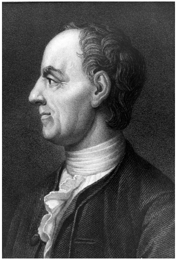

Both Euler's father and maternal grandfather were pastors who expected him to go into the family business. During his studies, Euler convinced Johann to give him private lessons. Johann had been a student in university with Euler's father and was able to convince the father to allow Euler to go into mathematics rather than become a pastor.

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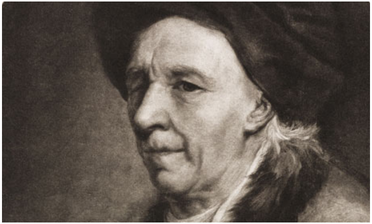

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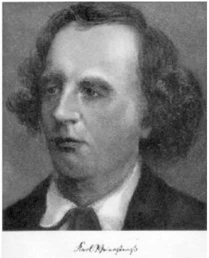
Weierstrass

Karl Weierstrass (1815–97)



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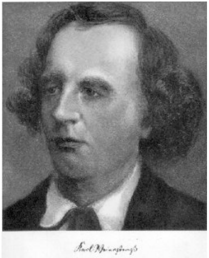

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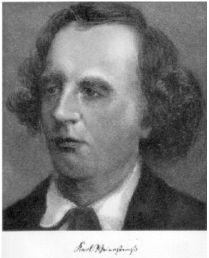

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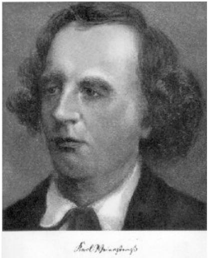
After negotiations by a friend of his father, the compromise reached was that Karl could get a degree from Münster that would allow him to teach mathematics in gymnasium.



Weierstrass

He taught at gymnasium starting in 1841, and during the 1840s wrote unpublished works that established the Weierstrass approach to complex analysis centered on power series. Many were only published in his complete works fifty years later although, to get ahead in our story, he exposed many of them in his lectures at the University of Berlin.

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"Fejér discovered his theorem at the age of 19, Weierstrass published this theorem at the age of 70. With time, the reader may come to appreciate why so many mathematicians regard the second circumstance as even more romantic and heart warming than the first."

Fejér

Lipót Fejér (1880–1959) was born Lipót Weiss (German for white) in Hungary and was a student of Hermann Schwarz (German for black). In high school, he changed his name to Fejér (Hungarian for white), in part because he expected less anti-Semitism. One of his students was Fekete (Hungarian for black!). His other students included:

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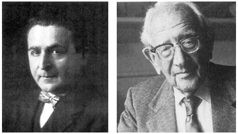

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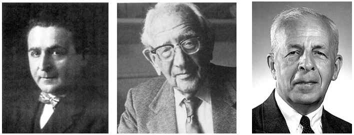

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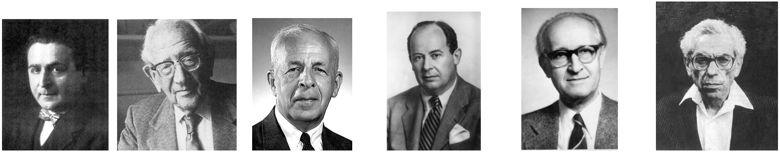

Stone

While on the subjects of fathers and polynomial approximation, I note that the father of Marshall Stone (1903–1989) was Harlan Stone (1872–1946), who was a chief justice of the U.S. Supreme Court.

Bastards

The parents of Stefan Banach (1892–1945) were not only not married, but his mother departed four days after his birth, leaving behind nothing but the name Banach. Stefan was raised initially by his paternal grandparents and then by friends of his father. As a teenager, he was left to fend on his own. While he did study some mathematics, he only managed a first degree in Engineering.

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Steinhaus, who regarded Banach as his greatest mathematical discovery, took Banach to Lwów where, first, Banach got a graduate degree (his dissertation defined and began the study of what we now call Banach spaces) and then, with Steinhaus, founded the famous Lwów school and the journal *Studia Mathematica*.

