PAOLA ANTONELLI BENOIT MANDELBROT

Paola Antonelli is senior curator of Architecture and Design at The Museum of Modern Art, where, beginning with her highly acclaimed debut exhibition, "Mutant Materials and Contemporary Design," she has consistently challenged popular definitions of design. She has curated exhibits in Italy, France, and Japan, contributed to numerous publications, and lectures frequently at global gatherings such as the World Economic Forum. In 2006, Antonelli earned the Smithsonian's prestigious Design Mind Award, and in 2007 was named by *Time* as one of the 25 most incisive design visionaries.

The father of "fractal" geometry, mathematician Benoit Mandelbrot coined the term in the 1970s to describe his investigation into the phenomenon of self-similarity. His ideas revolutionized mathematics and have had a profound impact on several fields across the physical and social sciences. Mandelbrot's numerous papers and books include *The Fractal Geometry of Nature*, which was recognized as one of the most influential science books of the 20th century. In January 2006, he was appointed Officer of the French Legion of Honor. He is currently Sterling Professor Emeritus at Yale.

While studying architecture at the Politecnico in Milan in the 1970s, Paola Antonelli was inspired by Benoit Mandelbrot's geometric ideas and visualizations, and eventually wrote her thesis on "Fractal Architecture." The two met for the first time last year when Antonelli invited Mandelbrot to a *Seed*/MoMA Salon, a monthly gathering of scientists, designers, and architects. Just before Antonelli's new Design and the Elastic Mind exhibit opened at MoMA in February, they reconnected to discuss fractals, architecture, and the death of Euclid.

Portraits by Julian Dufort

PAOLA ANTONELLI: So, here we are. It's 18 years after my thesis, and I finally get to meet you.
BENOIT MANDELBROT: Well, everything happens if you live long enough!
PA: That's right! I'll tell you briefly what it was about, because I just want to have your reaction. I was very, how should I put it...very naive about the mathematics involved in your thinking.
BM: I am naive about the art.
PA: Well, I hope so. It was not art, it was architecture. In any case, I had tried to read your first book about fractal geometry. Of course, I was skimming through it, not understanding any of the equations, but I noticed something: Some of the most recent architecture—and in particular I was studying the work of Coop Himmelb(l)au, an architectural group from Austria—could not be represented anymore through plans, sections, and elevation. There was no way. Not even with axonometry. Or perspective. Normal geometry just did not work.

Also, you couldn't photograph it; pictures wouldn't render the spaces at all. The only way was to experience them. And somehow, without really having any mathematical or any theoretical proof, I thought there was a connection between your book and this kind of architecture.

So I decided to explore this theory and do my thesis on it, which was called "Fractal Architecture." Now, thank God, it's only in Italian, so, you will never... Oh, my God, maybe, you speak Italian!
BM: No, but I can read Italian.
PA: Oh, no, no. But, it's really just very interesting to see how your theories, your geometry, and your work have had tremendous impact on the world, even on people who didn't know about them. When I interviewed Wolf Prix, who is the principal of Coop Himmelb(l)au, I asked him, "Do you know anything about fractal geometry?" He said no.

I just found it really interesting. There's a real impact that your science has on the world, and vice versa.
BM: Well, I've had a life, how to say it, full of adventures, though not always by choice. Things were very complicated during World War II. Altogether it never quite left me the leisure to decide who I was.
PA: Where were you?
BM: I was in central France, in an area you could describe as French Appalachia. There were deep valleys, and people considered Parisians foreigners. It's a very interesting place. It was not occupied, but was very closely supervised by the Germans. And one didn't think of the future particularly; the future was so distant. First survive and then there'll be a future. So, I never really decided in which field I was going to spend my life—a situation with pluses and many minuses. It's one of the most peculiar and striking aspects of my scientific life.

But over the years I've recognized things that are very close to my work and could not have conceivably been associated with mathematics.
PA: The power of fractals is that they're so instinctive. They're immediately graspable even without knowing there's a geometric law behind them.
BM: Well, that's the astonishing thing—and to me it was an amazing surprise. I was very visual, of course, but I did not view myself as a future scientist.

