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The Buzz Forum: It's Not That Simple

Broadcast Monday 26 August 2002
with Richard Aedy

Summary:
Complex systems science is characterised by emergent phenomena. Simple variables can lead to complicated, well-organised and even self-replicating results. The mathematics are so difficult that the field has only taken off in the last decade or so with the inexorable rise in computing power.

In this forum, we explore the history of complex systems and consider areas as diverse as ecosystems, climate and the outbreak of foot and mouth disease in Britain.

Details or Transcript:

Richard Aedy: Hello I'm Richard Aedy, welcome to The Buzz. We're doing something different on the show this week. We're running a forum on complex systems, we've got a great panel, an intelligent audience and a moderator of sorts. We've called the forum "It's not that simple".

Ladies and gentlemen, welcome to "It's not that Simple". (Applause)

We're here tonight to talk about complexity, complex systems, complexity science because it turns out that many phenomena are more complicated than we thought. Bushfires, the weather, traffic even the Australian Democrats, there aren't even ten of them. Complexity science has quite a history and we'll be hearing more about it in a moment but really it's exploded in the last 15 years or so because of the dizzying rise in computer power.

In a way, complexity theory says everything says everything is connected to everything else and this would please one of my favourite fictional characters, Dirk Gently the holistic detective invented by the late Douglas Adams. He, Dirk, not Douglas, believed in the fundamental interconnectedness of all things. And complexity theory is exactly like that – only very different.

For starters it uses mathematical tools, most notably non-linear dynamics and this stuff is not for the faint hearted. You want the biggest, fastest computer you can get your hands on. Needless to say all of our panellists are capable of doing this kind of maths in their head and because of that, before I introduce them I have to caution them.

I have here a rather dangerous looking device it sounds like this. (Whistle) You'll hear it whenever any of the panellists get too technical. The final arbitrator of what is too technical will be me. When I don't understand something, I will use it, and I should warn you that as soon as I completed my degree in molecular biology it was evident to everyone who knew me that my future lay in journalism. It would be better for all of us if I don't have to use this again.

Alright, the panel, on my far right John Finnigan, he began his career studying aeronautics, segued effortlessly into atmospheric research, these days he's Director of the CSIRO Centre for Complex Systems Science. Russell Standish is an Associate Professor at the School of Mathematics at the University of New South Wales. He's also on the editorial board of Complexity International a peer review journal of all things complex.

On my left, Brian Walker is a former chief of the Wildlife and Ecology Division of the CSIRO, he's also Chairman of the Resilience Alliance, a group of 15 laboratories around the world. And Professor Ann Henderson-Sellers is Director, Environment, at the Australian Nuclear Science and Technology Organisation. She has authored 439 publications including 13 books and is an elected fellow of America's Geophysical Union and Meteorological Society.

Ladies and gentlemen, our panel. (Applause)

Now I want to kick off with a bit of history. John Finnigan, most of us think of complexity as a new science, maybe 30 years old, where do its beginnings lie?

John Finnigan: I think of it as complex systems science, not just complexity. The systems part of it probably goes back to the D-Day landings in the 2nd World War when people had to shuffle you know huge herds of tanks and regiments of people and boats and things and organise this enormous enterprise and so they had to really invent a science to do this. The complexity part of it is much younger. It really is the underpinning science behind how systems work and that has various antecedents going back about 25 – 30 years. The big names in this field were originally mavericks, swimming against the tide in university departments. People like John Holland and they came together, or many of them did, in a seminal institute called The Santa Fe Institute, which is still, in many ways, the place to go to do complex systems science. So it's about non-linear systems, the way they interact, and it really needed, as you said at the beginning, computers of some power and availability to make it possible to study these kinds of systems.

You hear stories of the pioneers like John Holland going into the computer departments at their universities at night when everyone else had gone home and they could get a bit of access to the computers. Now everyone has one on their desk which is more powerful than the Defence Departments of the time of access to. So part of the reason that the subject has exploded in my view is the tools are available. Just like many other fields like astronomy and microbiology, you had to wait for the tools to be invented. Suddenly we are seeing the explosion of a kind of experimental mathematics that describes systems that are really critical to the way humans interact with each other and the environment being enabled by the availability of this tool.

That's not really a potted history but that's I guess a few points along the way.

Richard Aedy: Are we all happy with that?

Ann Henderson-Sellers: No.

Richard Aedy: Right.

