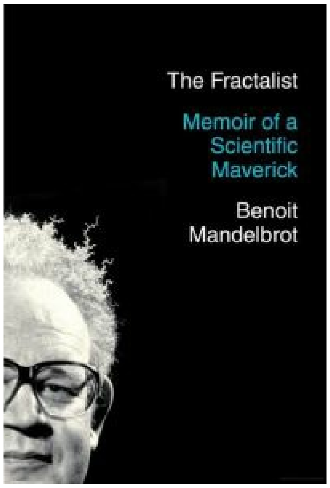

Book The Fractalist

Memoir of a Scientific Maverick

Benoit Mandelbrot
Pantheon Books, 2012

Recommendation

Benoit Mandelbrot, a Polish-born mathematician, is the "father of fractals." This genius discovered quantifiable order in "chaotic" entities like shorelines and clouds. Mandelbrot tells the story of his dramatic life in this fascinating, if occasionally challenging and perplexing, autobiography. Mandelbrot's intellectual discoveries prove compelling but, as you might imagine, their knotty complexity can be confusing for laypeople. Besides describing his eventful life, Mandelbrot also provides an absorbing perspective on the history of rustic *Mitteleuropa* before World War II. *BooksInShort* recommends his book to all those who love to read about history's brilliant thinkers and praises its artwork of colorful fractal patterns.

Take-Aways

- Benoit Mandelbrot, an academic and intellectual vagabond, worked in disparate fields, including mathematics, finance, engineering, statistics, linguistics and physics.
- Mandelbrot, a singular genius, developed fractal geometry.
- He discovered the "Mandelbrot set," the "most complex object" in mathematics.
- Mandelbrot's "theory of roughness" remains a unique intellectual accomplishment.
- He took pride in being an "outlier" during his eccentric, successful scientific career.
- Born in 1924, Mandelbrot fled the Warsaw ghetto in 1936 with his family to escape the Nazis. They relocated to France, where he was educated.
- His admiration for 17th-century mathematician and astronomer Johannes Kepler greatly influenced his career, as did his uncle, noted mathematician Szolem Mandelbrojt.
- Mandelbrot worked as a research scientist for IBM for 35 years and taught at Harvard, MIT, Princeton and Yale.
- His famous Zipf-Mandelbrot law provides "a numerical grade to the richness of someone's vocabulary."
- Mandelbrot died in 2010 in Cambridge, Massachusetts.

Summary

The "Theory of Roughness"

Most of nature's patterns are splintered and irregular, or "rough." This makes them infinitely more difficult to define and more complex than Euclid's venerable geometric forms. Throughout most of history, intellectuals despaired of finding a viable means of quantifying roughness. Mathematician, scientific outlier and breakthrough theorist Benoit Mandelbrot brilliantly solved this previously intractable problem. His theory of roughness remains a unique intellectual accomplishment.

> "A wandering scientist should never say never, and history shows that beautiful parts of abstract mathematics can well slumber for a while and become disconnected from their roots in reality."

Mandelbrot determined that the best way to measure roughness, which is universal, is to capture its "fractal dimension." His theory deals with such hitherto hard-to-quantify puzzles as: "What shape is a mountain, a coastline, a river?" "What shape is a cloud, a flame or a welding?" "How dense is the distribution of galaxies?" How can you state "the volatility of prices quoted in financial markets" or "compare and measure the vocabularies of different writers?" Such queries sparked Mandelbrot's unmatched intellectual curiosity. During his distinguished, long career, he dedicated himself to developing a systematic approach to solving these problems.

> "True mathematicians never do arithmetic." (French literary figure Paul Jouhandeau)

The work of Mandelbrot's great intellectual hero and scientific guiding light, Johannes Kepler, inspired Mandelbrot's variegated career. Kepler, a German 17th-century polymath, drew upon his profound understanding of astronomy and mathematics to determine the movement of planets. In a quest to become a modern Kepler, Mandelbrot made significant contributions to mathematics, finance, linguistics, engineering, statistics and physics.

"Fractals"

Using research and brilliant theorizing, Mandelbrot developed a new intellectual field: fractal geometry. He found the name "fractal" in his son Laurent's Latin dictionary. To illustrate fractals, Mandelbrot used the example of a cauliflower. If you examine an individual floret, you will see what appears to be a miniature cauliflower. If you cut everything away so that what remains is "one floret of a floret," and examine that under a magnifying glass, again you will again see a miniscule cauliflower. This self-repeating process goes on and on. A fractal is a self-repeating mathematical pattern that remains unchanged by scale. The same pattern determines the structure of a cauliflower and, for instance, a tsunami.

> "By pulling up their deep roots in a community that only a few years later vanished in smoke, my lucid and decisive parents saved us all."

