RETROSPECTIVE

Benoît B. Mandelbrot (1924–2010)

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A mathematician's revelation about visual irregularities in nature spawned the field of fractal geometry, now widely used to interpret patterns in diverse fields.

Fractal geometry was created by Benoît B. Mandelbrot nearly 40 years ago, and with the 1982 publication of his seminal book, "The Fractal Geometry of Nature," its application took off, opening our eyes to patterns in nature on all scales and across diverse disciplines. On 14 October, he died of cancer in Cambridge, Massachusetts. He fundamentally and irrevocably changed our view of the world and left us a tool that will continue to unveil nature's most peculiar commonalities that might otherwise be left aside as insignificant.

Mandelbrot was born in 1924 in Warsaw, Poland. With the rise of Nazism, his family left for France in 1936, where he pursued an education in mathematics and earned a doctorate at the University of Paris in 1952. His career path took him to prominent establishments: the California Institute of Technology, the Institute for Advanced Study in Princeton, the Centre National de la Recherche Scientifique in Paris, IBM Research in New York, Harvard University, the Massachusetts Institute of Technology, and to Yale University (where he retired in 2005).

Whereas the Renaissance saw geometry in the forefront, much of the 19th and 20th century sought an algebraic representation of nearly all mathematical fields. As a result, the patterns and forms that real nature presents were increasingly neglected. Geometry in the ordinary sense was left to school children, and even school mathematics departed from geometry in favor of an algebraic and abstract underpinning of curricula. Mandelbrot always felt this view was narrow and inappropriate for understanding nature. After decades of a mathematical trend to abandon visual representation of phenomena, which was spurred by French mathematicians (the so-called Bourbaki group) in the mid-1930s, Mandelbrot gave the eye a central role again.

His whole career became one long and ardent pursuit of the concept of "roughness"—the roughness of clusters in the physics of disorder, of turbulent flows, of exotic noises, of chaotic dynamical systems, of distributions of galaxies, of coastlines, of stock-price charts, and of mathematical constructions. Some describe Mandelbrot as one who chose the role of a maverick in the mainstream sciences. Quite to the contrary, his uncompromising devotion to analyze and understand the "rough" reality of nature isolated him from the mainstream. In his view, the common "smooth" representations of natural processes were entirely inappropriate and far from the essence of nature: "Clouds are not spheres and mountains are not cones." Alone, he shaped a program of geometry based on fractals, a term he coined to refer to mathematical shapes with irregular contours, just as seen in nature. The notion of self-similarity is key in fractal geometry: geometric shapes that break into parts, each a small-scale model of the whole.

His mathematical sources were deeply rooted in the entire history of mathematics, notably the work of Felix Hausdorff and Paul Lévy, and the "Mandelbrot set" that bears his name would likely not have been discovered without his peculiar contact with some forgotten jewels of mathematics produced at the turn of the 19th century by Gaston Julia and Pierre Fatou. He told me that his uncle, Szolem Mandelbrojt, had almost forced him to study their papers as the best introduction to good mathematics. In fact, his uncle, a traditional mathematician, student of Jacques Hadamard, and member of the Collège de France, sought to eradicate Benoît's preference for a geometric approach to mathematics. Fortunately, Mandelbrot's advocacy for geometry was without compromise.

The mathematical genre of Julia and Fatou has experienced a great revival through Mandelbrot, and their topic—iteration—became a guiding principle for his own discovery and work. Whereas classical geometry and many of its modern algebraic and other extensions encode objects from closed elementary formulas to differential equations, Mandelbrot made us aware of a mathematical universe yet to be harvested—the world of iterative processes. Within this framework, he developed the tools that appear ideally suited for the rough nature of the world. And "world" is meant literally, because his footprints are left in the theory of finance, linguistics, biology, medicine, chemistry, physics, earth science, cosmology, computer science, astronomy, many of the engineering disciplines, and of course, mathematics.

The Mandelbrot set provides perhaps the most striking example of a mathematical object whose properties would remain undiscovered without the guiding power of the human eye used by an able mathematician. For example, the key for understanding the myriads of patterns that sprout at the boundary of the Mandelbrot set is governed by a peculiar mathematical coding scheme within the field lines of its potential. Mandelbrot earned not only the credit for its discovery but also for expressing provocative mathematical conjectures about its properties. For instance, he proposed that the boundary of the Mandelbrot set, which exhibits all the marvelous and seemingly complex images that turned it into a cult object, has a fractal dimension of only two.

Now that Mandelbrot's work can be considered to belong to mainstream mathematics and the sciences, it is important to remember that there was once strong resistance and skepticism. I have often asked myself where Mandelbrot found the source of his strength, determination, and endurance in those decades when he was practically isolated in his own mathematical world. He used to claim that his geometrical view and associated gifts guided him and that he did not feel isolated at all. I would add that his pristine character as someone who sought the truth in life and nature led him as well. Moreover, I remember Benoît as a universal scientist and very conscious citizen of the world, knowledgeable and sharp in all branches of the sciences and beyond: the arts, politics, and history. It will take further generations to grasp the full significance and impact of his insight far beyond the borders of mathematics.

His personal history left him as someone who was fortunate to escape the darkest periods of mankind. He chose to remain forever suspicious toward any form of establishment and mainstream.

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