Ann Henderson-Sellers: I would say that John missed out the single most important person in the whole of the relatively short history of complexity and that's Ed Lorenz. As far as I'm concerned this complexity and complex systems, the description of complex systems, was – and perhaps still is – the archetypical weatherman's nightmare. Ed Lorenz found that, what was a very simple system of equations did not produce a simple solution. The paper was in 1963, I heard him give a talk which explained that paper in 1973, a decade later, and I remember being profoundly confused at that point but I would still say that weather was the origin of this John.

John Finnigan: Well I'll disagree. (Audience laughter)

I think we're already at the passing of the ways because what you're talking about Ann is Chaos Theory. And I agree that was a major shift, a major paradigm shift for scientists, this notion that complex and random behaviour could be generated by simple systems, which is what Ed Lorenz found.

I think complexity goes a bit past that to an even more surprising realisation that organised and intelligent behaviour can arise from interaction of simple systems. So chaos took us part of the way that hey, you know, simple things can interact, simple equations can be written down and you get fractals or you get you know weird behaviour in the weather or unpredictable behaviour in the weather. But to me it's even more startling that simple things can interact and what you get out of it is intelligent behaviour and organised behaviour.

Richard Aedy: Well look, let's nail down what a complex system is. Russell, what does a complex system have that a simple system does not have?

Russell Standish: In my mind the single most important aspect is something we call emergence and that obviously begs the question of what emergence is. A lot of people have debated this issue for a while. I would like to put it this way, in any of these sorts of systems there are at least two levels of description of what's going on. If you might think about say a living system, there is a description at the chemistry level of an organism and there's also description of an organism, say a lion. And the two are very different. In fact in the chemical description of a lion there is no concept of lioness in that. So in having these different levels or different languages describing the same system, where you have a situation whereby your macro or higher level language or whatever has concepts in it which simply aren't there at the lower level, then you have emergence.

Richard Aedy: So when you jump up the scale you get something that's more than the sum of its parts?

Russell Standish: Yes and that's because it's put in because the concept of a lion is useful to us as observers of that system.

Richard Aedy: You know a bit about lions, Brian. (Audience laughter)

Brian Walker: Yes, I think that's a part way answer which I'd agree with Russell on but it's really difficult. The question you've asked us is 'what is complex system science' and I think, in discussing it amongst a group of people involved in the past month or so that John and I have been involved in, we can kind of agree on what it's not. But it's very difficult to agree on what it is. It's a bit like love – you recognise it when you see it but how do you define it.

Richard Aedy: Have a crack. (Audience laughter)

Brian Walker: Well

Ann Henderson-Sellers: Complexity – not love. (Audience laughter)

Brian Walker: Thanks Ann. I think emergence is one property, I think that non-linear behaviour, now don't blow that whistle, that means simply that something changing smoothly in response to something else changing is the normal linear behaviour that we can think of about change and dynamics. What happens in complex systems is that you get abrupt changes, sudden threshold effects which occur and those create an emergent property that's not predictable. So it's not just that you get something that's emerging but that in complex systems, from the component pieces and their interactive dynamics you can't really predict what the outcome will be. And there are surprises that occur in the dynamics of complex systems. So to me it's the essence of unpredictability and emergence across scales, I agree with all of that, but it's the unpredictability part of it that makes it such a challenge.

Richard Aedy: Ann, are you bristling quietly or?

Ann Henderson-Sellers: No, no, no but I was going to offer perhaps not a different definition but a different view which might capture the history that we just looked at as well as thinking about was is complex systems science. I think for me it's a paradigm shift that has taken us a long time in science to recognise. If you will, the 20th Century was the century of science so we all did lots of science, there were world wars that drove and funded science, there were all sorts of very exciting discoveries. And the result of that towards the latter quarter of the 20th Century was that we knew that simple systems produced simple outcomes, simple results, and complex systems produced complex results and that was it, that was what science had understood.

As we just tippled into this century, the end of last century, we suddenly discovered, and it unravelled almost everything, that incredibly simple systems apparently can and do produce amazingly complex behaviour. And we've seen that all the way through the previous century and ignored it, we had set it on one side as scientists. And also that very simple systems produced complex behaviour and very, very complex systems, and this goes back to Russell's definition of if you look at a lion in all its component parts a great deal of complexity, but if another lion looks at the lion well it's a lion – that's fairly straightforward. So you can also get very simple behaviour from complex systems. Big paradigm shift.

