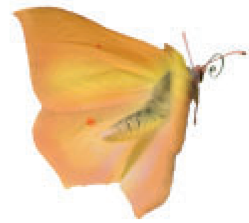
Math and Medicine: a Measure of Change



Journalist Haig Simonian recently met with Heinz-Otto Peitgen, an internationally respected authority on applied mathematics and visualization software, in Vienna, Austria, for *Medical Solutions* to talk about his newest ventures, including projects aimed at finding new and better ways to diagnose and treat breast cancer.

You studied mathematics and specialized in chaos theory. What exactly do you do now?
PEITGEN: Something very different from what I originally trained for. In mathematics, there's a division between pure and applied. Pure mathematicians tend to look down on their applied colleagues. For years, I was a real, passionate, pure mathematician. But then I gradually moved to applied.
As my interests developed, I became increasingly fascinated by chaos theory and fractal geometry. And, quite by coincidence, I came into contact with people in medicine who had a problem that needed to be solved.

Fractal geometry – what's that? And what does it have to do with medicine?
PEITGEN: At school, you learn Euclidian geometry: the geometry of shapes and objects. Fractal geometry is the geometry of nature. Some of the nicest examples are in the human body – fractal geometry looks at things like the vessels in an organ or the bronchial tree. It asks, for example, why a vessel in the liver is the way it is. Is it just chance, or is there a reason? If you can give such phenomena a mathematical framework, you can use math to describe, measure, and model them.

So what's the relevance to medicine?
PEITGEN: Gradually, I realized that fractal geometry in medicine wasn't just extremely exciting scientifically, but it also offered the challenge of putting such knowledge into practice.
You need to take a step back to understand. In November 1895, image-based medicine was born with the X-ray. Until the 1970s, we concentrated on exploiting that innovation – to the extent that today, we can hardly appreciate what an earth-shattering discovery it was.
Then we had a second breakthrough, with the arrival of computed tomography [CT] and magnetic resonance imaging [MRI]. Suddenly, we could do real three-dimensional imaging. MRI, especially, is one of the most demanding technologies imaginable. It's almost a miracle that we've managed to put it into application.
But now we're in a third phase, a silent revolution based on the fact that all processes in image-based radiology have become entirely digital. Digitalization is the starting point for measurement. And just as measurement has allowed the natural sciences to progress, it will enable medicine to progress.

That sounds fascinating. But what does it mean for the patient?
PEITGEN: For its first 100 years, radiology was all about interpretation. It was subjective and dependent on the interpretational ability of the specialist. Because of that, it was also very hard to transfer knowledge to broaden learning.
Being able to measure changes all that. It allows us to generate knowledge and make predications, taking us much further than when just looking at images. This third phase is going to change things entirely.

Can you give an example?
PEITGEN: Take breast cancer. We know the key lies in early detection. Mammography is quick, cheap, accurate, and relatively specific. However, as we learned that some lesions couldn't be detected, we turned to ultrasound. But here too, we

found that some forms were not traceable by either technique.
These types are particularly aggressive, making detection all the more important. In 1995, we thought magnetic resonance imaging could help. But how do you prove it's cancer you see, if you can't visualize it during biopsy? So we needed to develop a MRI-compatible biopsy device as well. We pioneered MRI breast imaging and MRI-guided diagnostic breast biopsy, with the first system on the market in 2005. And that led to better chances of preserving the breast as well. Intervention to remove just one growth runs the risk of missing others. It has now become possible to combine a surgical biopsy with support from breast MRI.

Heinz-Otto Peitgen was born in April 1945 near Cologne, Germany. He studied mathematics, physics, and economics at Bonn University, where he later worked at the Institute for Applied Mathematics. In 1977, after completing his doctorate in 1973 and his habilitation in 1976, he was appointed to a professorship in mathematics at the University of Bremen. His specialization in fractal geometry moved him increasingly into concrete applications for his research, particularly modeling and visualization. Since 1992, he has headed Bremen University's Center for Complex Systems and Visualization (CeVis), and founded the Center for Medical Image Computing (MeVis Research GmbH) in 1995.
Peitgen has published 22 books and more than 200 research papers, while also serving as a visiting professor at universities around the world. His work, which has helped to popularize the understanding of complex dynamic systems, has been recognized through many prizes for research and innovation in science, medicine, and entrepreneurship.
In 1997, together with his colleague Carl Evertsz, he set up MeVis Medical Solutions AG. Focused on accelerating the commercial application of groundbreaking research in computer aided diagnosis and therapy, MeVis Medical Solutions made its initial public offering on the German stock exchange in November 2007. The entire MeVis group now has about 200 employees.
Peitgen's favorite pastime is music: The 17th piano etude by Romanian-born composer György Ligeti (1923-2006) is dedicated to him.

Complex mathematical modeling can clearly be used to a great effect in medical settings. But can't such techniques also be applied to completely different dynamic systems, such as organizations?
PEITGEN: Understanding fractal geometry is also applicable in self-organization. That can include settings in business or daily life. The key is assessing to what extent tasks should be prescribed and codified, and to what degree they should be left to the people involved directly. Ideally, there should be a balance. In society, for example, there should be a limited number of rules and laws, with the rest left to individual freedom. Such societies tend to be the most creative. Certainly, we know from history the results of societies where orders came from the top; fortunately, there aren't many of those left. Somewhat the same thing applies to complex organization like companies. Prescribe too much, and people get frustrated and leave. We should take our example from the principle of self-organization in nature.

So is analyzing and discussing business also part of your activities?
PEITGEN: Yes, although I can devote only a very small amount of time to it. But I was asked to give lectures and advice long before my interest in medicine began. In fact, I was doing some consulting work for a brand management company when I first became interested in how to apply fractal geometry in radiology.

Is your thinking about organizations also applicable to other medical contexts, like how to run a hospital?
PEITGEN: Certainly. There's nothing more complex than a hospital. A factory is nothing by comparison. I'd love to do such work. And you'd think administrators would be eager to discuss how they might be able to improve their processes. But the trend is towards top-down, prescriptive thinking, based on codified approaches, rather than leaving more decision making to the people involved. In my mind, that's not right. I believe medicine is on the wrong path.

You're also known to have strong opinions on the role of scientists in disseminating knowledge. You established a company to accelerate the commercial development of your own research. Is that a model?
PEITGEN: Given the feverish pace of innovation today, scientists need to ensure that their findings are maximized, or they risk being overlooked. Traditionally, a researcher would make a discovery, publish it, and then move on, leaving it to others to exploit the work commercially – or not. I'm more applied. I really want to bring ideas to use. And, if I really want to achieve that, I have to extend my responsibilities.

The scientist as entrepreneur is inevitable?
PEITGEN: No. I respect those colleagues focused exclusively on research. But it's a question of motivation: I had already achieved professional satisfaction early in my career as a pure mathematician. More recently, my priority has been to disseminate our work. That's why we set up MeVis Research and MeVis Medical Solutions, to take our academic research into projects with practical applications in medicine to exploit the benefits more quickly.

***Haig Simonian** is the Switzerland correspondent for the* Financial Times.

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Heinz-Otto Peitgen, PhD, Faculty of Mathematics,
University of Bremen, Germany