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Features

Looking at life with Gerardus 't Hooft

by The Plus Team

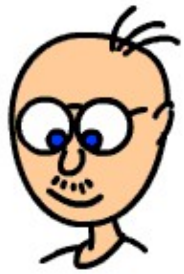
Professor Gerardus 't Hooft was born in 1946 in Den Helder, the Netherlands. He completed a PhD in Physics in 1972 at the University of Utrecht, where he has been a Professor of Physics since 1977.

't Hooft and his colleague Professor Martinus J.G. Veltman received the Nobel Prize for Physics in 1999, for their work on the quantum structure of electroweak interactions.

't Hooft has been a member of the Dutch Academy of Sciences since 1982, and has received a number of other awards, including the 1979 Dannie Heineman Prize from the American Physical Society and the 1982 Wolf Prize for his work on renormalising gauge theories.

The article that follows is an extract from 't Hooft's conversations with Rachel Thomas of the Plus team, in his own words.

"I remember, from as long as I have memories, that I have been interested in natural phenomena, in nature, and also in abstract thinking and mathematics. I always wanted to understand and to research the forces of nature, the mysteries of nature which attracted me enormously.



For example, I remember when I was very young that I was intrigued by the concept of the wheel. I thought the guy who had invented the wheel must have been someone very smart, because it worked so well. I noticed one day that there were two children's bicycles upside down, and the wheels were touching. I discovered that if you rotate one wheel, the other wheel also rotates. This is the principle of transmission, and I remember I was very intrigued by it − by the fact that somehow you can use the forces of nature to do something for you.

Science in general, and Physics in particular, were practiced quite a bit in my family, particularly on my mother's side. My grandmother married a professor who was an esteemed zoologist. Her brother, my great−uncle, was Frits Zernike. He was a physicist of a rare kind, as he was extremely skilled both in doing experiments and theoretical analysis. He won the 1953 Nobel Prize for Physics.

Unfortunately I never got to know my great−uncle Frits very well, since he was already very old when I was small. My mother's brother, however, was also a theoretical physicist (now retired). When I was a boy, he was a professor, and he would frequently visit our family. I would always bombard him with questions about physics in general, and he was always very patient with me. Mostly he would explain things, but sometimes he wouldn't. Instead, he'd say "Look, this I can't explain to you. You'll have to wait until you come to University, where you can attend my lectures and find out how it really works." I could hardly wait.

I was always interested in science, and I now work in particle physics. However, I was also very interested in mathematics, both for its own sake and most particularly because I wanted to apply mathematics to physics. It had always been made clear to me, by my family and teachers and by what I read about physics, that mathematics is quite essential. I learned that there are many complicated, deep issues in mathematics that can help you to understand physics problems, and so I have always been very interested in mathematics.

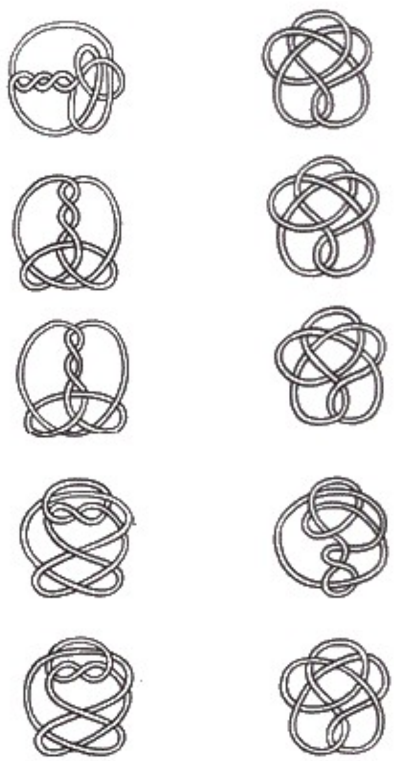
Gerardus 't Hooft at the conference [Photo and copyright Anna N. Zytkow]

Today, we are discovering that nature is very mathematical, very methodical, very logical. To me, this is a strong indication that our entire world is ruled completely by mathematical equations and predictions − and not only that, but that humans have the capability to sort it all out; they already have come a long way.

It is quite conceivable to suspect that humans will figure out the ultimate equations that are at the basis of everything. Some people attribute it to our extreme arrogance that physicists can even dream of such ideas, but many others of us have this feeling, this impression, that truly fundamental equations may exist − equations that will be universally correct, needing no tampering, no further corrections of any kind, equations that describe how our world is running at the tiniest possible scales and with the most extreme accuracy.