Richard Aedy: I don't know much about complexity but I know a lion when I see it. (Audience laughter)

This is a special edition of The Buzz on Radio National, a forum on complexity coming to you from the National Convention Centre in Canberra, I'm Richard Aedy.

Bushfires are something that you have to think about Brian because you look at how to manage ecosystems.

Brian Walker: If you take a difficult complex system of a natural phenomenon a system of fire and shrubs and grasses and weather variability between years and then you couple that with another complex system which is people and managers and governments trying to subsidise and control what they do and you put that lot together you have a very unpredictable outcome. And so it's the combination of human and natural systems that I think provides an added level of complexity. I don't know if you want me to go beyond that but…

Richard Aedy: Yes I do because even if you take out some of that there's enough complexity in there anyway in just how an ecosystem will change over time, isn't there?

Brian Walker: That's right and there are lots of different ecosystems where you can see that. Colleagues of mine have been working on lake ecosystems and lakes can exist in one of two very distinct states. There's a state that we all want which is clear, clean water with some big macrophytes, big plants around the edge and no algal soups and decomposing mass.

Richard Aedy: And then there's Lake Burley Griffin. (Audience laughter)

Brian Walker: That's right, that's the alternate state. And it turns out that all over the world lakes can exist in either of these two states and they flip very suddenly.

Russell Standish: Or Lake George. (Audience laughter)

Brian Walker: That's a different story, that's the dry state. But what drives this is the amount of phosphate in the mud and it's another of these slow variables. And phosphate increases slowly in the mud of the lake as it gets washed in from surrounding agricultural areas and up to a certain critical level again, if you stopped putting in more phosphate the system reorganises itself and goes back to the open condition. But beyond that critical threshold, because of a whole lot of changes that we now understand in the lake, the system reorganises itself towards the very, I was about to say a word you wouldn't approve, the very awful state, the smelly water state, the eutrophic state (I got that in). So there's these two states that the lake can exist in and they are separated by this very marked threshold effect.

Richard Aedy: So the lake's going I'm fine, I'm fine, I'm fine, I'm not fine.

Brian Walker: Too late. All of a sudden too late and if you say 'oops, damn I'm going to stop putting phosphate in' it's too late. Even though it's a tiny critical level more, the system then goes on and on and on into that further state. But it's this threshold effect of complex systems that is so important.

Richard Aedy: And it comes up in climate too doesn't it Ann? We know from the fossil record that when things switch, they switch fast?

(Pause)

Well look I know it I don't know what you've been….

(Audience laughter)

Ann Henderson-Sellers: I'm glad you know.

(Audience laughter)

Richard Aedy: I don't want to call your expertise into question here Ann.

Ann Henderson-Sellers: Yes. Well the issue is that at different times these systems behave in different ways. We can think of three different pictures of how a climate system might look and it doesn't have to be the climate it could be almost any sort of system. One is where the wiggly graph ends up just going horizontal. The second one is where the wiggly graph looks like a nice standard oscilloscope trace, so it just goes up and down, I can't do it without waving my hands. Don't blow your whistle. And the third one is where the grass is just apparently completely irregular. Now one of the things that we try and understand in climate science is why does the climate do all of those things at different times and what moves it from one state to another?

If we replot whatever variable we were plotting, let's call it temperature – it doesn't matter it could be a different sort of parameter – in what's called phase space, which we're not going to explain but it doesn't matter, then we get three different pictures

(Whistle)

Richard Aedy: I want to know what it is.

Ann Henderson-Sellers: But the pictures are what's important so I'm going to tell you through the pictures – the first one is the graph of temperature was just going to finally always have the same value, and the picture in phase space always ends up at the same point. So the line, if you will, looks a bit like a firework and it whizzes round but it always ends up at the same point in the sky.

The second picture where we have the oscilloscope plot actually looks a little bit like, if you will, a triangle with rounded corners. So all that happens in phase space is that the point just goes I was going to say round and round but triangle and triangle. And the third picture, the one that we're most interested in because it's very likely that climate is chaotic, that it is a complex system, it's essentially a figure of eight, on its side if you will, an infinity sign. And although we never know from one point to the next where that trajectory is going to go we do know that it will always be around that strange attracter

Richard Aedy: John Finnigan is this all true or is she sending me down the garden path?

