Complexity

– not as complicated as it looks

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General practice is undoubtedly complicated. The almost inexhaustible permutations of patients, illnesses and situations make primary care a challenging endeavour that demands the full attention of everybody who works in the field. In some respects this kind of complication can be the attraction of primary care, since personal and professional challenges are what often drive us to new heights of achievement. But complicated systems also throw up unexpected problems, which are not readily explained or understood, and which cause frustration.

Complicated phenomena, therefore, govern our lives. They provide richness and satisfaction, both in health care and in other aspects. So when physicists developed theories and explanations for why apparently orderly systems sometimes show complicated and unpredictable behaviour, it should be no surprise that the new ideas were adopted enthusiastically not only by their colleagues but by a much wider group of people, including biologists, social scientists, geologists, economists, engineers, mathematicians and managers. These theories, often referred to collectively as complexity science, refer to the paradoxical observation that systems which are constructed from simple interacting components can often produce complicated, counterintuitive or unpredictable effects.

What is complexity?

There is a distinction to be made between the complicated and the complex, in the sense that complexity refers to a specific set of principles which can be used to analyse the behaviour of observable systems, and to make quantitative predictions about their behaviour. Many apparently complicated phenomena might be explained by complexity science, but not all complicated things are complex. Complexity depends on there being specific mathematically defined properties that can be observed and measured. One example of such a property is the presence of similarity at different scales. This phenomenon is widely present in nature, for instance in the ruggedness of a rocky coastline, which is essentially similar whether viewed by standing over a rock pool or observing a continent from space.

The Mandelbrot set is a well-known example of self-similarity. This mathematical construct has self-similar properties, which are shown in figure 1 at four levels of magnification. As you zoom in to the picture, you see the same level of detail at every level: beyond the initial stages of magnification you can't tell how zoomed in you are just by looking, because the same distinctive patterns crop up at every scale. Complex systems show precisely these same properties: a graph showing the size of stock market price changes or the variation in heart rate over time (both systems which have been demonstrated to show self similarity on different scales) will look similar if each data point represents one, 100, or 1000 days or heartbeats.[1]

The presence of properties such as self-similarity appears to be associated with the characteristic behaviours of complex systems. These include:

- **Connectedness.** Simple systems in which the individual elements are connected together and can influence each other often form a basic structure that can demonstrate complex behaviour. Complex systems show properties and behaviour, which are of the whole system, and cannot be explained by analysing the properties of single components of the system.
- **Emergent phenomena.** One of the most intriguing aspects of complex systems is that they can show very organised patterns, but such patterns emerge spontaneously rather than as a consequence of design. At first acquaintance this can ap-

pear to be rather spooky, but emergent phenomena are not about hypothesising some mysterious organising intelligence. Emergence is about the evolution of systems with given starting conditions and external influences. For example flocking birds fly in distinctive patterns and movements which can be accurately reproduced by modelling the reaction of each bird to its neighbour, rather than by assuming some conscious plan among the birds to fly in a certain way. By contrast, the pattern of passenger jets approaching and leaving a major airport, although complicated, does not constitute an emergent phenomenon: central planning and control dictates that planes fly in a certain way, without allowing individual pilots to exercise spontaneous interaction.

- **Robustness to external influence.** If a complex system has some stable emergent state, then it has evolved as the best adaptation to local circumstances. Often, small – or even large – attempts to change that state will have little effect.
- **Unpredictable consequences.** The corollary of emergent patterns and robustness is that, occasionally, even an apparently minor intervention in a complex system can produce extreme and unpredicted consequences.

Complexity theory, then, has considerable potential to show why some otherwise inexplicable phenomena in the world around us arise in certain ways. It explains why organised patterns sometimes appear to develop spontaneously, and it explains why events sometimes proceed in ways we had not predicted.

Uses of complexity

It is worth considering two different aspects of discussion about complexity: the technical and the intuitive. Using scientific methods, a successful research programme carried out across a number of very diverse disciplines has applied the mathematical tools of complexity theory to specific situations, and has found that there is a good degree of explanatory and predictive power in these models. This has been used to make predictions about the nature of systems such as power networks, the stock market and internet traffic volumes.

In the example of forest fires, the size of a fire is determined by characteristics of the forest and its environment, such as tree density, fire breaks and the wind direction, rather than being reducible to the properties of individual trees or the initial spark. The frequency distribution of fire sizes follows the power law relationship predicted by complexity theory.[2] In this case, an example of the unpredictability inherent in complex systems is that attempts to increase a forest's yield by extinguishing all trivial fires are countered by larger, more catastrophic, fires fed by the small scrub which would otherwise be consumed safely in small fires.[1]

More intuitively, the ideas of complexity theory raise the enticing prospect of explaining some of the diverse and puzzling behaviours and events that people see in their everyday lives. Understandably, this possibility has captured the imagination of many people including some seeking new models for organisational management. The use of metaphors derived from the study of complex physical systems has led to schools of management which emphasise the effectiveness of allowing structures and solutions to problems to evolve, or 'emerge' from groups of individuals, rather than by imposing centrally defined methods.

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Implications for primary care

Complexity theory has implications for people researching and working in primary care, reflecting both the technical and intuitive approaches outlined above. The first is the issue of scientific research into physiological and social aspects of health systems. The second is in the management and organisation of primary care, whether at the level of practice teams, primary health organisations or across the whole country.