Other examples exist throughout nature – for instance, clouds demonstrate a self-repeating fractal pattern – as well as in art. The Sierpiński gasket, a fractal "mathematical structure" that Mandelbrot named, is a popular decoration in Italian churches. Indian and Persian artworks employ fractal patterns. Other intellectuals also noticed self-repeating patterns in life and nature, but Mandelbrot, who said, "I mix mathematics and art every day," is the one who figured out how to quantify them and to understand them as processes rather than stand-alone entities.

> "Leaving French academia for an American industrial laboratory – a colossal gamble – had proved I was prepared to take controversial stands."

Mandelbrot calls the field of fractal geometry "the oldest, most concrete and most inclusive" form of geometry, "specifically empowered by the eye and helped by the hand." His study of rivers enabled him to differentiate between two types of fractals: "the self-similar – shapes scaled by the same amount in every direction, like coastlines – and the self-affine – shapes scaled by different amounts in different directions, such as turbulence." His "multifractal model that addressed the intermittence of turbulence" shapes the baseline of thought on the "variation of financial prices."

> "Having worked in many fields but never wholly belonging to any, I consider myself an outlier."

In 1975, Mandelbrot published his first book on fractals. In 1980, he discovered – rather than invented – the Mandelbrot set, the "most recognized icon" of quadratic dynamics and the "most complex object in mathematics." In 1980, he taught the first class on fractals. His second book, *The Fractal Geometry of Nature*, came out in 1982, the same year as the first fractals meeting, which took place in Courchevel, a ski resort in the French Alps. In 1989, the Fractals in Physics conference took place in Saint-Paul de Vence, a town near the French Riviera.

"The Outlier"

During his lengthy career, Mandelbrot thought about and investigated various areas of knowledge that other professionals considered unfashionable, including "unevenness, inequality, roughness and the concept of – as well as the word – fractality." While being an outlier, as he repeatedly described himself, Mandelbrot invariably proved many times to be decades ahead of everyone else. He defined his career by saying, "Since I became a scientist, much of my work has consisted of bringing a medley of old issues back to life and triumphant evolution."

> Paul Lévy's "self-directed boldness and insight cost him much in his career and early recognition, but I found his independence admirable. I felt ready to pay the same price."

The term "outlier" that he used has technical significance in statistics, which was one of Mandelbrot's primary fields. In statistics, an outlier is "an observation that is so very different from the norm that it may be due to accidental foreign contamination." Mandelbrot always used to turn his professional focus on "values far from the norm [that are] key to the underlying phenomenon," which was the perfect summary of his work in the scientific fields he transformed.

Academic and Intellectual Vagabond

The Mandelbrots were Ashkenazi Jews with Lithuanian roots. Benoit Mandelbrot was born in the Jewish ghetto in Warsaw, Poland, on November 20, 1924. His father, who had a deep reverence for scholarship, was a reluctant shopkeeper and a salesperson of women's hosiery. His mother was a dentist. His uncle, Szolem Mandelbrojt, a brilliant mathematician, greatly influenced his nephew. In 1931, Mandelbrot's father moved to Paris for work. His family joined him in 1936 as "economic and political refugees" from Warsaw.

> "All truths are easy to understand once they are discovered; the point is to discover them." (Galileo)

The Mandelbrots first lived in Paris's Belleville neighborhood, a 19th-*arrondissement* slum. During World War II, they lived in Tulle, in the mountainous southeast region of Vichy – the "Appalachia" of France. They feared that others would inform on or betray them, sending them to the Nazi death camps. However, the native Tullois protected the Mandelbrots and, with their help, the family stayed alive. Later, the Mandelbrots returned to Paris.

Carva

Mandelbrot attended the École Polytechnique, called Carva, a prestigious military college. He next studied at Caltech, in California, where he found his courses less advanced than at Carva. At Caltech, Mandelbrot wrote his master's thesis on mathematics as it pertained to mechanics – specifically, propeller theory.

> "When freewheeling scientific research is properly managed, it is not a financial extravagance."

While there, he met his future wife, Aliette Kagan. After Caltech, Mandelbrot returned to France to serve as a reserve officer in the French Air Force Engineers. In 1950, at age 26, he became a student again, specializing in math at the University of Paris.

The "Zipf-Mandelbrot Law"

For his Doctorat d'État ès Sciences (PhD), Mandelbrot initiated a dissertation in two parts. The first part addressed the "universal power law distribution for words," as had been developed by American linguist George Kingsley Zipf. The second concerned generalized statistical thermodynamics.

> "Mathematicians do not pick problems from thin air for the pleasure of solving them...A mark of greatness resides in the ability to identify the most interesting problem in the framework of what is already known."