John Finnigan: The interesting thing about climate is it's both chaotic and it isn't depending on what bits of it you look at.

Ann Henderson–Sellers: Which I think I said.

John Finnigan: You did, you did. If you look at the climate record for the last million years there are sudden temperature changes, like ten degrees in a few decades. And that's what got climate change scientists – really made them sit up and thought 'well we have climate models and the climate models are pretty good at the slow changes but there's nothing in the climate models that allows these very sudden changes'. And people then started to say 'well, if there are abrupt changes like this what has to be in the climate model? What's in the system that provides these sudden changes from one state to another? And that's the sort of complex system behaviour, the threshold behaviour like the lakes.

Richard Aedy: See you could have given me this answer, this is exactly the answer I was looking for from you and instead… (Audience laughter)

But, while I've got you, let's look at something that's been in the news – the foot and mouth disease outbreak in the UK last year. Ann Henderson-Sellers, how is this seen as a complex system?

Ann Henderson-Sellers: I haven't the faintest idea. (Audience laughter)

Richard Aedy: John Finnigan?

John Finnigan: Brian Walker is the biologist. (Audience laughter)

Brian Walker: For a long time people have been trying to make more money again by selling livestock. And the way they've done this is to increase efficiency - through Europe, and especially in Britain, they halved or more than halved the number of slaughterhouses. And at the same time that this was happening, people were reducing the genetic variability in all of their livestock. They were going for the one kind that was really very efficient. And at the same time that this was happening there was some weird European Union subsidies which enabled people to make more money by selling their animals in some other country. And you can call your Welsh lamb, 'Welsh lamb' even if it's produced in England if you leave it in Wales for a couple of weeks or some limited time.

So all of these combination of funny economic subsidies that are going on and trying to increase the market efficiency and people were moving animals around terrifically. And at that point, if you write an equation for the spread of the disease, you maximise all of the parameters of equation for letting that disease rip through the whole lot and at that point foot and mouth came in.

So it comes back to the point that we were making earlier that these things have cross-scale effects, they have properties that emerge at a different level and all of a sudden it hits you as a big surprise.

Richard Aedy: Ann you're not buying this, are you?

Ann Henderson-Sellers: No, a question and a comment because if your picture is right about foot and mouth then the whole globalisation thing will ultimately mean that we all die of plague because we'll be so interconnected. Right, that's my question but my comment…

Richard Aedy: Oh hang on, hang on, give him a go.

Ann Henderson-Sellers: No, no, no because I want to make my comment as well because it's important…

Richard Aedy: No, we'll come back to your comment, I now see Brian as an anarchist - (Audience laughter) – and I haven't seen him as an anarchist until now.

Brian Walker: OK. I've got an answer to Ann and she's right, it might not be the plague but going back to your opening comments. I loved Dirk Gently's interconnectedness of everything and actually he's right in the sense that if you do get things completely interconnected you are actually going to have an awful outcome. And the management consequences for the world is the fact that what we're doing is we're making the world more and more susceptible to sudden transmissible events and that in fact what we've got to talk about – there are certain things you can't do anything about like the chaotic nature of the weather. What we've got to learn there is how to live with it and live with uncertainty. But when you're living with a complex system with people and nature and this kind of example in globalisation, you've got to look at certain principles that you can make the system either more efficient and productive, but at the cost of the robustness or resilience of the system.

Ann Henderson-Sellers: If that's so then how come this planet has managed very successfully for the last four and a half billion years to really not have a climate that's any different from what we have now? How come our planet is so resilient?

Richard Aedy: I don't know. Russell though does. (Audience laughter)

Russell Standish: Sounds like you're leading up to the James Lovelock idea of Gaia.

Brian Walker: But there have been Ice Ages.

Richard Aedy: Yes! Yes! (Audience laughter)

Brian Walker: You're implying Ann that there was one constant temperature from 4 billion years ago which is nonsense.

Ann Henderson-Sellers: Yes, two thirds of the planet is covered by liquid water and even during an Ice Age essentially that same proportion has liquid water on it. This is not a big change.

Brian Walker: But the hiccup of an Ice Age is all you need to make a real hard economy. (Audience laughter)

Ann Henderson-Sellers: So who introduced people into my question?

Brian Walker: I did. (Audience laughter)

Ann Henderson-Sellers: Four and a half billion years we're not even there.

