

Editorial (17.1)

Complexity and understanding

March 31, 2015 · Editorial

Peter Allen


At first sight these two words seem to suggest opposing tendencies. A situation is 'complex' and that is why we find it difficult to decide what to do. But, we think that if we understood the situation, its origins and expected responses, then it would be easier to decide on what action, if any, to take. Obviously we are constantly trying to work out what is 'going on' around us and to talk to people and try to illuminate the situation. But this is not called 'science'. This is just straight forward passive pragmatism. We don’t try to ask questions and illuminate a situation before it has occurred, but simply deal with what has arisen as best we can. A scientific approach begins when one thinks of a question and how it could be explored, using a method that has at least some generality. In hard traditional science knowledge grows by the repeated performance of repeatable experiments. That means that an experiment is performed for a closed system or with completely specified environment, and the elements that are contained within the system are completely defined and known. Atoms in a box, links and levers in a machine and crystal lattices are all instances where experiments can be performed all over the world by whoever wants to, and the same behavior will be found. As Popper stressed hard ‘science’ consists of the domain in which repeatable experiments can be performed, and learning only occurs when either a new experiment gives unexpected results or we find that what we thought was a repeatable experiment fails to repeat itself. Hard science only knows for sure things that are not true, not things that are definitely true.

Popper is quite right, but his definition only includes a small part of the universe. For the universe is the result of on-going evolutionary processes, in which multiple levels of emergent structure and organization have come into existence, and whose precise internal structures cannot be clearly defined. Obviously, in biology and especially in human systems, if one is to try to understand ‘scientifically’ the behavior and responses of a particular situation then one is faced with the fact that people and organisms are not transparent, and have ‘hidden’ capacities and responses that their individual and cultural history and evolution have created. Individuals are different because of their innate differences and also because of the precise individual histories that they have encountered in their lives, and indeed in the stories they have heard or read within their culture.

This very diversity is part of the evolutionary ‘success’ of the organisms involved in any observed ecosystem in which they are not currently crashing. But this inherent and somewhat unknown diversity is what makes a ‘hard scientific study’ so difficult. A repeatable experiment will have predictable results if the internal spectrum of responses is the same. As we know from complexity models, innovative ideas and responses come from non-average individuals and so in order to predict a response correctly, one would need to know details of all the ‘hidden’ ideas of individuals, in order to see which one may lead to emergent change – either successful, or disastrous. This would seem to me to be an impossible task, although one could reflect on what kinds of individual initiative could potentially destabilize the current system. This was the intention behind my early papers on evolution going back to the 1970s. Anyway, we can now see why biological and social science will never have the same ‘solidity’ as hard, physical science – because you cannot guarantee that any two systems are identical so cannot be sure that you have a predictable outcome from a repeatable experiment. This is why experiments with identical twins are important, though this can only guarantee genetic identity. Clearly, one can nevertheless repeat experiments on different systems and look at the different outcomes that occur – and attempt to find ‘explanations’ for these differences. These explorations can be useful in guessing possible outcomes, but
this is not the same thing as a ‘scientific law’. Another point is that people and many organisms will not necessarily respond the same if an experiment is repeated on them! While the atoms and molecules, and cogs in machines do not usually get bored, or have a sense of humor, people often do. And they may well ‘learn’ from the previous experiment and change their response, or simply get annoyed with the repetition and ‘sabotage’ the research as a result. All this points to the idea that we can only hope for a ‘soft science’ when dealing with many people or organisms. This is despite the fact that within an organism there may well be quite predictable biochemistry that goes on. Because there are levels of internal structure that have evolved (molecular, intracellular, intercellular, organs etc.) then although the biochemistry is hard science, the behavior of individuals and populations within ecosystems may not be. This is clearly true of people since knowing their biochemistry does not reveal their history, culture and ideas, and so may fail entirely to predict their behavior – other than passing out, becoming ill of indeed dying.

Each population, culture or economic sector is itself made up of diverse elements and this micro-diversity changes over time as a result of the successes, failures and fashions that actually occur. Not only can we say that ‘prediction’ will be uncertain for such systems, but also we will never really even understand their history because the precise micro-details and circumstances of the individuals involved in making history cannot be known. All we can do is to describe what happened, and who was involved, though it would be difficult to say why individuals made the decisions and took the risks they did. For living systems, we build interpretive frameworks rather than scientific laws.

Although the laws of physics must still hold, open systems with complex interactions between their elements can achieve a level of autonomy and freedom and will do things that have not been encountered before. For example, ‘emergence’ can occur as new patterns of organization occur, with new characteristics, new variables and new capabilities. We find not only that our quantitative prediction of the variables values is wrong, but they are qualitatively wrong and are probably looking at the wrong variables and asking the wrong questions.

