2. Towards a New Ontology of Complexity Science

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Introduction

I think that this is a Promethean moment. I think that when we look back on today, we'll say 'that was when things became different'. This may sound a bit like King Henry on St Crispin's day at Agincourt:

> This story shall the good man teach his son;
> And Crispin Crispian shall ne'er go by,
> From this day to the ending of the world,
> But we in it shall be remembered;
> We few, we happy few, we band of brothers

Now I find this a worry, because aren't we the inheritors of a tradition that has striven for the last two and a half millennia to demonstrate that most moments are not Promethean, that our time and place in the universe are not special? Isn't it the politicians and spin-masters, not the scientists, who exhort us to think that now is different and that we are different? But the evidence worries me, and, what is more, the implications worry me. So indulge me while I lay out the evidence that, contrary to the null hypothesis, we really are living in a singular moment in the history of this bit of the universe. And then indulge me further while I unfold some of the consequences.

I think there are two big historical processes intersecting at the moment: the coming into being of a fully connected world, and the coming into being of a new way of doing science. Both only make sense from a complexity point of view, and, at base, that is why 'we happy few' matter in all of this. These two processes are going to interact incredibly strongly, I believe, and that will take us into radically new territory. But it is the novelty of each of these two processes that define our moment as Promethean, and it is to these that I will first turn.

A fully connected world

I want to argue that, for all of life's lease on the planet up to today, we, we living things, have lived with frontiers. Our ecosystems behaved as if there was an *out there* and a *round here*, a system in an environment. We know this by looking at the sorts of adaptations living things have. They show, broadly, organisms reacting with heuristics to the immediacy of their environment. It is true that there are some adaptations that show a subtlety that betrays close coupling—many interactions on coral reefs and symbioses of all sorts show this. But for most of the time, most organisms behave as if the world is loosely connected, that there is fuzziness and slop in the world, and that, to survive, organisms need to focus on just getting through the moment.

We can see that this is a sensible, efficient response to a physically dominated world, where grand biogeochemical cycles and forcing factors are more *geo* than *bio*. But as life evolved and radiated and became more complex, one might expect that evolution would turn its hand to how to survive in a world made complex by other living things. And here we see something curious. It is true that complexity—the emergence of complex adaptive systems—does encourage some closer coupling. Every naturalist's notebook is full of such wonders, and every diver and birdwatcher has seen them. But it is also true that heuristics—rules of thumb—account for much if not most of the interactions between living things. It seems that evolution demands that living things adapt frugally to the emerging complexity of the world, using the sorts of heuristics and work-arounds they used in earlier, simpler times. Even though living things are faced with the emergence of complexity, they are constrained in their response by such prosaic things as history, mutation rates and generation times.

There seem to be two canonical but conflicting rules that govern the way in which living things respond to the world around them. And neither insists that the complexity of the world be acknowledged in any deep way. The first is that, for most practical purposes, what happens next is, to a first approximation, a simple extrapolation of what just happened. Even complex non-linear processes look just like simple linear ones when taken one little step at a time (this, after all, is the key discovery of the calculus). The second is, for living things in a world made complex by other living things, after a few steps, something else will happen. Thus there is no need to get too involved adapting to (that is, predicting) the impact of some complex long term process when it could be overtaken at any time by the *Next Big Thing*.

By and large, evolutionary success for living things has meant coping with the monotony of endless moments as well as the occasional surprise. This is the law of the frontier, and reflects the fact that adaptation through tight couplings is found mostly within organisms—the things we call physiology—or within cells—the things we call biochemistry. The couplings between organisms are generally much looser and those between ecosystems looser still. The world, as a system, is really a bunch of loosely connected subsystems, where the connections, for *adaptational* purposes, are more or less indistinguishable from the random buffetings of *the environment* coming through the frontier.