Mathematics in high school was easy but much less exciting than French history or language. I did well, but it was not something very important to me. Then, I stopped school for a while, which turned out to be very important. I went on studying, but my way.

Once back at school, for each problem the professor posed, I had an instant solution—never the same as his. My solutions involved shapes. So I was taking these very dry questions that he asked, and without being particularly conscious of my thinking process, solving them all—near instantly—in terms of real shapes. This took no effort whatsoever. I had, how to describe it? A very freakish gift. In every mathematical question that was asked, I just saw something real that had the same properties.
PA: The things that you saw, were they coming from the real world? Were they coming from intuitions? What would you connect them to?
BM: They were coming from everywhere. During the period I wasn't in school, and couldn't study systematically, I read a lot, whenever I could. So I would remember many things through, how to say, mathematical simplifications.
PA: So, you had the intuition and then you would recognize this intuition in the things that you saw.
BM: Absolutely.
PA: I'm sure you know that your work has had tremendous impact in architecture and in design, not only formally, but also philosophically. The idea of the algorithm, of the growth of structures, and the growth of objects. Who was the first architect or designer that contacted you and wanted to talk about it and wanted to learn directly from you?
BM: Well, actually, I think that it wasn't that they came toward me. I came toward them.
PA: Really? Interesting. So, who did you refer to?
BM: Well, a paper I wrote, and that was widely quoted, concerned fractals and architecture. It was in a certain sense a critique of the Bauhaus. A very short paper, but very influential.

I focused on Mies van der Rohe and the Seagram Building because of my anger against Mies van der Rohe's misunderstanding of something I very much care about. By contrast, take Charles Garnier, who primarily designed the opera houses in Paris and Monte Carlo.

He was not very popular, but represented—at least for somebody with a French education—the kind of principle of what architecture should do.
PA: Meaning?
BM: Meaning, for example, walking toward the Garnier opera house in Paris, from far away, the most striking thing is the roof. You come closer, other things appear, but they are always of approximately the same degree of complication.

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> "I noticed something: Some architecture could not be represented anymore through plans, sections, and elevation. Not even with axonometry. Or perspective. Normal geometry just did not work."

Whereas Mies van der Rohe seen from a distance is just a big box. As you get closer you see a grid of windows on the box, and as you get really close, you can see some some things of whoever lives behind the windows.

The building itself had the smallest number of scales imaginable. It is very simple to describe. And the architect was proud of it.
PA: Of course he was! He simply was not going after the same effect you're talking about, which is organicism in architecture. That's truly what you are praising. But, somehow you also need to have complete abstraction and the simplification of details in order to be able to appreciate organicism. Modern architecture had a reason to exist.
BM: Well, modern architecture had two reasons to exist. One is the desire, on the part of architects, to be different. And the other is the desire, on the part of the builders, to be cheap. Look at modern architecture in early manifestations, for example, in Russian building designs shortly after the revolution—many of which were never


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actually built, for lack of funding. They were very conscious of the fact that this was not something beautiful.

So, Garnier, who, again, was not a creative genius, but was a representative of a certain school of architecture, put it very, very strongly. From a distance, you could see something, and as you come closer, you see something else but always of the same kind.

PA: That's like medieval architecture. It's like the Cathedral of Milan. Yeah, I understand.

BM: Absolutely, and this is so much more interesting architecturally and aesthetically.

PA: What is really amazing to me right now is how contemporary architects are using the idea that is behind fractals, the idea of a rule that lets them work at different scales indifferently, at least until the moment when the real design application, the reality of the client or manufacturer wanting a building or a toaster, sets in.

I am thinking, for instance, of Ben Aranda and Chris Lasch, who you may remember spoke right after you when we had the salon at MoMA. They are two architects that have founded their practice on understanding algorithms and finding ways to take scientific concepts and translate them for architecture's benefit and evolution.

So, it seems to me that it is not only and simply about the formal beauty of fractals, it is the idea of growth that your theory has really given to architects and designers.

And now we're seeing the algorithm become the principle, and the subject of research, for so many architects today. They're hoping that they can ultimately input an algorithm, give it a push, and then all of a sudden an object, a building, a city, and a world will grow out of it.