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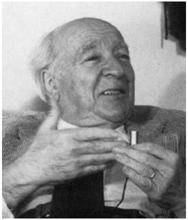

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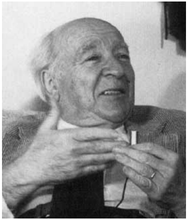

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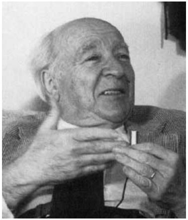

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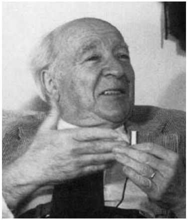

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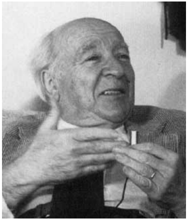

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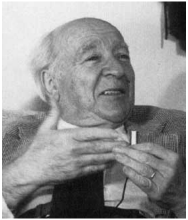

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Then, they say it's trivial.

Finally, they say I did it first."

d'Alembert

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d'Alembert

Jean-Baptiste le Rond d'Alembert (1717-1783) was found abandoned in the church of Saint-Jean-le Rond in Paris named after John the Baptist. He had been abandoned by his mother, Claudine Guérin de Tencin, whose literary salon was a social center during the reign of Louis XV. Her many lovers included Richelieu and Louis-Camus Destouches, an army officer who was d'Alembert's father.

d'Alembert

While neither parent officially acknowledged d'Alembert, his father did arrange a foster home where d'Alembert lived for almost fifty years and, when he died, d'Alembert was left an income that allowed him to pursue mathematics rather than the more mundane law that he'd studied.

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d’Alembert discovered the wave equation as describing plucked strings and found the general one dimensional solution. He was an editor with Diderot of the *Encyclopédie* which led to his being made a member of Académie Française (the immortals). Laplace was his student.

Kolmogorov

Andrei Kolmogorov (1903–87) was also a bastard. His mother died in childbirth and his father had nothing to do with him. He was raised by his mother's sister; Kolmogorov was his maternal grandfather's name. In Soviet Russia, he was able to get an education.

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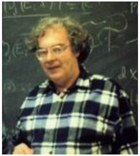

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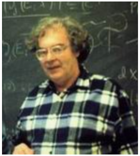


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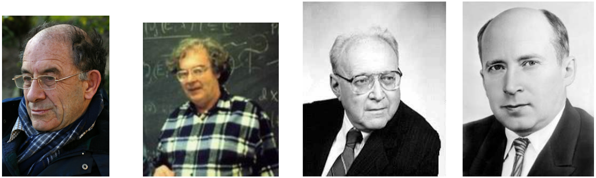

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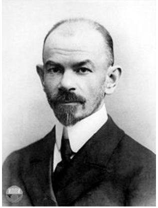

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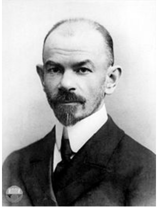

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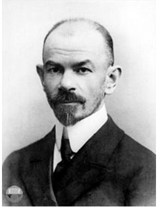

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On January 17, 2012, the Russian Academy formally rescinded their motion condemning Luzin.

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Despite being a bachelor, in his later years, Littlewood traveled with his "niece," Ann, who he eventually acknowledged was his daughter.

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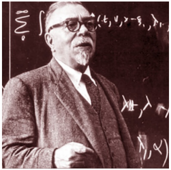

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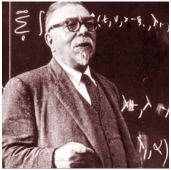

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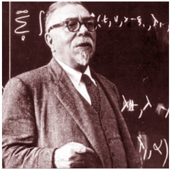

who upon meeting Littlewood exclaimed:
"Oh, you exist. I thought Littlewood was a pseudonym Hardy used for his weaker papers."

Fathers-in-Law

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Fathers-in-Law

Schwartz's great uncle was Jacques Hadamard (1865–1963), but it appears he had no mathematical influence other than to express dismay that the 16-year old budding mathematician did not know about the Riemann zeta function!