In reality, elements join together to form collective entities and things around us are characterized by structure and organization at various scales. Over time, the performance of the system’ results not just from the elemental behaviors but also the structures of which they are part. The phenotype is not the genotype. Structures with various forms and symmetries possess emergent capabilities which accord differential successes over others. Micro-diversity includes these different collective entities and organizations and so innovations occur at different levels of structure, breaking previous symmetries with consequences that are completely unknowable! Life itself is the astonishing result of the emergent properties of folded macro-molecules such as proteins, and their emergent capacity to reproduce imperfectly.

In evolved systems how do we go about building sensible ‘interpretive frameworks? The answer is what we could call the inductive – deductive loop. We perform experiments on multiple systems and see whether we can discern patterns in the results. These patterns are then our ‘theory’ about such systems. Using our ‘theory’ we then investigate further cases and deduce expected results. When the expectation is fulfilled, it reinforces our ‘theory’, but if our theory is ‘denied’ by the experiment we are forced to change our beliefs.

The inductive-deductive loop

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**Fig. 1: The inductive-deductive loop**

This inductive-deductive loop is really the most fundamental view of the ‘learning process’. Over the years I
have often included in my papers a figure of the ‘learning loop’, whereby the experimenter generates beliefs about the world. The dotted line as being someone’s skull and the diagram shows how actions made on the basis of accumulated beliefs and values get a response from the world.

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**Fig. 2: The learning loop**

If the response is ‘as expected’ then it will tend to reinforce the beliefs of the individual. However, if the results of an action come back and are not what was expected – then the individual has to decide what to do about it. The amazing thing is that there is no ‘science’ about how to review ones beliefs in the light of their denial. When I devised this picture of learning, I was (unconsciously) representing the actions of an honest scientist (me) – a seeker of truth. But of course, in reality, most people may well want to deny the denial, to pass rapidly on without drawing attention to it, and may not wish to show that their beliefs were incorrect. The faithful might even consider it a test of their faith and simply ask their leader what they should do. The ‘induction/deduction’ loop for social science does not pick up this personal, individual desire to find their ideas fulfilled. Since there is no scientific guidance on how to modify one’s views in the ‘best possible way’ then, for example, people with left or right wing views might modify the ‘question’ asked in order to try to extract the answer they want to find. This might be favorable to the views of their ‘friends’ or opposed to the views of their rivals. We may therefore join with other like-minded thinkers in a new set of beliefs/values that seem congenial. The new ideas may well prove satisfactory until the next crisis.

Another possible issue is that different ‘schools of thought’ may adopt different lessons from the failure of the previous ideas and oppose their ideological enemies in battle. In this way the process of ‘learning’ in social systems is not the rational, truth seeking process that we may wish for. Instead, the questions examined will reflect the particular views of the individuals, and so following a failure of a previous consensus, people and groups may interpret evidence in different ways, ones that support the views and opinions of the particular social group that the individuals are attracted to.

Furthermore, if the agents that are contained in our interpretive framework see the probable changes that it would predict, then they may well change their behavior to take advantage of the ‘knowledge’. This ‘reflexivity’ would then invalidate the framework and make it an additional part of the situation being viewed. This all goes to show that instead of seeking truth as in hard science, in evolved systems we can only seek for better interpretations of what has, is and might happen. A multi-agent model will have to contend with the idea that the behaviors represented may be affected by the ‘predictions’ of behavior of the system – thus changing agent behavior.
In summary then, we can say that ecological and particularly human systems cannot yield scientific laws of the kind possible in physics or chemistry. This is because ecological and human systems are the result of a long, multi-level evolutionary process which is on-going. This means that our research leads us hopefully to useful interpretive frameworks, with the proviso that we need to constantly ask whether things inside the real system have not in fact changed and look to revising the variables and interactions that are in our interpretive framework. So, modelling and the generation of clear interpretive frameworks are valuable in revealing when changes may have occurred in the real situation and behavior. Without this possibility of monitoring expectations all would be unclear. Forming interpretive frameworks and models allows us to focus on where in the system change seems to be happening, and some study and revision has become necessary.

In summary, complexity and complex systems are really the most important part of our lives. Recently, science has widened itself to the study of open, non-equilibrium systems (complex systems) and found strong limits to our possible knowledge and understanding. But of course, if we could have perfect knowledge of what must happen around and inside us, then there could be no freedom. The price of creativity, of innovation and of discovery is the lack of restraint on what can happen, and the impossibility of fully understanding the past, present or future of our lives. The laws of physics and chemistry are, of course, obeyed, but they allow for the creative evolutionary processes that lead to higher levels of organization and structure allowing emergent characteristics, features and capabilities. So, feeling regret that we cannot hope for a really ‘hard’ social or ecological science fails to recognize the wonderful, unlimited richness of what can evolve.