BM: Well, that would be very exciting and I am very pleased to hear you say it. I have, of course, a good inkling of it. I can speak of other great masters, or unknown masters, who proposed no principle, recorded neither reasons nor comments, but did work along these lines. So, the long time it took for this to be codified is astonishing. It's astonishing that the motivation behind these other great works was not more actively pursued. Because they are manifestations of the fact that certain numeric ideas are permanent.

I am not only a scientist, and I find it very important that great architects have very often followed the same path as scientists. And now, it seems, the evolution of these ideas continues in the kind of architecture you describe, this time with a scientific spine.

But in the past, nobody could understand them, nobody could appreciate what was behind them and so they weren't often recorded. But, well, history has its own funny ways.

PA: In a way it is almost a fractal attitude, an indifference to time; the past and the present and the future have the same instinctive approach to things.

BM: Ha, yes. It's mind-boggling.

FROM CUBES TO FRACTALS

PA: I would like to ask you about some major phenomena that have happened in the world since the publication of your books, phenomena that seem almost manifestations of fractals in the world. One is the internet, for instance.

BM: I was well placed to know about the internet since of course it became very important when I worked for many years at IBM. And colleagues mentioned to me some strange things about the way in which the internet became organized. There was no single overall architect and many things were happening by local decisions. A terrible mess ensued and the question was, can you see any order in that mess? I was pleased to discover some order, though it was not my field.

PA: And what about contemporary architecture? Have you seen the idea of fractals translated in a particularly powerful way in recent architecture?

BM: My influence may or may not have helped, but certainly the mood is different. Most of modern architecture was, how to say, cheap. For example, driving from de Gaulle airport into Paris, you go by many buildings that are absolutely abominable.

They are cubes of the worst kind and I would hate to live there. Admiration for this simplified art, this Euclidean architecture, which sticks to cylinders or cubes or parallelepipeds, was very short-lived. And most people didn't like it. The profession, I'm sure, had no choice at the time. A few people enjoyed it, a few people got a good name for it. But at this point, I think it's safe to say the idea that perfection is a cube is over.

PA: Hmm.

BM: I remember, afterwards, when suddenly fractals became all the rage, at least in some schools. And I was afraid it would just die off like many little fads. But in fact, it continues.

This has been for me an extraordinary pleasure because it means a certain misuse of Euclid is dead. Now, of course, I think that Euclid is marvelous, he produced one of the masterpieces of the human mind. But it was not meant to be used as a textbook by millions of students century after century. It was meant for a very small community of mathematicians who were describing their works to one another. It's a very complicated, very interesting book which I admire greatly. But to force beginners into a mathematics in this particular style was a decision taken by teachers and forced upon society. I don't feel that Euclid is the way to start learning mathematics. Learning mathematics should begin by learning the geometry of mountains, of humans. In a certain sense, the geometry of...well, of Mother Nature, and also of buildings, of great architecture.

Now, do you think I'm just having dreams of grandeur in my old age, or is it true that I provided mathematics with a wider audience? I get letters all the time from high school students, from all kinds of places, and they often begin by saying: "Well, we just realized that you are still alive! We thought you'd be long dead." Which is a bit... well, I mean...

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PA: Flattering!

BM: I'm getting used to it. But what do you think; don't you think that mathematics like this is more alive, warmer? That it is catching?

PA: What really helped fractal geometry and its application in school, I think, is the computer. Having computers in classrooms has been a blessing for all sorts of more visual and more organically based forms of geometry and mathematics.

It helped popularize the idea of fractal geometry and make it become more comfortable and easier for people to accept. And then it also became something for the more elite culture of architects and designers to adopt. I wonder whether the idea of the use of algorithms in architecture was introduced not only by biology, but also a lot by fractals.

And the fact that there is more and more science in many architects' and designers' work is

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very telling. Before, science was kept at bay, and architecture found its inspiration elsewhere; now, science instead appears to be more immediately useful and present in their vocabulary, perhaps because it has gotten so much closer to a real description of the world.

BM: At one point in history a copy of Euclid was shipped from Spain to Italy, and translated. It provoked an extraordinary change in very many aspects of life.