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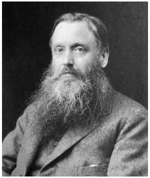
But Vicar Smith would not allow Airy to marry Richarda because the Lucasian chair only paid $\pounds 100$ per year. In 1830, the Plumian Chair of Astronomy, which paid $\pounds 500$, opened, Airy got it and Richarda! He went on to become Astronomer Royal.

Grace Chisholm Young

Grace Chisholm (1868–1944) studied mathematics in Cambridge with William Young (1863–1942), her tutor.



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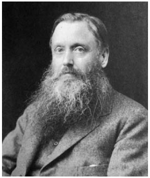

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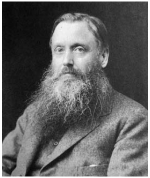

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She returned to England, married Young whom she encouraged to become active in research (he had not been!).

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Works credited to him include the independent rediscovery of Lebesgue integration two years after Lebesgue, the Hausdorff–Young inequality, Young's convolution inequality, and Young's inequality on conjugate convex functions (e.g., $xy \leq \frac{x^p}{p} + \frac{y^q}{q}$).

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"The fact is that our papers ought to be published under our joint names, but if this were done neither of us would get the benefit of it. No. Mine the laurels now and the knowledge. Yours the knowledge only. Everything under my name now, and later when the loaves and fishes are no more procurable in that way, everything or much under your name. At present you cannot undertake a public career. You have your children."

Weyl and Schrödinger

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"Those familiar with the serious and portly figure of Weyl at Princeton would have hardly recognized the slim, handsome young man of the twenties, with his romantic black moustache. His wife, Helene Joseph, from a Jewish background, was a philosopher and literateuse. Her friends called her Hella, and a certain daring and insouciance made her the unquestioned leader of the social set comprising the scientists and their wives.

Weyl and Schrödinger

Anny, Schrödinger's wife, was almost an exact opposite of the stylish and intellectual Hella, but perhaps for that reason Weyl found her interesting and before long she was madly in love with him . . . The special circle in which they lived in Zurich had enjoyed the sexual revolution a generation before the United States. Extramarital affairs were not only condoned, they were expected, and they seemed to occasion little anxiety. Anny would find in Hermann Weyl a lover to whom she was devoted body and soul, while Weyl's wife Hella was infatuated with Paul Scherrer."

Lyapunov

We close our tales of families with a love story.

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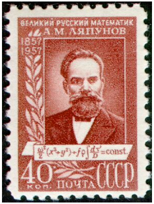

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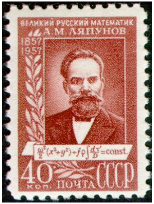

In 1886, he married Natalia Sechenov—he'd met her as a teenager when he was being tutored by her father, his cousin.

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Johann Peter Gustav Lejeune Dirichlet (1805–59) was a German of Belgian extraction ("the young one from Richlet"). Because of the poor education in Germany at the time, he went to Paris and studied with Fourier and Poisson. After his famous work on Fourier series, the Germans wanted him to return to a professorship, but the lack of a German degree was a problem. Like Weierstrass later, this was solved by arranging an honorary degree for him.

Dirichlet

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Dirichlet

By the way, Dirichlet's wife was Felix Mendelssohn's sister, and the Dirichlets, Mendelssohns, and Jacobi had close social connections.

Bernstein

Sergei Bernstein (1880–1968) was a Jewish Ukrainian mathematician known for his work in approximation theory (Bernstein polynomials and inequality) and for his integral representation theorem for completely positive functions.

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This thesis solved (or partially solved; later contributions include E. Hopf, de Giorgi, and Nash) Hilbert's Nineteenth Problem—one of the first to be solved.

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Bernstein returned to Russia where his Ph.D. wasn't recognized, so before he could teach, he had to be a graduate student and then submit a master's thesis. Eventually, after he was teaching, he submitted a Ph.D. thesis that went a ways towards solving Hilbert's Twentieth Problem.

Jensen

In June 2012, I attended a conference in Copenhagen that met in the Danish Academy of Sciences. There was a huge painting of a meeting held around 1900, and a number of famous Danish scientists of the period were pointed out to us.

