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LIVING AT THE EDGE OF CHAOS

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Abstract

People live and work in precarious environments. They live on river flood plains, in the shadow of volcanoes, in areas subject to tropical storms, and on coastal plains ravaged by hurricanes. But the same environmental features that are life-threatening also secure the renewal of the fertility of the land that people depend on. It is not an accident that people live, in large numbers, in environments that are complex and chaotic. Those environments are subject to interlocking feedback loops that make prediction of the future extraordinarily difficult. The development of complexity theory is relatively very recent, and a way to understand such environments better. Complexity leads to various strands of thought, ranging from self-regulating systems, such as Lovelock's notion of Gaia, to a heightened peril of unexpectedly extreme conditions arising from ordinary antecedents (the so-called 'butterfly effect'). This can make it difficult to interpret complexity theory in a way that is practically useful. In addition, there is the ironic conclusion that being better able to anticipate disaster can actually make the situation worse; if more people can live on a flood plain, then when a disaster eventually happens, many more people will be exposed to danger. This paper examines the double headed coin of disaster / opportunity through the application of complexity theory, with a particular emphasis on the need to re-think 'sustainability' in the light of the new science.

Keywords: Flood plain, environments, chaotic systems, complexity, James Lovelock

Introduction

Every day brings us bad news about floods, volcanic eruptions and earthquakes. We see houses washed away, and people living on flood plains losing their homes, their farms and crops, and their livelihoods. We see people overwhelmed by ash and lava, or being buried under the rubble of falling buildings. In all cases life and limb are at risk. Which raises the question: Why do people live in such dangerous places?

To answer this question, we need to look at the broader picture. This is a living planet, which renews itself and its fertility through floods, earthquakes and volcanoes. The best places to live are the most dangerous. Not many people live on the parts of the earth that are very stable geologically. And if we look beyond our own planet, not many people live on astronomical bodies that are very stable – the moon, for example. In the bigger context, our planet supports life because it is changing and unstable. And we do not expect to find extra-terrestrial life on sterile bodies. Life seems to thrive at the edges of that chaos that we see on a planet that is shaken by earthquakes and volcanoes, and where continents move and weather patterns are changeable. And even on that planet, people choose to live in the most dangerous, changeable and unpredictable places.

Chaotic systems seem, in this sense, to be very are attractive, But the science of chaos is relatively new, and we understand chaotic systems imperfectly. But two features of chaotic systems stand out for comment: in chaotic systems extreme events happen more often than we think they ought, and chaotic systems seem to be able to self-regulate, or to pick out the influences that will influence them. Economists have long tried to predict extreme events, such as market booms or market collapses on the basis that market fluctuations are normally distributed, or the Black-Scholes hypothesis. This says that small changes are much more common than large changes. But in chaotic systems large changes are much more common than the Black-Scholes model suggests; we have a once in a lifetime storm every twenty years. And at the same time chaotic systems seem to be able to resist being pushed away from equilibrium by external shocks. This feature gives chaotic systems another of their informal names – self-regulating systems.

These are strange features of chaotic systems that we cannot hope to understand with old mechanical models of cause and effect. We need some new tools to understand, even imperfectly, what is going on. And one of the figures who is most helpful in understanding such systems is James Lovelock.

James Lovelock

James Lovelock died in 2022, so this is probably a fitting time to pay tribute to his contribution to understanding the topic in hand. And it is approximately fifty years since he expounded his theory of Gaia, so it may be a good time to revisit his work, and see what it means for understanding why life, and people, seem to flourish in the most dangerous settings.

To illustrate his theory of Gaia, that the world as a whole can be seen as a living organism, Lovelock introduced the metaphor of Daisy World. On the planet of Daisy World there are two species of daisies: white daisies and black daisies. White daisies flourish at slightly higher temperatures, while black daisies flourish at slightly lower temperatures. When the temperature of Daisy World rises, white daisies start to replace black daisies, and the surface colour becomes lighter. The lighter surface reflects more of the heat of the sun, and the planet starts to cool. The opposite happens when the planet cools, the black daisies flourish, and more of the heat of the sun is absorbed.