To begin with, it was read by architects and painters; Giotto, a great painter, had no idea of perspective, so he was incapable of representing the beams in that amazing long refectory that he painted.

However, after Euclid became known, his geometry could be taught to anybody. Therefore, there was a moment in history when a mathematics, very different from anything that existed before, came back to the West by the intermediary of Italian painters. This may or may not have contributed to the greatness of the Italian Renaissance.

So, mathematics can have a direct influence on everybody's world. Earlier mathematics had developed very separately from the world. Early on, Euclid was very far from everyday reality; but then the world changed, and mathematics became indispensable.

THE NEW GENERALISTS

BM: So I know that you are preparing an upcoming exhibit at the museum. I've visited it many times, and each time, it's bigger!

PA: It is definitely bigger.

BM: And each time it's more varied. But tell me, what viewpoint or theory or approach do you hope to foster with this exhibit?

PA: My specialty, my passion, is contemporary design. I'm trained in architecture, and I am proud to spontaneously spot traces of the indifference to scale that you preach, I view architecture, urban planning, design, objects as theoretically the same.

This particular exhibition, which is called "Design and the Elastic Mind," comes 14 years after I started at MoMA. With every exhibition, I've tried to show people the importance of design, and this time I found a very strong alignment with science.

Interestingly, both design and science are trying to change their position in people's perception. Science is trying to be perceived as more part of the real world and less lofty than before, and designers are tired of being considered decorators, because they have a much more structural roles in shaping people's lives. They really anticipate behaviors and guide change.

Designers take scientific revolutions and they make them usable and exploitable, comprehensible to the average human being. The internet is an example: it used to be lines of code, and then the designers came. It became an interface, and now we're using it.

So this particular show is about how designers and scientists work together—how they worked together two years ago and how they'll work together in two years. It's about the present. It's about the discoveries that are being made right now.

BM: Ah, interesting.

PA: There's a very strong component of nanophysics and nanotechnology and how they can help shape a model of collaboration for science and design in the future.

Something that is truly interesting, that Peter Galison at Harvard first talked about, is the idea of "nanofacture"—the idea that scientists are compelled to become designers because of the possibility of building things atom by atom. And you might have given them a hint already, with fractals, because it was already something playful that they could do.

Scientists are designing. And designers are trying to learn about science and collaborating with scientists. And together, they are trying to help people cope with the tremendous changes in everyday life—in scale, in resolutions of screen, in contact with big crowds of people...

And what I hope, as I do with every show, is that people will recognize themselves in it. I hope that people will immediately say, "Oh my, this happens to me, too," and therefore understand the role of design—and this time, also of science—in their everyday life.

BM: Well, it is very encouraging for me, because I'm an old man and, as I always mention at some point, I never made up my mind who I really was, which allowed me to spend my life on many things. So what you're telling me is that I can just relax, because I won't have to decide!

PA: I don't know. You're very responsible for what goes on right now. I don't think you can relax any time soon!

BM: Well, yes, but at least I won't have to become a specialist, because everybody is going to become a generalist.

PA: Generalism is very important. The interesting aspect of your theory was that it was very easy to generalize. And I'm not saying it as a disadvantage; I'm saying it as a quality. It's possible to grasp it, even if you are not a scientist or really versed in mathematics.

So I think that your ideas and your approach were almost the beginning of generalism. And designers are big generalists, and scientists are trying to become a little more generalist because sometimes they feel that they have become too specialized.

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But I think you can't sit down and relax quite yet, because you see what happens when architects like Ben and Chris get ahold of you. Discussions go into the wee hours of the morning. I think that the immediate application of your ideas, in design and architecture, has only just now begun to happen.

BM: Great news.

PA: Yes, it is. ∞

15.1 A HEAD FOR NUMBERS

While we'd like to think that humans are cognitively superior to all other animals, in a recent study, young chimps outperformed human adults in a memory test. Three pairs of mother and infant chimpanzees learned the order of the Arabic numerals by sitting in front of a screen on which the numbers briefly appeared. The screens were covered by white boxes and the subjects then touched the boxes in the order of the numbers underneath. Young chimpanzees were better at this task than their mothers, and both groups outperformed humans in speed and accuracy.