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Q&A Gerhard Ertl

A lateral thinker

The winner of the 2007 Nobel Prize in Chemistry ponders biology's big questions with Diane Wu.

When you were a student, did you meet any of your scientific heroes?
I met physicist Frédéric Joliot-Curie. I was studying at the University of Stuttgart and in my second year a friend suggested that we go and study in Paris. This was quite an adventure. We attended lectures by Joliot, who was a very spirited and energetic man (although he was already sick, and died one year later). I never forgot his lectures: "Today we ask the question, what is nothing? Quel est rien?" Nobody knew how to answer. But that was how he introduced the neutron to us — the neutron is a "nothing" of charge.

"The big fundamental problems today are in physics and biology."

In 1959, I spent a year at the University of Munich where Werner Heisenberg taught quantum mechanics. There were at least 300 students in the class, and it was hard to follow. We had to solve problems and, if you were successful, you got a certificate: "You participated in the exercise of quantum mechanics", signed by Heisenberg. I value mine very highly and still have it today.

What are the big questions in chemistry today?
Chemistry doesn't have any really big fundamental problems. The last big question in chemistry was 'what is the nature of the chemical bond?' — and that was answered almost 100 years ago with the advent of quantum mechanics. The big fundamental problems today are in physics and biology.

In physics, the big question is: how can the two great theories in physics — quantum physics and the theory of gravitation — be unified? There are other questions: what is the content of our Universe? What are dark matter and dark energy? Only four per cent of the Universe is the matter that we are made of; what is the rest?

In biology, there is: what is life? We know which elements are important for life, but will it ever be possible for humans to create artificial life? These are the big questions. Chemistry has nothing compared with this.

Erwin Schrodinger posed the question 'what is life?' seventy years ago in his book of the same title. How close have we come to answering it?
The question that Schrodinger was asking was very specific — in essence, do we expect that new laws will be necessary to describe biology? And he couldn't give an answer, mainly because he was not able to explain the formation of structure in biology. Not only molecular structure, but larger structures as well – for example, how does a cell divide only in the middle? We can start to answer these questions using non-linear dynamics — and that is the field that interests me the most.

What is the importance of structure to life?
Self-organization is the basis for all kinds of structure formation. Closed systems that have no external inputs will eventually find a state of equilibrium that can be disordered or ordered. For example, salt ions precipitating out of a solution can assemble into ordered crystals. Open systems have a continuous inflow of energy, which allows them to hold a position away from equilibrium. For example, a cell has an inflow of energy in the form of food, which allows it to maintain its structure and function. The mathematical description of these processes requires non-linear differential equations, ▶

Gerhard Ertl won the Nobel Prize in Chemistry in 2007 for elucidating what happens at the molecular level at solid–gas interfaces. His pioneering work established the field of surface science. Ertl is now professor emeritus at the Department of Physical Chemistry, Fritz-Haber-Institut der Max-Planck-Gesellschaft in Berlin.

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Diane Wu is a graduate student at Stanford University. She researches upconverting materials, which convert light from lower to higher energies and have nascent applications in bioimaging and solar energy conversion.

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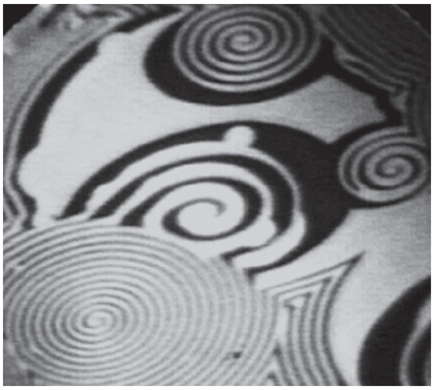

Patterns of gas on a platinum surface

so it is often called non-linear dynamics. Studying biological systems using non-linear dynamics shows that existing physical laws are sufficient to describe order in living systems — just as Schrodinger predicted but could not prove.

How did you come to be interested in non-linear dynamics?
Twenty-five years ago, I was working on reactions at surfaces, and came across a well-known problem: reactions on a surface often show illogical behaviour. For example, in an open system with constant inflow, you would expect constant outflow. But sometimes the outflow becomes oscillatory. That's a consequence of the complexity of the chemical reaction, and is based on the underlying non-linearity of the equations used to describe the kinetics.

What mysteries in biology besides structure formation can be addressed with non-linear dynamics?
Theoretical physicists are helping to answer many medical questions. For example, the electric pulses of the heart are chaotic and can be analysed and modelled with the tools of complexity.

Cardiac pulses are not localized — they are electric currents that spread across the whole heart in waves. These waves propagate through a chemical reaction coupled to electric phenomena. One of the pioneers of describing this field of complexity was cardiologist Arturo Rosenblueth who, together with mathematician Norbert Wiener, wrote a paper about how this kind of pattern might emerge. Researchers in medicine are interested in in dynamic systems in the body, and how they respond in a non-linear way to various inputs. Complexity can be used to describe and predict this kind of physiological response.

I'm working on a book which summarizes our knowledge about complexity in different fields. I hope to arrive at one unifying concept that can be applied to different phenomena. ■

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Q&A Dan Shechtman

The technology starter

The winner of the 2011 Nobel Prize in Chemistry speaks to Valerie Gerard about creating leaders and achieving prosperity though technological entrepreneurship.

What does it mean to you to have won the Nobel prize?
I see everything that happens in my life as an opportunity. With the Nobel prize comes the opportunity to talk to people around the world. I am on a mission to talk to other scientists, to students, to decision makers, and to the population in general about the importance of education for all, and in particular good science and engineering education and of technological entrepreneurship. Many people around the world are disenchanted because they do not see a future. We need leaders, at all levels of society, to show these people the way forward.

How can we find these leaders?
We have to make them. The first thing to do is to teach them to be good human beings. Young people today are surrounded by mirrors; wherever they look, they see themselves. We need to break the mirror and let them see what other people need, understand where they come from, and communicate. Then we have to build a leadership character, to let young people take on responsibilities at junior levels and then rise to