Brian Walker: No, we're on the tiny tip of the top if you put what's it? A needle on the top of Cleopatra's needle, that's in the time scale when people have been around. What happened then was that system that we're in, until that little bit, never had consciousness. Now, for the very first time in the history of this planet we have forward looking behaviour – consciousness of the future and that's what people are doing. So they're deliberately manipulating the system and thinking that they can do it and that's the big danger because they're trying to maximise efficiency and optimise something and reach a particular goal. And by doing that, without recognising the complexity of the system they're in, they are going to come up against more and more of these nasty surprises.

Ann Henderson-Sellers: So we've been fine for four and a half billion years but we're buggered now?

Brian Walker: Oh no, the world will carry on after we've had some really bad, nasty experiences. (Audience laughter) I'm not saying we'll land up in a vacuum but your pension fund could be really badly ruined.

Ann Henderson-Sellers: It is already. (Audience laughter)

Russell Standish: Brian, there is another aspect to global connectivity which is on the plus side. That the very same routes which viruses travel to cause plague and outbreaks like that are also the same routes in which ideas travel. And the analogy between viral transmission and transmission of ideas in the form of memes, if you've heard that term…

Richard Aedy: Oh, we're not going to do memes, are we? (Audience laughter)

Russell Standish: Is very much related to that connectivity issue so there are in fact positive aspects to that global interconnectivity.

Brian Walker: Unless it's a bad idea. (Audience laughter)

Russell Standish: Of course.

Richard Aedy: This is The Buzz on ABC Radio National and Radio Australia our weekly technology show and this week it's a special edition, we're talking about complexity.

When I was young I read a book that was very old. It had a rhyme in it which said, 'for want of a nail a shoe was lost, for want of a shoe a horse was lost, for want of a horse a rider was lost, for want of a rider the battle was lost, for want of a battle the war was lost and all for the want of a horseshoe nail.' So this stuff is not new, we've known it for centuries. John Finnigan.

John Finnigan: You've actually left the most profound question perhaps to the end. What we find from studying systems like this and trying to model them is that this property of contingency that we're so used to, the idea that a random action can lead to a whole chain of consequences is actually so natural to the way we operate and view the world that we no longer consider it something worth explaining. But it is in fact, you can in fact think of worlds, imagine worlds, where contingency doesn't happen, where things smooth out instead. Instead of the consequences ramifying and expanding, they don't, they all come back very smoothly to more or less what was going to happen anyway.

If that were the case then we wouldn't have novels and arts and plays, that's absolutely fundamental to the human condition. So it's very interesting to think that a great deal of what we consider interesting in humanity depends on contingency and contingency isn't absolutely necessary. Universes without contingency can well be out there, fortunately we don't happen to be in one.

Brian Walker: I think that's a very good comment. It seems to me the exciting thing that's happening in this is what do we do about it? And as I said, in the sense of the purely physical parts of complexity, we need to understand the uncertainties and try to learn to adapt. But as soon as you bring people in, the system starts to have multiple possible outcomes and those are dictated by rules. And I think what's really interesting right now at the Santa Fe Institute, John Holland – who is one of the architects of all this – is leading a group on thinking about the evolution of rules. How do rules evolve in complex societies? So what are the rules for changing the rules? And getting an understanding of that level of complexity is, I think, where the excitement part comes in.

Richard Aedy: And on that note I would like you to all thank our panel. John Finnigan, Russell Standish, Brian Walker and Ann Henderson-Sellers.

APPLAUSE

"It's not that Simple" was recorded in the National Convention Centre as part of the Australian Science Festival in Canberra. I'd like to thank Chris John from the Festival for his patience, good humour and for having the idea in the first place.

The Australian Research Council supported the event and supplied the much- needed drinks afterwards – I'm very grateful. Thanks also to Peter McMurray for recording everything so beautifully, to John Diamond for studio production and finally to The Buzz's producer Sue Clark for – well, everything really.

We should have this transcribed in the next few days, you'll find it on the website at abc.net.au/rn, then click on The Buzz. And if you've got any comments our email is thebuzz@your.abc.net.au

I'm Richard Aedy, we'll be back next week, thanks for listening.

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Dr Brian Walker
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http://www.ned.dem.csiro.au/BoschettiFabio/CSF/csiro-css.htm

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Dr Brian Walker on the web
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Professor Ann Henderson-Sellers on the web
http://www.ansto.gov.au/ansto/environment1/staff/hsellers.html