Benoît Mandelbrot

(1924–2010)

Mathematician, and father of fractal geometry, who described the roughness of nature.

"The financiers and investors of the world are, at the moment, like mariners who heed no weather warnings."[1] Those words were written by Benoît Mandelbrot four years before the recent financial crisis. Mandelbrot, a mathematician world-famous for his work on fractal geometry, died on 14 October at the age of 85. His financial prescience was a natural outgrowth of his original and penetrating view of the world.

At a time when mathematics focused on lines, planes and spheres, Mandelbrot wrote: "Clouds are not spheres, mountains are not cones, coastlines are not circles, and bark is not smooth, nor does lightning travel in a straight line."[2] His life's work was the creation of ways to describe these objects more accurately. He was able to see and describe the true roughness of the world.

Mandelbrot was born into an educated Jewish family in Poland. As he put it: "I was expected without saying to become a scholar of some sort. Any other activity would have required a specific reason."[3] In 1936, his family, seeing the rise of Nazi Germany, moved first to Paris and then to a small town in central France. After the fall of France, the threat to Jews from the German occupation was ever present. To survive, Mandelbrot moved often, making his attendance at formal schools irregular. He was briefly a groom and an apprentice toolmaker. At one point, he narrowly escaped deportation and probable death.

During his brief attendance at an advanced school in Lyons, he discovered that he had a remarkable gift for visualizing geometric objects. This gift enabled him to quickly solve difficult algebraic problems in different ways from other students. As the war ended, he returned to Paris and prepared intensively for entry to the grandes écoles — the elite French universities. Despite his uneven schooling, he placed almost at the very top in the examinations and entered the École Polytechnique, then in Paris. He once described to me the confusing emotions he experienced during this sudden transformation from near fugitive to a member of the upcoming technocratic elite, and his belief that his irregular life with its limited schooling had given him the time and the freedom to develop intellectually in his own way.

When Mandelbrot graduated from the Polytechnique, the dominant mathematics in France was pure and abstract. Mandelbrot's goal, like his background, was different. He wanted to find order where everyone else saw a lawless mess. He wanted to learn about real, concrete complex problems. He was able to do this with a scholarship at the California Institute of Technology in Pasadena. There he learned about turbulence and was exposed to the molecular biology being developed by Max Delbrück's group. Returning to Paris, in 1952 he wrote an unorthodox doctoral thesis about the law that governs the frequency with which individual words occur in ordinary language.

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In 1958, Mandelbrot returned to the United States with his wife Aliette Kagan, who was to be his devoted companion throughout his life. There he joined IBM's newly formed Research Division in Yorktown Heights, New York, where his abilities were quickly recognized and where he had almost complete intellectual freedom for more than three decades.

VARIANCE AND ROUGHNESS

When I first knew Benoît at IBM, he was already modelling the variations (roughness) of stock prices. I remember him telling me that price changes, even over a long period, were concentrated in only a few hectic days of large price swings. He went on to find similar data for the floods of the Nile, cotton prices, wheat prices and interest rates. Real price variations were far rougher and more extreme than those that could emerge from the models then being used. He realized that to obtain realistic results, a model of day-to-day fluctuations having an infinite variance was needed.

Mandelbrot's thinking about the roughness of natural objects surfaced in a now-famous paper, 'How Long is the Coast of Britain? Statistical Self-Similarity and Fractional Dimension', published in *Science*[4] in 1967. There he first used statistical self-similarity and Hausdorff fractional dimension to describe coastlines in a more accurate way. In subsequent work he extended this approach to describe the shapes of mountains, the branching of rivers and the insides of lungs. In 1975 he coined the term fractal to describe the rough but structured forms he saw all around him. This ever-expanding work appeared in various forms, culminating in his book *The Fractal Geometry of Nature* (1982).

Mandelbrot's remarkable conclusions often directly contradicted the accepted view. Inevitably, this slowed their acceptance, but he always persisted with an intellectual courage that I greatly admired. In 1974 he became an IBM Fellow, IBM's highest technical distinction, but outside recognition came more slowly.

Eventually his work took hold, helped both by its intrinsic importance and by the sheer beauty of the pictures that his and others' work on fractals generated. One fractal, suitably named the Mandelbrot set, became globally recognized, and questions about its properties sparked the interest of many mathematicians. Finally in 1985 he received the Barnard Medal, awarded by the US National Academy of Sciences, and after that came a flood of recognition, honorary degrees, elections to prestigious academies, prizes and the Legion of Honour.

In 1987 he moved to Yale University in New Haven, Connecticut, becoming the Sterling Professor of Mathematics in 1999, and transitioning to emeritus status in 2004. At Yale, he steadily expanded his work and its area of application, surrounded by the fame and recognition his achievements had earned him.

The Wolf Prize citation summarized those achievements well when it said of Mandelbrot "He has changed our view of nature". ■

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3. Mandelbrot, B. in *One Hundred Reasons to be a Scientist* (ed. Sreenivasan, K. R.) 157 (Abdus Salam International Centre for Theoretical Physics, 2004).
4. Mandelbrot, B. *Science* **156,** 636–638 (1967).