Daisy World is a complete ecosystem that can manage to regulate its own temperature within fairly tight limits. But I say that this is a metaphor because it is clearly a greatly simplified model, with only a single dimension of control. Although it can be used to suggest an insight into the behaviour of our own planet, the earth has many interlocking feedback systems, and not only one. The carbon cycle has a biological feedback system directly analogous to Daisy World. When carbon dioxide levels rise, plants grow faster, removing more carbon dioxide from the atmosphere. But there are also the water cycle, the nitrogen cycle, and other physical systems involving the weather and ocean currents. Daisy World can hint at how each of these systems operates alone, but nobody yet has an accurate idea of how they interact together.

The result of all of these considerations is that the earth seems to have been able to maintain conditions for the development of life, in a relatively stable homeostasis, over millennia. There may be underlying geological conditions, involving earthquakes, continental drift, and volcanic eruptions, which together form a basis upon which the other physical systems can find a way to operate. It is certainly the case that we do not see similar life patterns on the moon, which lacks earth's geological instability. But at the moment nobody really understands the processes well enough to be sure.

However, it is at least possible, and seems increasingly likely, that the earth is not in the Goldilocks zone (not to hot, not too cold; not too much gravity, not too little gravity; not too much oxygen, not too little oxygen, and so on) because of a happy initial placing. On the contrary, it looks as though the earth, or Gaia, is creating its own Goldilocks zone.

Biologists are even beginning to think of how such systems might self-manage at the micro level. Until recently it was widely thought that only human beings could change their environment. Animals can and do change their environment, but they do it by moving to some other place where food is more abundant, or the temperature suits them better. But only mankind build new towns and garden cities, manipulating their environment in the here and now, without moving. So, although migratory birds, elephants and wildebeest perform prodigious feats to change their environment by moving, until recently animals were not credited with the ability to act more directly on their immediate environment. However, even here, biologists are beginning to change their view, and to think seriously about the part that beavers, deer and even wolves play in shaping an environment that is beneficial for a variety of species. Before we become too sure about predicting exactly how the earth will respond to specific changes, and how current trends can be projected into the future, we should perhaps recognise the depth of our own ignorance about exactly how the ecosystem that support our very existence operates.

The Success of Science

We have, perhaps, been encouraged to ignore our ignorance of complex systems by the very success of science in explaining the world. And science, and the technology that it supports, has been extraordinarily successful in improving our understanding. But we need to recognise that the success, which builds on the strengths of science, has limitations that, ironically, are also produced by those very strengths.

Before 1945, science was mainly about analysis. It broke things down into their elements. Chemical compounds, living organisms, mechanical systems and so on were all seen as composed of smaller, interacting pieces. In order to understand the larger system, first the smaller sub-systems were analysed. Thus every pupil in school knows that water is H_2O; we understand something that is complicated better if we understand what it is made up of. Obviously, nobody can overlook the fact that water (a colourless, tasteless liquid) has properties that are different from those of hydrogen (a colourless, flammable gas) and oxygen (a colourless odourless gas). So there cannot be a simple reductionist view that if you know the parts you must also know the whole. But the properties of oxygen, and the shape of the molecule that it forms with hydrogen, may help to explain why water is such a very peculiar substance.

But, in general, although this approach, of breaking complicated systems down into their component parts, proved incredibly successful, it focused attention on how parts function in isolation, and tended to mask, or side-line, the complexity of interactions. Traditional science has not been good at taking the holistic view of systems, and tended to be confounded by the notion that the whole might be more than the sum of its parts.

Since 1945 we have seen the development of new sciences – complexity science, chaos, operational research, and so on, all of which attempt to embrace a more holistic view of how the parts of systems can interact in very different ways, and with unexpected outcomes. To take one well known example, complexity theory has introduced the idea of the butterfly effect. This effect, named after the idea that the flap of a butterfly wing in the Amazon can produce a tornado in Texas, actually posits that a 'cause' which is in principle below the level of being detectable, can produce an 'effect' that is unimaginably large. I put the words cause and effect in scare quotes because the existence of the butterfly effect undermines our common sense notion of cause and effect. When the philosophers of traditional science asserted that every effect has a cause, I do not think that they had in mind a cause that was so tiny as to be, in principle and not merely in practice, unobservable.

