Complex systems

Complex systems are non-linear systems (ie where there is no clear deterministic order) in which the interaction between the parts gives rise to the collective behaviour of the whole. Its origins lie in chaos theory, which enjoyed a brief mass popularity as an emerging discipline in the mid-1990s, based on the delightful but largely misunderstood image of a butterfly fluttering its wings in Beijing causing a hurricane in New York (the butterfly effect). As one New York commentator dryly observed, 'Why don't they just kill the butterfly?'

In reality, the butterfly effect is merely an image for a more complex idea - sensitive dependence on initial conditions, a principle which lies at the heart of complex dynamic systems (chaos) theory. Sensitive dependence on initial conditions means that the outcomes of a system can be dramatically changed by small changes at the input stage, whereas major changes in the transformation process may, relatively, have far less significant effects.

One way of demonstrating this is to construct a simple graph based on the iterative[1] equation:

$$x^n = rx^{n-1}(1-x^{n-1}).$$

In this equation the letter r has a constant value for each set of three separate computations (r = 2.7, 3.0 and 4.0, respectively) and x is a figure between 0 and 1. Since the basic equation is unchanged and the value of the constant increases slightly for each computation, logic suggests that the effect of increasing it from 2.7 to 3.0 will be similar, but magnified, by increasing it from 3.0 to 4.0 (see table)

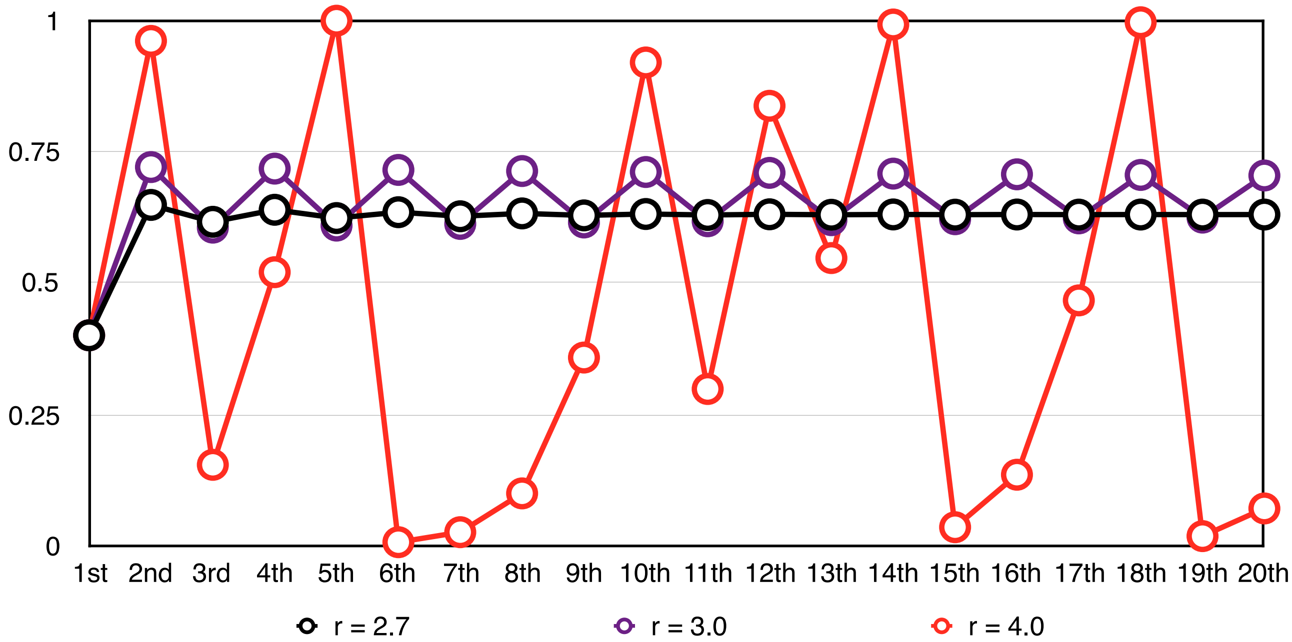
Iteration	r = 2.7	r = 3.0	r = 4.0
1st	0.4000	0.4000	0.4000
2nd	0.6480	0.7200	0.9600
3rd	0.6159	0.6048	0.1536
4th	0.6388	0.7171	0.5200
5th	0.6230	0.6087	0.9984
6th	0.6341	0.7146	0.0064

But the graph shows what happened when this simple progression is extended over 20 iterations. The first line (r = 2.7) starts as a slight 'zig-zag' but quickly smooths to an almost straight line and the second line (r = 3.0) develops into an almost regular cycle. But it is the third line (r = 4.0) which shows the most perverse change, becoming unpredictable, stable yet periodic. A pattern is apparent, but it is a pattern which appears to follow no clear rules.