Every academic, including his uncle Szolem, warned him against this pairing. The problem was that he focused on two disparate subjects. The first topic was unique; the professional field of quantitative linguistics did not even exist in the early 1950s. Nevertheless, against learned advice, and without the counsel of a PhD adviser, Mandelbrot proceeded in pursuit of his "Keplerian dream" to develop his "wild" dissertation. This turned out to be a positive, watershed event.

> "Louis Pasteur is credited with the observation that chance favors the prepared mind...My long string of lucky breaks can be credited to my always paying attention."

His dissertation, *Games of Communication*, eventually led to the Zipf-Mandelbrot law, which provides "a numerical grade to the richness of someone's vocabulary." His dissertation was a little acorn from which a mighty oak – his remarkable theorizing on fractals and roughness – would eventually develop. This singular, renowned work helped Mandelbrot's career achieve a unique orbit that led to more groundbreaking discoveries.

> "The very heart of finance is fractal."

In a eureka moment – which he calls a "Kepler moment" – Mandelbrot determined that while Zipf's original law has no relevance to grammar – the core of linguistics – it connects strongly to information theory and, therefore, to statistical dynamics. Through researching and writing his dissertation, Mandelbrot developed an intense interest in power law distributions. While pursuing this arcane subject, he promised himself that he would "become a solo scientist" – an outlier.

> "Benoit shifted the whole word under our feet, giving thousands of people the tools to see the world in a new way." (Michal Frame)

After earning his doctorate, Mandelbrot went to work at the Research Laboratory of Electronics (RLE) at the Massachusetts Institute of Technology (MIT). Later, he joined the great mathematician John Von Neumann at Princeton. Mandelbrot worked at Princeton's Institute for Advanced Study during 1953 and 1954. He returned to Paris in 1954, staying until 1955, to work with the National Center for Scientific Research.

Professor Mandelbrot: Academic Nomad

In 1955, Mandelbrot married Aliette Kagan, the love of his life. They honeymooned in Geneva for two years. From Switzerland, they moved to France, and Mandelbrot became a junior professor of mathematics at the University of Lille. In 1958, the Mandelbrots returned to the United States, and, that same year, he went to work at IBM Research in Yorktown Heights, New York. Mandelbrot worked at IBM until his retirement in 1993.

> "An applied mathematician's relation to reality is fraught with problems."

The Mandelbrots first purchased a house in Chappaqua, New York. Five years later, they moved to Scarsdale, their home for the next 35 years. At IBM, Mandelbrot was able to access a computer for his research on a regular basis. He took great advantage of this then rare opportunity, claiming about half of the research division's time for his projects.

The time span that Mandelbrot describes as the "golden period" of his career coincided with IBM's "golden age...in the sciences." During his long career with IBM, Mandelbrot availed himself of many extended academic leaves of absence to work as a visiting professor at significant universities, including Harvard, Massachusetts Institute of Technology (MIT) and Yale. His visiting professorships and lectures garnered him a great deal of positive attention within IBM.

He used to describe this period as a time of "academic nomadism." During this time, he engaged in a series of "traversals" in "seemingly incongruous areas of research." In 1999, at the age of 75, Mandelbrot achieved tenure at Yale University as the Sterling Professor of Mathematical Sciences.

Although he did not plan ahead for it, during this period – which he used to describe as "my life's fruitful stage" – Mandelbrot began to study "the behavior of financial prices" and price variation. In *Research Note NC87*, he put his focus on financial speculation. In 1963, he developed "The Variation of Certain Speculative Prices," which economists routinely cited thereafter. IBM's computers proved central to Mandelbrot's research and data analysis.

"My Wandering Life"

In 2010, Mandelbrot died of illness at age 85, in Cambridge, Massachusetts, shortly before he planned to make the final changes to his memoir. Writing "as my wandering life fades away," Mandelbrot knew that he didn't have much time left.

He was a man of wide-ranging loves and eclectic interests: "the roughness of coastlines and price graphs, the music of Charles Wuorinen and György Ligeti, the paintings of Augusto Giacometti and prints of Hokusai." Mandelbrot sensed universal features and recurring patterns in all these things, as well as in the art of Salvador Dalí, the dramatic works of Tom Stoppard, the poems of Wallace Stevens and the design of the Eiffel Tower.

A rare genius, Mandelbrot introduced the concept of fractal images to the world. He taught others how to decode them by applying a few basic rules. He provided great insights and numerous intellectual gifts to the world. Perhaps his most significant legacies are the force and endurance of his joyous curiosity and his passionate pursuit of knowledge. Mandelbrot lived his life convinced that, "Bottomless wonders spring from simple rules...repeated without end."

About the Author

Benoit Mandelbrot, a world-famous mathematician, is the father of fractal geometry. He developed a formal "theory of roughness" in nature and discovered the Mandelbrot set, the ideal example of mathematical visualization.
