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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 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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M GRAYSON



## 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 through 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 disenchanting 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

the top. If these young people become the real decision makers, we will have a better world.

### What can we do for those countries that are not succeeding?

Education for all is job one. To provide good standards of living, we need scientists and engineers. Don't get me wrong, we also need musicians, poets, writers and film makers to give taste to life. To live in good economic conditions, however, we need technology people who are motivated to start companies.

It is in the interest of developed countries to make sure education reaches all rural and disadvantaged parts of the world. In Europe, the average number of children is around 1.5 per woman, and in some Far East countries it is closer to one child. But in central Africa, the average number of children per woman is very high — in Niger, for example, it is 7. This imbalance results in waves of immigrants and refugees. The main factors that limit the number of children are education for women and urbanization.

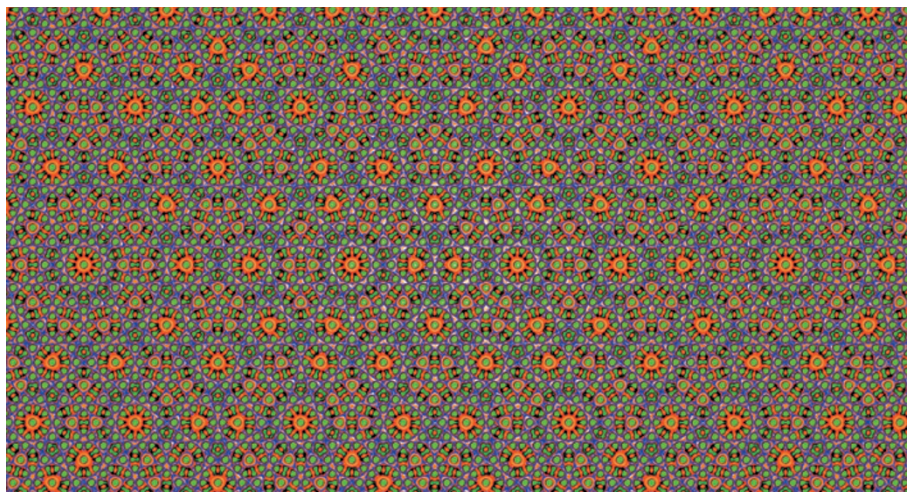
### What is the role of technological entrepreneurship in improving a country's economy?

When start-ups grow, they can double their workforce each year. They are a great way to boost employment of educated people. Those with less education might appear to have more limited chances, but they can also become entrepreneurs: for example, they can open shops or provide services. Entrepreneurship should be promoted by governments everywhere, through education and support. I am against too much government intervention in business, but they should support entrepreneurship.

### How are entrepreneurs made?

I have been teaching technological entrepreneurship for 27 years at the Technion in Israel. It is a large class open to all students. I show the students the stepping stones to success, where the stumbling blocks are and how to jump over them. I developed this class even though it is not my profession — I am a materials scientist — because entrepreneurship is important for my country. In that period Israel has become a start-up nation: according to Saul Singer, co-author of the book *Start Up Nation: The Story of Israel's Economic Miracle* (Twelve, 2009), "Israel has more start-ups per capita than anywhere else outside Silicon Valley."

I like to think that I have something to do with it. In entrepreneurship, there is the know-how, which can be taught, and there is the spirit of entrepreneurship, which comes with knowledge and can be greatly promoted by role models. In Israel we know about



Computer model of a quasicrystal pattern, which shows order but is not periodic.

entrepreneurship and many feel that it is a good idea to become an entrepreneur. It's our national sport.

### What are the risks associated with starting up a business?

Most start-ups fail. We tell the students that failure is OK. We obviously don't recommend failure, but if you fail, it is not personal, it is not a shame. If you fail, you start again. You failed either because you made a mistake, which you will not make again, or because of something that you could not foresee, like a shift in the market. I trust you more than a novice to entrepreneurship because you have been through the process; you are now an experienced entrepreneur.

### How can someone avoid the common pitfalls of financing a start-up?

We teach our students where to get money and what money not to touch. Not all money is the same. For instance, never touch your own money, and never take money from your relatives or friends because there is a good chance that you will lose your relatives and your friends. Good money comes with good advice or with help in marketing, from strategic partners or business angels who trust your idea and want to work with you. I have a problem with venture capitalists: although they can make a lot of money available, they want their money back too soon — within five years. In five years you cannot strive, you cannot build your start-up to become a good, large company.

Or you can do boot-strapping: working without money. You might need other people's expertise and without money you cannot pay for it. But you do have something valuable that you can share: your company. Give them a share of your company, and be generous. The value of your company now is exactly zero. Be generous with that zero. If you are successful, in the end there will be plenty of money for everybody.

### Could anyone become an entrepreneur?

It depends on character. I am an entrepreneur by nature. As a hobby I make jewellery; when I make a new piece, I immediately think of the process that will make 10,000 pieces. Not everybody should become an entrepreneur, but entrepreneurship should be promoted all around the world, for our well-being.

### Is industrial research a good option for those non-entrepreneur scientists?

Industries today lead a lot of excellent research because they have their feet on the ground; they know what is needed for their next product to sell. Universities have the advantage of studying esoteric subjects that industry would not consider, which sometimes bring interesting results. I have never worked for industry but I think that, today, working for a good company is a fantastic opportunity for a researcher. After all, the number of professorships around the world is limited. ■

**Dan Shechtman** won a Nobel prize for the discovery of quasi-periodic crystals (structures that are ordered but not periodic), which revolutionized the field of crystallography. He is now the Philip Tobias Distinguished Professor of Materials Science at the Technion-Israel Institute of Technology in Haifa, Israel, where he also teaches technological entrepreneurship — a passion of his. He is also a Distinguished Professor at Iowa State University.

**Valerie Gerard**, a post-doctoral researcher at Trinity College Dublin, Ireland, is developing semiconductor and metal nanoparticle-based composites for biomedical applications.