So the science that has developed in the last eighty years has done something to correct the specific focus on analysis that was central to traditional science. There have been some moves toward synthesis, and integrating parts to produce an image of complete ecosystems. But much of the traditional thinking persists. For example, I find it difficult to imagine how we are going to think if we have to dispense with the traditional ideas of cause and effect.

The important lesson here is that science has solved the problems that it can solve, and has tended to ignore the problems that it cannot solve. And the success of science in solving the problems that it can has obscured the fact that there are problems that it cannot. And, perhaps even worse, we have generally assumed that the problems that science cannot solve and ignores do not exist. An example of what this means for how we understand complex systems, and our own place in them, may be helpful.

Newton produced one of the most successful theories of all time, which survived scrutiny over more than two centuries. That was he universal (sic) theory of gravitation. He looked at the force of gravity acting between the sun and a single planet. Or he looked at the gravitational force between the earth and the moon. He also looked at the force of gravity between the earth and a body on the surface of the earth, say an apple. His great achievement was that, in looking at these pairs of astronomical bodies separately, he was able to show that exactly the same explanation could be used in each of the three cases.

He did not look at the forces of gravity acting between the sun and two or more planets, but this was not seen as a problem, because it was assumed, as noted above, that it was assumed that if one understood the sub-systems it would be possible to assume that the larger system would behave itself in a reasonable way. But Newton did not look at an astronomical system that involved the sun, the earth and the moon, much less a system that involved the sun and six, seven or eight planets.

If one were to be cynical, one might suggest that Newton did not address the more complicated systems because his mathematics was not good enough. In his day, nobody could do the maths to solve the 'three body problem'. And that has not changed; we still cannot. But it can also be seen, in the light of the traditional philosophy of science, that this was not really a problem. Newton could explain the path of the earth around the sun, and the path of Mars around the sun, and the path of Jupiter around the sun. It seemed a very reasonable assumption that the tiny effect of interactions between earth, Mars and Jupiter could be ignored. The orbits of the planets were assumed to be very stable, and to have continued very much as they are now for all time since the creation of the solar system.

But if we now let into our imagination the idea of the butterfly effect, we are open to the idea that very small influences can have huge effects, we have to recognise the possibility, at least, that the planets could line up in such a way that the earth would be catapulted off into deep space. In the interests of not causing excessive alarm, and worrying readers that the earth may be doomed to be launched out of the solar system to an icy death in deep space, I should perhaps add that scientists think that we are probably safe for the next million years.

However, knowing what we now know, being able to imagine what we can now imagine, and knowing what to look for, it seems likely that the orbits of planets are much less stable than was once believed. The idea that the planets have moved and changed positions, and that the order of the planets in the solar system that we learned in school has, over aeons of time, changed, is gaining increasing ground in astronomy. The assumptions of traditional science has limited what scientists have looked for, and what they found. As those assumptions have changed in recent years, so too have the range of phenomena that could be imagined, and then observed.

Continental drift was once thought to be so fantastic as to be impossible (and that remarkably recently too). Today, the theory of continental drift is more or less universally accepted, and we regard the system of land bridges and convolutions that geologists posited to explain some anomalous observations as absolutely fantastic. A similar transformation in thinking about what is possible and what impossible is happening in many sciences.

What does this all mean?

The world consists of many interlocking chaotic systems. Most of the time these self -regulate very well to our advantage. But we really do not understand them very well. Sometimes the results are not what we expect, and can even be the opposite of what we expect, as when ‘global warming’ seems to lead to some parts of the world getting colder.

What I most definitely do not want to suggest is that everything is going to be alright, because whatever damage we do to the environment, the earth is a self-healing, self-regulating system that can compensate for the damage that we are doing. It seems to me that that kind of complacency would be completely misplaced.