Primary care research

There is good evidence that many human physiological systems appear complex in the technical sense.[3] Further research in this field may have substantial implications for clinical management. For example, if blood glucose levels naturally vary in a complex fashion, then this could explain why too rigid a focus upon attaining a fixed target might not be appropriate, let alone possible. Much work on complex aspects of physiological systems, with a particular focus upon cardiology, has been led by the American physician Ary Goldberger.[4] Mood, and symptoms such as pain, are also known to vary considerably over time and may also be amenable to understanding using complexity theory.

There have recently been some early signs that the flows of volume in health systems may be complex. Variation in waiting lists has been found to show a power law distribution, a mathematical indication of self similarity across different scales.[5] This suggests that waiting lists could be self organising emergent properties of some health systems, and might go some way to explaining why changing waiting lists is such a notoriously difficult exercise, to the chagrin of governments and health managers in many countries.

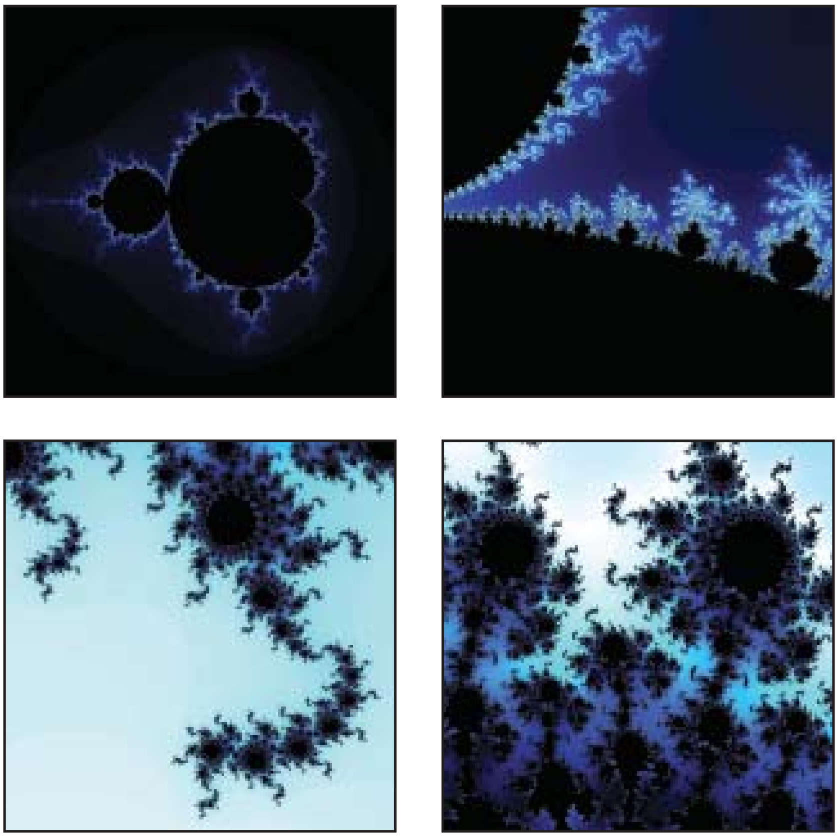
There is much room for research on other health systems phenomena. In primary care, questions such as the distribution of frequent consulting patients may be susceptible to this sort of analysis, while possibly the most interesting question of all is the mechanism which underlies clinical error. These are questions which may well be explored by using the analytical tools of complexity science, and which have the potential to contribute to real improvements in the way that care is organised and delivered.

Complexity and primary care management

Many of the tenets of management associated with ideas from complexity science may be applicable in a primary care context. Some of the work, which highlights the effectiveness of management approaches based upon giving freedom to individuals, is applicable to the situation in which clinical professionals seek to work in primary care.

This sort of account highlights some of the interesting contrasts between New Zealand IPAs, which were initially self-selecting groups of GPs who had a relatively high degree of freedom and resources to develop local health services in whichever direction they preferred, as opposed to American HMOs or other health organisations which have traditionally focussed on constraining and limiting clinical autonomy. The principles of complexity explain why a flexible structure, which has the freedom to evolve in a responsive fashion to its environment, can deliver results which exceed very highly planned structures.[6] Complexity predicts that a health system which allows the individual players to interact to find local solutions to problems will, in the long run, be more stable and more effective than a very highly optimised health system which is planned in detail by a central agency. In the past decade, some of New Zealand's best developments in primary care have developed in an environment of flexibility, which has allowed great diversity to flourish.

Figure 1: The Mandelbrot Set At Four Levels Of Magnification



So how good is it?

The set of ideas known as complexity have been around for some time but their application to health care in general, and to primary care in particular, has really only just begun. There is great potential in the use of this kind of approach to extend clinical knowledge and practice, and to optimise some of the organisation of health services. Moreover, some of the management practices influenced by complexity may well provide useful insights into effective leadership and teamwork in primary care at a number of different levels, from national organisations to individual clinics. The origins of complexity theory in nature and in the scientific method lend a rigour, which should prevent it being just another passing fad.

The answers complexity theory gives us are not necessarily straightforward to understand and apply, nor do they represent a short cut allowing us to flout normal levels of scientific rigour. But at a time when clinical research is increasingly focused on the restrictive gold standard of the randomised controlled trial, and managers in many parts of the world see variation as something to be abhorred, complexity theory opens up new insights and opportunities to understand and improve health and health care provision.

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