We see this in the dynamics of all ecosystems on earth. This includes, of course, the dynamics of human societies. Those systems that behave as if they have a frontier can adapt with simple *here and now* heuristics and succeed, whether they are the Huns invading Europe, the English colonising the new worlds, some weed invading a rangeland, or just a barnacle on the shore facing tides and storms. What makes today different is that man 'knits up the ravelled sleave' of the world through all his activities, and it is just about complete. Globalisation is just a fancy term for closely connecting the world's economies, and hence its societies, and this has more or less reached the point where we can speak of a world economy as a single functioning entity. In parallel with this, our economic exploitation of the world's natural ecosystems is now more or less complete. And economic exploitation means close connection. There are really no wild, unexploited places left. The last coral reefs, seamounts, deserts and taigas are getting locked in as I speak. There are no frontiers.

We see the evidence all around us, even if we focus on the epiphenomena and not the underlying structural change in the way the world works. We see SARS, blackouts, the Asian financial bust, ballast water, the ozone hole, global warming, and even bushfires connected to red tides as a list of phenomena instead of symptoms of the emergence of a singularity: the fully connected world. We, we living things, now live in a world system where the balance of effective adaptational strategies has shifted decisively and forever from heuristics to what we might call symbioses—the sorts of strategies that evolution favors in closely connected systems, the ones we see today inside cells and organisms, and between symbiots. No doubt evolution will sort this out over the next several hundred million years, but in the meantime: 'Houston, we have a problem'.

A new kind of science

Hold that thought, and allow me to return to my second singularity that helps define today as a Promethean moment: the coming into being of a new kind of science. The phrase is Stephen Wolfram's, but I want to stretch it further than he did, because I think he only got halfway there (Wolfram 2002). He was really describing an old *new kind of science*. Let me explain. We can make a strong argument that the sort of science we do when we simulate, particularly when we simulate complex systems, is sufficiently different to normative science that we may call it a new kind of science. The argument (and Wolfram is by no means the first to make it) goes roughly that science first went through an observational stage, then an experimental stage and now is going through a simulation stage. These stages parallel developments in the tools and technologies we use, in particular mathematics, and also roughly track the sorts of phenomena that are understandable by different stages. This argument is countered by the logical positivist idea that experimental science is the real dinkum science, preceded in a developmental sense by observational science, and extended, reluctantly and in special cases, to simulation. And the most typical special case is complex systems. But in this view, experimental science remains the core of science, and we complex systems scientists remain beyond the pale with our success judged by how well we can eventually bring our problems into the core.

Our program, by these lights, is to make the complex simple enough to allow it to be handled eventually by normative science. Our simulation is a means to an end. Now Wolfram and others challenge this, arguing that we have been seduced by the success of experimental science at picking the low hanging fruit on the tree of knowledge. The real problems and real knowledge hang much higher up, forever beyond its reach. And if we condemn science to be what the logical positivists call normative, we condemn ourselves to ignorance. To that point I am in full agreement with the Wolfram view, but I put a different interpretation on the history of science, one which is based on thinking of the science enterprise itself as a complex adaptive system, and not necessarily as some sort of progression through stages: this is now normative, later that is. In this view, which I have elaborated elsewhere, I use the same evidence as a Wolfram might, but I do not come to a view that we are changing what we mean by normative science, that is changing in earlier times from observational to experimental and now to simulation. Instead I am rather more interested in just what science is.

My argument is that science is not a process—a method—for finding the truth, and hence does not really have stages (Bradbury 1999). It is rather a body of knowledge about the world *and* a recipe for growing that body of knowledge *and* a bunch of people busying themselves with that knowledge and that recipe all mixed up together. But it is important to realise that science is neither just the algorithm nor the output, but the whole lot including the people. It is also important to realise that we can push this analogy too far, that science is a special mix. Each part can change the other. The knowledge can change the recipe; the recipe can change the people.

Thus science is not a process for finding the truth or anything else. It is not a process at all, but a system, a complex adaptive system. It is a complex adaptive system made up of two interacting complex adaptive systems—the scientists and the knowledge system, the former a social system, the latter a playground of memes—with the interaction strongly mediated by the recipe. Now I need to make it clear that this recipe for growing the knowledge is not what is often called *the scientific method* or what we called earlier *experimental* or *normative* science—the approach used by most scientists since the seventeenth century. It is instead a recipe for discovering the scientific method, and *all* the other methods that achieve the same ends, which are to increase the body of scientific knowledge, to improve the recipe and to change the people.