This is, of course, very much a case of feeling and belief at the moment − we can't say anything for sure. But my feeling is that it is quite likely that nature is built extremely logically, with precisely defined laws that can be expressed simply given the right "ingredients". We haven't yet understood at all what these ingredients are, we don't know how to describe the degrees of freedom in nature at this time, or how we should formulate the mathematics. But many of us are trying, each in our own way, to see if we can make further progress, if we can improve our understanding of what is going on.

Eventually I think that this is really something more delicate, more special than just differential equations or integrals. I think that it is much more likely that at the very tiny scale all you have to deal with are numbers, and I am thinking of integral numbers, and small ones at that. Just small, simple numbers, but very many of them.



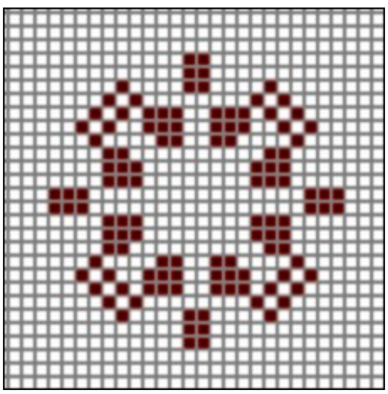
Some of the distinct 10−crossing knots

Take, for instance, Knot Theory. In Knot Theory, you take a long rope and you mess it all up into a terrible knot. How many fundamentally different ways can you tie a rope into such a knot, particularly if you glue the ends together again? How many kinds of knots can you have?

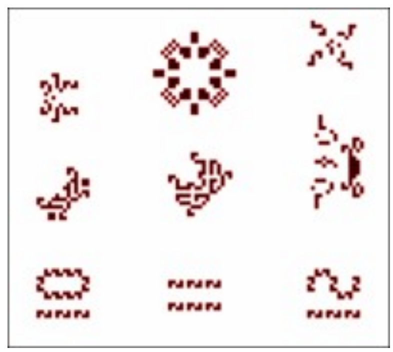
This just happens to be a mathematically extremely interesting and intricate question, and it is basically controlled by integral numbers, not differential equations. How many times does one thing go around the other? It goes around two times, three times, four times, but there's nothing in between, these are just integral numbers. So, this shows that the physics of tying knots is controlled by integral numbers, much like the sort that could be at the basis of all that is happening in this world.

I don't know how well the readers of *Plus* know about Conway's Game of Life. They might have seen it. It's a beautiful system. The nice thing about the Conway Game of Life is that it is controlled just by numbers, none other than ones and zeros. You put ones and zeros on a great big grid, and, at the tune of some specially chosen "Law of Physics", these ones and zeros propagate around. In fact, you can think of the grid as representing the entire universe, practically infinitely large. I think Conway's game of life is the perfect example of a toy universe. I like to think that the universe we are in is something like this.

Most investigators of Nature think that such an idea is far too simplistic, or too far fetched, and also too far away from our daily experience, including our experience of subatomic particle physics itself. They say "Look, this is hard to imagine, this is not the way our world actually looks, at least not as we perceive it to be". So in other words, we don't see Conway's Game of Life at the subatomic particle scale, our universe appears to be vastly different. But we also realise that if you go to much, much higher resolution, you can go to much, much smaller details in the subatomic particles. And there our world must look very different from what we are used to now.



A Conway game seen up close ...



... and from a little bit further away. Seen from a million times further away, quite different kinds of structures and regularities may appear.

So for instance, if you take Conway's Game of Life, you take a grid consisting of millions and millions of boxes, with ones and zeros in them. If you look at it from a great distance, what you see is quite different from what you see when you look at the individual boxes. At a great distance, you see shapes and figures moving around. You don't see the individual boxes anymore, you just see global features moving in a complicated way. The laws that those global features appear to obey are vastly different from the underlying rules of the Game of Life. And they look a little bit like the laws of Physics that we do perceive, though only a little bit.

So we like to coin the idea that perhaps there could be an ultimate underlying theory of the world which looks like Conway's Game of Life. Of course, most of us do expect that it's not going to be that simple. Nature is likely to be more delicate, more elaborate, more special, and more unique than just the very simple Conway Game of Life. But the whole philosophy to me sounds very promising, and it's conceivable that there is something like this going on.

One day, a school teacher asked all the kids in my class "What do you want to do in your life?" I was trying to say that I wanted to be a professor, but at that moment I couldn't think of the word. Instead I said I wanted to be "a man who knew everything". I don't think I've accomplished that aim, but what I did accomplish was to become a serious researcher who helped, I think, to solve some deep riddles in nature."

Plus is part of the family of activities in the Millennium Mathematics Project, which also includes the NRICH and MOTIVATE sites.