Prof. Russell Stannard: The questions on everyone's minds
Superstrings

Russell: What is everything made of? This for instance. Atoms. And atoms are made of electrons and a central nucleus. The nucleus is made up of neutrons and protons. Neutrons and protons are made up of quarks. So everything is ultimately electrons and quarks. Tiny, tiny point-like particles. And being point-like means they have no inner structure, so we don't have to worry about what parts they might be made up of. Quarks and electrons are the end of the line. Which is good. But are they really point-like? Do they have no volume at all? One of the most fascinating fields of study at the present time is the theory that the fundamental constituents of nature are not point-like particles, but strings – tiny vibrating strings called superstrings. A bit like this. And depending on how the string vibrates, you get different particles. So this might be an electron, that might be a quark, and this might be a bundle of light energy called a photon. Each different particle is a different mode of vibration of the same sort of string. Now with a string, only certain modes of vibration are allowed.
That's the characteristic note for a string of that length under that particular tension. And that's the characteristic note you get if you change the tension. So we'd expect the same behaviour to be true of a superstring. Only certain modes of vibration are allowed. And these different modes will have different energies. And because energy and mass are related – Einstein's theory of relativity: E = mc2 - E (the energy) equals m (the mass). Because of that, these different allowed energies will correspond to different allowed masses. In other words, only certain masses are allowed - which is exactly what it is with the quarks and electrons. So this begins to look intriguing. You see while we thought in terms of just point-like particles, all we could talk about is how those point like particles move through space. But once we've got the idea of them being strings, we have another handle on it. The fundamental particles differ in mass, but they also differ in other ways. Some have electric charge; others don't. So the question arises as to whether we can account for the additional properties by invoking yet further variations in the way the superstring vibrates. You see this string can only vibrate in two dimensions - that way and that way. Okay, we can imagine the ends not being fixed and that would give you vibration in that way, which would add variety a bit like this.
With a slinky spring you can get vibrations laterally like that, but you can also get vibrations longitudinally. That gives us vibrations in three spatial dimension. Now it turns out that if we could have vibrations of this in nine spatial dimensions, we could account for all the properties of all the fundamental particles - which would be great. Except, of course, you're sitting there thinking, '"Tough! There aren't nine spatial dimensions. There are just three." That and the time dimension. But just three spatial dimensions. Or are there? Take that pointer over there. The other day I noticed there was a chalk mark on it, I meant to clean it off. How can I specify where the mark is on the pointer? Well, how far was it from the end? Well I noticed it was 18 inches? Let's go and take a look. Nine… eighteen. No mark. But wait. In saying that it was 18 inches from the end, we haven't specified precisely where the mark is. All that tells us is that it's somewhere around the circumference of the cross-section that's 18 inches from the end. If I twist it round… There we are! So in order to specify the position of the mark precisely we need not only the distance from the end, but also its distance around this extra curled up dimension. And this is an idea incorporated into string theory. Where are these 6 other spatial dimensions we need? They're curled up.
Here are the three familiar extended dimensions, x1 , x2 , and x3 .. And what I've tried to do here for that point there is to show you two extra curled-up dimensions, we've got x4 there and we've got x5 there. And that's as far as I can go as far as a drawing's concerned you know we can't in fact form a mental image of it. In fact there should be six curled up dimensions there. And not just true of that particular point in space but of every other point in the normal conventional three dimensional space. Six extra curled up dimensions at every point, as well as the three extended ones. So, the promise of string theory is that one day we will be able to account for all the properties of all the fundamental particles in terms of the particles being superstrings vibrating in 9 spatial dimensions and one dimension of time. It's no wonder so many theoretical physicists are enthusiastically engaged in this work. But the

worrying thing is that, despite so many people working on this problem for the past 30, 40 years, they have yet to come up with a single prediction that could be verified. You see, it's all very well talking about string theory, but there are many variants of string theory. The geometry of the curled up dimensions. I showed a sphere over there. Like this okay. And there we have x4 and x5. But it might not be like this. It might be more like this. X4 and x5. Or some other twisted topolgy.

Then there's a variant of string theory that's based on ten special dimensions, not nine. Not only that, but the dimensions are so small it's thought we shall never be able to devise a way of seeing them. Same goes for the superstrings themselves. They are tiny. Forget about the Large Hadron Collidor at CERN, 27 kilometres in circumference. That's absolutely no good at all for seeing strings. The strings are believed to be so small it would take an accelerator the size of a galaxy in order to be able to observe them directly, to check that they really are strings, finite sized strings and not point-like. So, what does that mean? Are we destined never to know whether this attractive idea is true or not?

These are but two of the fundamental questions facing science today. What we've been looking at in this series has not meant to be an exhaustive list of outstanding questions facing science today. Other scientists would doubtless have liked to see a mention of other topics as well. But one thing seems certain to me: One day all of this kind of science - fundamental science - the discovery of new laws of nature – all of it one day, must come to an end. And not when we have discovered everything, but when we have discovered whatever is open to us to understand - when we have finally come up against the Boundary of the Knowable in all directions. When will that be? Who knows? A hundred years? A thousand years? Indeed I don't see how we - or more strictly speaking, our descendents – how they will even know when science has come to an end - rather than just thinking that it's just going through a particularly boring, bad patch. Well, perhaps when they discover that the science text books haven't needed updating for the past millennium. Which in itself is quite a thought: Not only are there things we shall never understand, we shall never even be sure what it is we shall never understand!

After piece

Tony: Give us a tune Russell.

Russell: Not likely, I never did learn a musical instrument. Well not beyond you know, Chopsticks on the piano. I could never remember which notes came next, I have a very bad memory. That's why I took up physics, you don't have to have a good memory for physics, you just learn a few things and then you work everything else out from that, logically sort of thing.

Tony: Yeah, okay fine. Okay everybody, so moving on.

Russell: Is that a wrap by the way? Have we finished?

Tony: Yep, I think so. Yep.

Russell: So you don't need the props anymore?

Tony: Nope, no that's fine thank you.

Russell: Mmm, Okay.