Jensen

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I asked where was Johan Ludwig Jensen (1859–1925) who revolutionized the study of convex functions (think Jensen's inequality) and invented Jensen's formula—a cornerstone of Nevanlinna theory. I was informed that he spent his career as an engineer for the telephone company (I knew this), didn't have an advanced degree, and so wasn't ever elected to the Academy.

Cotlar

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Cotlar spent much of his career as a Professor a Professor in Buenos Aires where he helped nurture the talents of Argentine born Carlos Berenstein and Norberto Kerzman. After the 1966 coup by the military junta which ordered beating of students and faculty at the University, Cotlar went into exile Caracas, returning to Buenos Aires after the return of democracy to Argentina.

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His theory of 1925 made a big splash and he was shortly afterwards a professor at the University of Helsinki where he became rector in 1941. He cooperated with the Nazis and, indeed, was the chair of the support committee for the Finnish branch of the Waffen SS.

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After the war, he was dismissed as rector and spent some time in Zurich. His defenders claim he was not so much pro-German as anti-Russian. He fought in a Finnish–Russian war at the time just after the Russian revolution, and morally supported Finland in its 1939 war with Russia.

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Fourier

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In 1829, Fourier's student Dirichlet proved piecewise C^1 functions have convergent Fourier series (using the Dirichlet kernel).

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"Apart from his prefectorial duties Fourier helped organise the 'Description of Egypt' . . . Fourier's main contribution was the general introduction–a survey of Egyptian history up to modern times. An Egyptologist with whom I discussed this described the introduction as a masterpiece and a turning point in the subject. He was surprised to hear that Fourier also had a reputation as a mathematician."

Cantor

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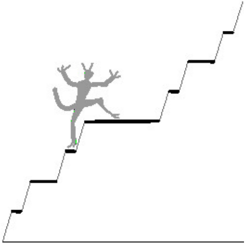
One naively thinks theorems are either true or not and can't be controversial. But radically new approaches can face strong attacks. I want to consider three now-central pillars of modern mathematics, but they were not always so. First, Georg Cantor (1845–1918).



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His initial burst of activity started in 1873 and ended about 1885, with his discovery of the Cantor function. There was a second few years around 1891. In between and in the later years of his life, Cantor was incapacitated by depression, now believed to be caused by bipolar disorder.

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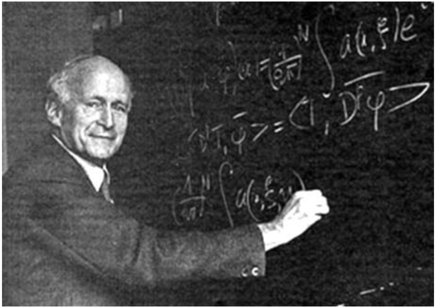
“Distribution theory was one of the two great revolutions in mathematical analysis in the 20th century. It can be thought of as the completion of differential calculus, just as the other great revolution, measure theory (or Lebesgue integration theory), can be thought of as the completion of integral calculus. There are many parallels between the two revolutions. Both were created by young, highly individualistic French mathematicians (Henri Lebesgue and Laurent Schwartz). Both were rapidly assimilated by the mathematical community, and opened up new worlds of mathematical development. Both forced a complete rethinking of all mathematical analysis that had come before, and basically altered the nature of the questions that mathematical analysts asked.”

Lebesgue and Schwartz



But the assimilation, while “rapid,” wasn’t overnight. Hermite initially dismissed Lebesgue’s work as insignificant. As for Schwartz, Treves (Schwartz’s student) tells the following story in his obituary for Schwartz:

Lebesgue and Schwartz

“In 1948 Laurent Schwartz visited Sweden to present his distributions to the local mathematicians. He had the opportunity of conversing with Marcel Riesz. Having written on the blackboard the integration-by-parts formula to explain the idea of a weak derivative, he was interrupted by Riesz saying, ’I hope you have found something else in your life.’

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"*Later Schwartz told Riesz of his hopes that the following theorem would eventually be proved: every linear partial differential equation with constant coefficients has a fundamental solution (a concept made precise and general by distribution theory). 'Madness!' exclaimed Riesz. 'This is a project for the twenty first century!' The general theorem was proved by Ehrenpreis and Malgrange in 1952."*

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Part of the irony is that Riesz's students Gårding and Hörmander used distributions to reformulate and study quantum field theory and PDEs, respectively.