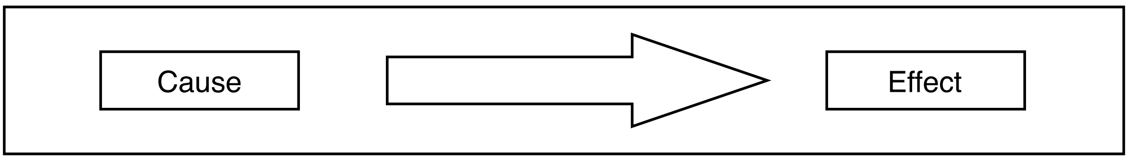
This is *sensitive dependence on initial conditions* - the initial condition in this case is the multiplier, which changes from 2.7 to 3.0 and then to 4.0. If this all seems to be rather arcane, it isn't. An organisation is often a complex system, in which a multitude of components interact in a way which may appear to be linear (like the first iteration) but which reveals itself to be non-linear as changes start to take effect. At first the change brings some variations in outcomes (like iteration 2) but as the change grows, so the erratic swings start top appear.

[1] Iterative simply means that the answer to the equation after one computation is simply fed back into it for the next computation. This is expressed in the equation by describing the answer to the present computation as x^n and the outcome from the previous computation as x^{n-1}

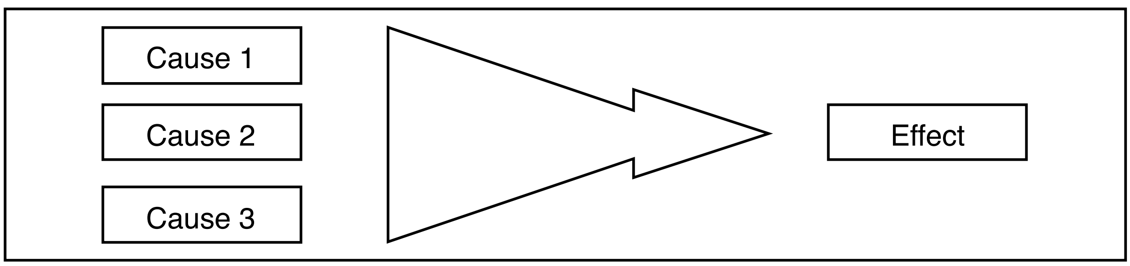
Complexity in action



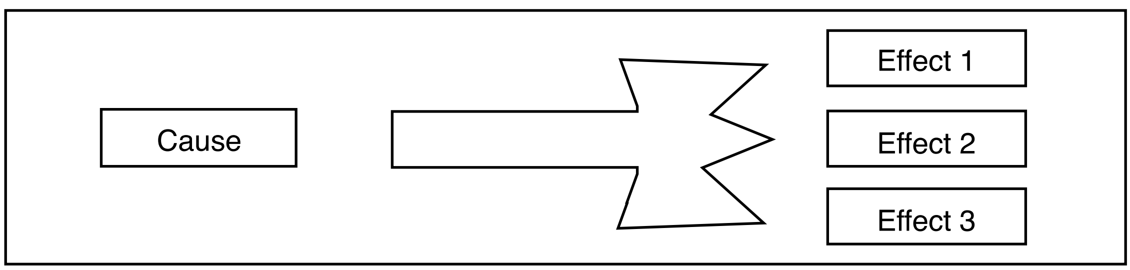
Underneath this paradigm is the notion of cause and effect. A simple linear dependency occurs because a single cause leads to a single effect:



However, most activities are more complicated than this, and there are several different causes of any effect:



This is described as *multi-causal*, and it becomes obvious that the potential outcome is less certain as the scale and direction of change in the causes will produce a range of possible outcomes. What's more, a single cause may have more than one effect, it is *multi-final*.



Increasing complexity results from both multi-causal and multi-final causal systems; true complexity is the result of both *multi-finality* and *multi-causality* - various causes interact to produce various outcomes and, as the chart showed, the effects then become causal, producing greater uncertainty in the final outcomes.

Although the diagram both simplifies and over-states the reality of most complex systems, it highlights the challenge for any manager engaged in a change programme, that making a small change in one aspect of the organisation can have repercussions elsewhere that, in turn, set of unpredicted consequences.

Does that make it impossible to manage a complex system, especially if it is being put through a major change programme? No, but it demands a much more insightful approach, one that recognises the level of uncertainty and unpredictability in the system, and doesn't assume that the outcomes will necessarily be what was planned. After all, as Ambrose Bierce said, planning means bothering about 'the best method of accomplishing an accidental result'!