I think that the dangers of climate change can be illustrated by returning to consider Daisy World, Imagine that the climate on Daisy World gets hotter and hotter as a result of global warming. White daisies will flourish, but black daisies will become an endangered species, and may even become extinct. If that were to happen, Daisy World would lose one of its important mechanisms for managing temperature; it would have no mechanism to protect it from cold. If we then suppose a sudden shock that reduced the temperature of Daisy World, in the absence of black daisies the planet will spiral to ever lower temperatures, and be completely incapable of self-regulation. Such a spiral will result in lower and lower temperatures that will eventually kill the planet.

I have no doubt that climate change is real and it is serious. But in my view its seriousness is the result of not this or that specific change in temperature, but in the possibility that we are removing (killing) mechanisms of self-regulation that can help to maintain the homeostasis that has been maintained for millennia. Just as in the example of Daisy World above, global warming can be the start of a process that eventually leads to a process where the planet freezes to death, I distrust those who offer the prognosis that the current trends in rising temperatures can be projected into the future, and that overheating is the only danger we face. The real danger that we face is that we are damaging the resilience of the planet, and its ability to respond to a variety of threats. We are doing irreparable harm to the self-regulating mechanisms that have made the planets ‘safe’ for human life for millennia.

But I can easily imagine shocks that suddenly lowered the temperature of the planet. In relatively recent history we have the example of the eruption of Mount Tambora. That eruption in 1816 through so much dust into the atmosphere that it blocked out the heat of the sun and produced the ‘year without a summer’. In the event that had a dramatic impact on the lives and livelihoods of the population of the earth, in failed crops and food shortages. But without the self-correcting mechanisms that existed at that time the impact could have been longer lasting, or even permanent. And we cannot be absolutely sure that those mechanisms are still intact and ready to function in case of need.

Or we might prefer to choose a different cataclysmic disaster, such as a change in the orbit of the earth leading to an increase or decrease in the intensity of energy received from the sun. Such a change might be to reduce global warming or to increase it, but either way it would be more damaging the more systems of self-regulation we have damaged.

Putting those things together, I can easily imagine very different outcomes than just the earth getting progressively hotter, although getting colder could be just as bad. I am sceptical about anybody who is too sure that they know what is going to happen next, and although I accept the diagnosis that we need to be concerned about global warming and the damage that we are doing to the feedback systems that maintain the conditions of life on earth, I have severe reservations about the prognosis that the present trend of increasing temperature is the only threat that we face, or that we know exactly how damaging a particular increase in temperature will be. We do not, in my opinion, know enough to be able to predict how the current climate crisis will unfold, and certainly not to assert with certainty that these are the ‘end days’.

Conclusion

As a scientist I want to see better and deeper understanding of complex and chaotic systems. I want to see the holistic approaches, that scientists are beginning to develop, developed further. I want to see a greater appreciation of the benefits that come from such chaos and self-regulation. We are beginning to think that animals create their own habitat; they do not just live where there is a suitable habitat. Perhaps is it not an accident that we live in the Goldilocks zone.

All of these areas of understanding need more research and more insight, and I rely on science to produce those insights. We are still very far from understanding exactly what is implied by the changes that have come about in recent developments in science. We still tend to view this crisis through an outdated lens on cause and effect that may not be relevant to our present situation, and may blind us to the real dangers we face in reduced resilience.

And as an educator I want to see a better understanding of that science. Especially, I do not want to see ‘science’ being used as a foundation for a new dogma. I want people to be able to embrace the uncertainty in the world – the uncertainty that is made possible by chaos, and that makes chaos possible. Producing resilience to change is going to take a major shift about the way that we think about cause and effect.

But I do not believe that science can protect us from every danger. As I noted above, uncertainty and chaos seem to be part of the complex mix that make life possible. People choose to live in places that are threatening, and probably always will. What I hope is that we will find new ways to think about uncertainty that help us to live with and mitigate the dangers. Any news bulletin that reports an accident where the survivors are ‘in a stable condition in hospital’ prompts the thought in me that the only stable condition is death.

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