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Fréchet

There are those who think that Maurice Fréchet (1878–1973) was a pivotal figure in twentieth century mathematics. Angus Taylor, who spent his career at UCLA (after getting a Ph.D. in 1936 from Caltech), is among them, and I am sympathetic to this point of view.

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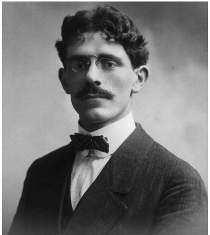
Why? In his 1906 thesis, Fréchet defined metric spaces. He didn't have the triangle inequality but a number of alternatives that included it (shortly afterwards, F. Riesz focused on the triangle inequality).



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Introduction
Family Matters
Educational Follies
Underappreciated Mathematics
Death of a Mathematician

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I end my discussion of Fréchet with dueling quotes: the first is from Dieudonné's comment to Taylor about the naming of Fréchet space:

Fréchet

"Fréchet was always striving for generality without caring for applications, and this was thoroughly repugnant to the Bourbaki spirit, where no notion could be accepted if we could not be convinced that it was useful in some classical problem (although many readers, for lack of background, did not realize it). Nevertheless, we thought that Fréchet's name deserved to be attached to those spaces, not so much for his 1926 paper, but because in his 1906 thesis."

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The second is from a letter the 71-year old Alexandrov sent to "Cher Maitre et ami," the 89-year old Fréchet (my translation):

"What is your place and role—it is a place among the greatest mathematicians of our time, it is the role of a true master."

Prime Number Theorem

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"It was said that whoever proved the Prime Number Theorem would attain immortality. Sure enough, both Hadamard and de la Vallée Poussin lived into their late nineties. It may be that there is a corollary here. It may be that the Riemann Hypothesis is false: but, should anyone manage to actually prove its falsehood—to find a zero off the critical line—he will be struck dead on the spot, and his result will never become known."

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The irony of the quote is that Odlyzko has done computer searches to find zeros off the critical line.

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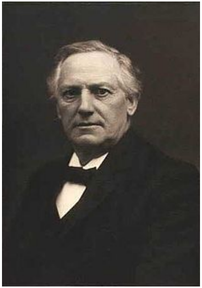

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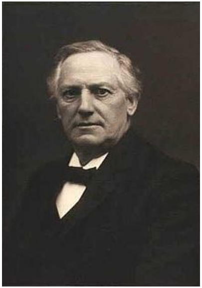

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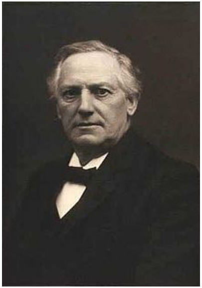

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There is the celebrated short paper on the Riemann zeta function, its functional equation, the Riemann hypothesis, and his vision of the complex analytic view of the distribution of primes. And there are papers on higher-dimensional theta functions (and Riemann–Roch) and on the Riemann approach to hypergeometric functions (and monodromy).

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Nazi Mayhem

Finally, I turn to the depressing view of what Hitler and Stalin and their systems did to various mathematicians. Those who fell victim to the Nazis are numerous—I'll focus on two:

Nazi Mayhem

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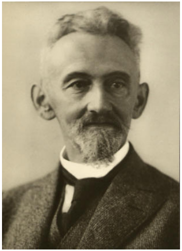

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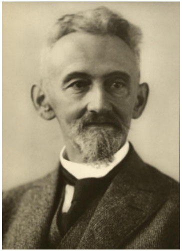


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As the 1930s progressed, things got progressively worse: he was dismissed from his position in 1935. On January 25, 1942, expecting to be picked up for deportation to camps in the East, Hausdorff, his wife, and her sister took overdoses of barbiturates and died.

Schur

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Schur

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Schur

The following story told by Shiffer illustrates the isolation and humiliation suffered by someone like Schur:

"Schur told me that the only person at the Mathematical Institute in Berlin who was kind to him was Grunsky, then a young lecturer. Long after the war, I talked to Grunsky about that remark and he literally started to cry: 'You know what I did? I sent him a postcard to congratulate him on his sixtieth birthday. I admired him so much and was very respectful in that card. How lonely he must have been to remember such a small thing.'"