What sets it apart from other such systems, such as art, religion or politics, is that the idea of *belief* is deliberately and persistently winnowed out of science; despite the persistent human tendency to keep putting it back in. Each of those other human enterprises has at its base a kernel of some fundamental and fundamentally unprovable, and hence illogical belief, whether it be belief in a god, an aesthetic or a manifesto, on which it then constructs the logic of itself. Even mathematics has this character, and is thus not scientific.

The practice of complexity

Seeing science as a complex adaptive system allows us to be sympathetic to Wolfram's idea of a new kind of science. It also allows us to see why the practice of complexity is at a Promethean moment. At the present time, our science broadly accepts the rules of engagement set by the experimentalists: experimental science still controls the way we think about complex systems. This is a deeply cultural problem with a history at least Newtonian and probably Platonic. It has to do with a philosophical belief in elegance, that the universe will be ultimately explicable in simple elegant ways, that behind the messiness of the world there lies the music of the spheres. This has driven mathematics and physics, in particular, into a compact from which we struggle to emerge. I see some hope for change—in computer-aided theorem proving, for example—but I also see a great reluctance to abandon the belief of an underlying simplicity in the way the universe works.

We see the belief at work whenever we see a complex systems model that deliberately keeps itself simple under the guise of tractability, or insists on simplified outputs, or whenever we see modelling that dwells on complex dynamics emerging from simple interactions. But make no mistake, it is a belief, and it holds us back. It reinforces the idea of a normative science to which complex systems science is subordinate. Science needs to renegotiate its concord with mathematics, to the ultimate benefit of both, before we can move on to our new kind of science.

What we would move on to is what I call *deep complexity*. It promises to be a science that accepts the contingent complexity of the world, adapts its ideas about explanation, prediction and control as goals for science, and learns a new concept of understanding. However, I am not talking about some post-modern deconstructed science, where everything is relative, where there is no such thing as absolute truth. I am talking about a new kind of science that completely fulfils science's necessary and sufficient conditions as a complex adaptive system. But, be assured, it will be very different from the logical positivist view. It will be complex not simple, drawing its strength more from the coming ubiquity and transcendent power of computing rather than the analytical power of mathematics. It will be a cooperative, even symbiotic, endeavour with the net as it evolves into a richer complex adaptive system. And the understanding it creates will not always be global—the gold standard of experimental science—but local and embedded, but still connected—still a part of the fabric of science.

This new science will relate to observational and experimental science on its own terms, not those dictated by the logical positivists. It will be data and parameter rich, drawing on both observational and experimental science, but in much more fluid ways than at present. This is the new science waiting to be born. We happy few, we band of brothers, we see our science poised, at a moment of profound change, but held back by the culture of normative science. What will bring on the birth, what will provide the push, I think, is a change in the interactions: firstly, those between science and the world—the demand for a new sort of science for a newly complex fully connected world; and secondly, those within science—the emergence of a set of tools that allows complex systems science to renegotiate its relationship with the rest of science.

Thus the abject failure of normative science to deal with the complex problems of a connected world will provide a push from the world. And the beginning of grid computing and sensor webs will allow for the first time for big complex problems to be modeled in their full complexity, but will also involve a renegotiated relationship with observational and experimental science and encourage the liberation of complexity science. The agenda is huge—to change science, to change society, to understand wholly new classes of problems, and to do that with new non-human partners. And we are few—perhaps a few thousands worldwide. But once, the calculus was understood and used by even fewer. We might be few, we band of brothers, but the battle needs to be joined today, so that tomorrow we can say with Henry:

> And gentlemen in England now a-bed
> Shall think themselves accursed they were not here,
> And hold their manhoods cheap whiles any speaks
> That fought with us upon Saint Crispin's day.

References

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