Schur

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Fritz Noether

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Fritz Noether (1884–1941) was the brother of Emmy Noether (1882–1935). Emmy is justly more celebrated than Fritz, but Fritz made one great discovery. In 1921, he realized certain singular integral equations were noncompact but had an integer invariant—their index. Thirty years later, in others' hands, this blossomed to the theory of Fredholm operators, custom-made for Gel'fand, Atiyah, and Singer ten years after that.

Fritz Noether

Both Emmy and Fritz had German positions from which, as Jews, they were dismissed in 1934. Emmy went to the U.S. and died of cancer a year later.

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Final Thoughts

I hope you've learned that our forefathers are fascinating as people and that you'll consider using Mr. Google and Ms. Wikipedia to look up the names you find on theorems.

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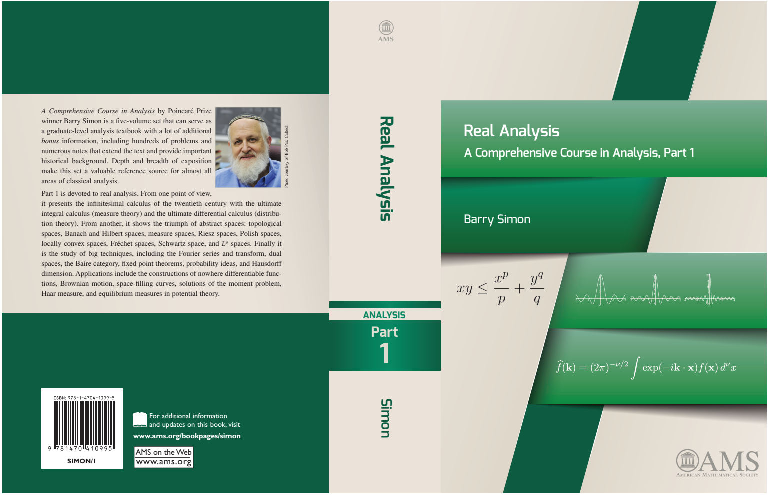

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Part 1 is devoted to real analysis. From one point of view, it presents the infinitesimal calculus of the twentieth century with the ultimate integral calculus (measure theory) and the ultimate differential calculus (distribution theory). From another, it shows the triumph of abstract spaces: topological spaces, Banach and Hilbert spaces, measure spaces, Riesz spaces, Polish spaces, locally convex spaces, Fréchet spaces, Schwartz space, and L^p spaces. Finally it is the study of big techniques, including the Fourier series and transform, dual spaces, the Baire category, fixed point theorems, probability ideas, and Hausdorff dimension. Applications include the constructions of nowhere differentiable functions, Brownian motion, space-filling curves, solutions of the moment problem, Haar measure, and equilibrium measures in potential theory.

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Real Analysis

ANALYSIS
Part
1

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Real Analysis
A Comprehensive Course in Analysis, Part 1

Barry Simon

$$xy \leq \frac{x^p}{p} + \frac{y^q}{q}$$

$$\widehat{f}(\mathbf{k}) = (2\pi)^{-\nu/2} \int \exp(-i\mathbf{k}\cdot\mathbf{x})f(\mathbf{x})\,d^{\nu}x$$

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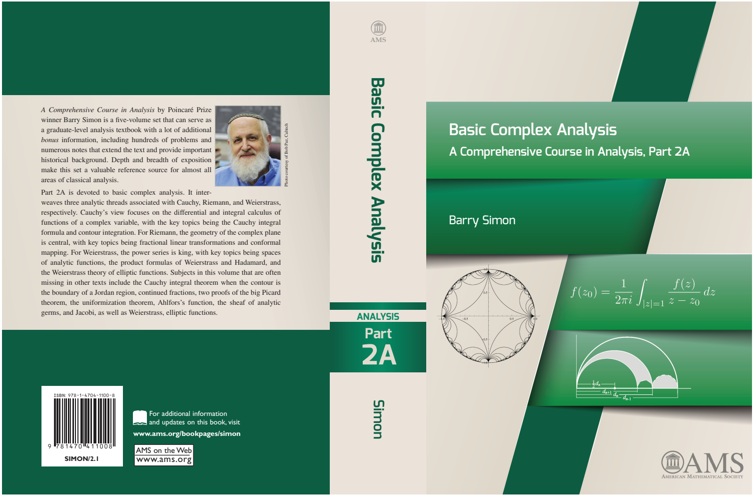

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Part 2A is devoted to basic complex analysis. It interweaves three analytic threads associated with Cauchy, Riemann, and Weierstrass, respectively. Cauchy's view focuses on the differential and integral calculus of functions of a complex variable, with the key topics being the Cauchy integral formula and contour integration. For Riemann, the geometry of the complex plane is central, with key topics being fractional linear transformations and conformal mapping. For Weierstrass, the power series is king, with key topics being spaces of analytic functions, the product formulas of Weierstrass and Hadamard, and the Weierstrass theory of elliptic functions. Subjects in this volume that are often missing in other texts include the Cauchy integral theorem when the contour is the boundary of a Jordan region, continued fractions, two proofs of the big Picard theorem, the uniformization theorem, Ahlfors's function, the sheaf of analytic germs, and Jacobi, as well as Weierstrass, elliptic functions.

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Basic Complex Analysis

ANALYSIS
Part
2A

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Basic Complex Analysis

A Comprehensive Course in Analysis, Part 2A

Barry Simon

$$f(z_0) = \frac{1}{2\pi i}\int_{|z|=1} \frac{f(z)}{z - z_0}\, dz$$

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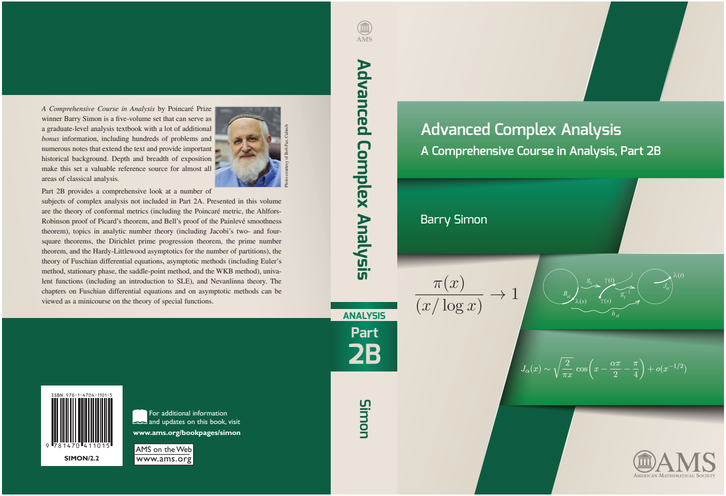

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Part 2B provides a comprehensive look at a number of subjects of complex analysis not included in Part 2A. Presented in this volume are the theory of conformal metrics (including the Poincaré metric, the Ahlfors-Robinson proof of Picard's theorem, and Bell's proof of the Painlevé smoothness theorem), topics in analytic number theory (including Jacobi's two- and four-square theorems, the Dirichlet prime progression theorem, the prime number theorem, and the Hardy-Littlewood asymptotics for the number of partitions), the theory of Fuschian differential equations, asymptotic methods (including Euler's method, stationary phase, the saddle-point method, and the WKB method), univalent functions (including an introduction to SLE), and Nevanlinna theory. The chapters on Fuschian differential equations and on asymptotic methods can be viewed as a minicourse on the theory of special functions.

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Advanced Complex Analysis

ANALYSIS
Part
2B

Simon

Advanced Complex Analysis

A Comprehensive Course in Analysis, Part 2B

Barry Simon

$$\frac{\pi(x)}{(x/\log x)} \to 1$$

$$J_\alpha(x) \sim \sqrt{\frac{2}{\pi x}}\cos\left(x - \frac{\alpha\pi}{2} - \frac{\pi}{4}\right) + o(x^{-1/2})$$

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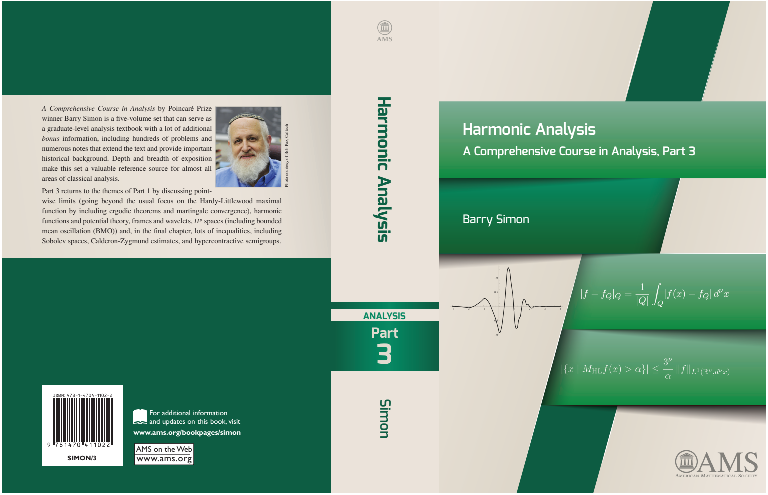

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Part 3 returns to the themes of Part 1 by discussing pointwise limits (going beyond the usual focus on the Hardy-Littlewood maximal function by including ergodic theorems and martingale convergence), harmonic functions and potential theory, frames and wavelets, H^p spaces (including bounded mean oscillation (BMO)) and, in the final chapter, lots of inequalities, including Sobolev spaces, Calderon-Zygmund estimates, and hypercontractive semigroups.

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Harmonic Analysis

ANALYSIS
Part
3

Simon

Harmonic Analysis
A Comprehensive Course in Analysis, Part 3

Barry Simon

$$|f - f_Q|_Q = \frac{1}{|Q|}\int_Q |f(x) - f_Q|\, d^\nu x$$

$$|\{x \mid M_{\mathrm{HL}}f(x) > \alpha\}| \le \frac{3^\nu}{\alpha}\|f\|_{L^1(\mathbb{R}^\nu, d^\nu x)}$$

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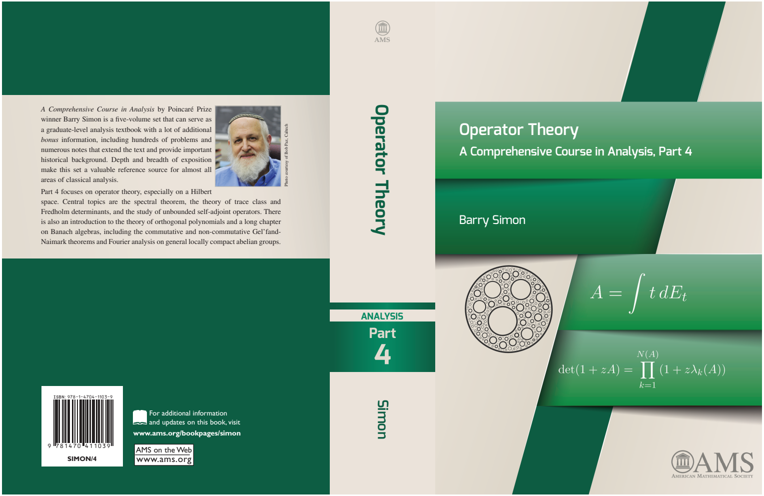

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Part 4 focuses on operator theory, especially on a Hilbert space. Central topics are the spectral theorem, the theory of trace class and Fredholm determinants, and the study of unbounded self-adjoint operators. There is also an introduction to the theory of orthogonal polynomials and a long chapter on Banach algebras, including the commutative and non-commutative Gel'fand-Naimark theorems and Fourier analysis on general locally compact abelian groups.

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Operator Theory

ANALYSIS

Part

4

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Operator Theory

A Comprehensive Course in Analysis, Part 4

Barry Simon

$$A = \int t\, dE_t$$

$$\det(1 + zA) = \prod_{k=1}^{N(A)} (1 + z\lambda_k(A))$$

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