The Interdependence of Order and Disorder:
How complexity arises in the living and the inanimate universe

Denis Noble CBE FRS
Emeritus Professor of Cardiovascular Physiology, University of Oxford

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Abstract

Denis Noble explores how biological systems harness complexity and stochasticity to overcome challenges. One of the examples he considers is Barbara McClintock's work on the shuffling of maize chromosomes, where chance is used to find combinations that would enable them to survive. This is a clear example of the symmetry between order and disorder.

Can order and chaos be mutually dependent?

Standard biological theories of life see chance simply as enabling our genetic material, DNA, to accumulate random mutations. Natural selection then blindly filters the successful organisms from the unsuccessful ones in the struggle for existence. Order slowly emerges in this way during evolution. This is the essence of the neo-darwinist Modern Synthesis. Amongst other consequences it reduces living organisms, including us humans, to being mere vehicles for the transmission of DNA to future generations. Chance and order are independent processes. There is no way in which they can combine during the lifetime of the individual. Chance is experienced but not directly used by organisms themselves.

We must turn this view on its head. Contrary to the ideas of neo-darwinism, living organisms harness chance as a way to solve the immediate problems they encounter in their environments. There are many ways in which this interdependence of order and disorder can occur.

Nearly a century ago a botanist in the United States, Barbara McClintock, was working on maize using a microscope to study the chromosomes in the cell nucleus. This is where the genetic material, DNA, is kept. She found that under environmental stress, such as radiation,

the plants start shuffling large parts of their chromosomes. They were using chance (the shuffling) to find combinations that would better enable them to survive. She published this ground-breaking discovery in 1953 in the journal Genetics, only to find that no one took any notice. Not a single scientist even asked for a copy of the paper. Very disappointed, she stopped sending her work to *Genetics*. 30 years later, in 1983, after other scientists had also found such large 'jumping genes', she was awarded a Nobel Prize for her discovery – at the age of 81.

Even the award of a Nobel Prize, though, did not change the paradigm. So, is such harnessing of chance in organisms just a rare exception?

Well, no. I have to tell you that it is far from an exception. You are harnessing chance in this kind of 'dance between order and chaos' all the time. All organisms with immune systems do so. When they encounter a new virus, bacterium or any other foreign body, they tell a very specific part of their genomes, the part that could make a new antibody to tackle the invader, to produce literally millions of new DNA sequences. Your immune system then works out which random variations work in neutralising the invader. It then tells the immune system cells that succeed to reproduce. That is how you fight off the new infection. In this way, chance is used to produce something, the immune response, which is very far from chance. You, in effect, create new DNA sequences and you do that even during your own lifetime. You don't have to wait for evolution to do so in your descendants.

You are not conscious of your immune system doing this. But could conscious choice be working in much the same way. Could your sense of free agency derive from the interdependence of order and disorder?

Reductionists would say no. You only think you have a real choice in how you behave. That feeling is just an illusion. Your genes and your neurones (created by your genes) make you do what you decide to do.

Again, I disagree. Random disorder occurs at all levels in your nervous system. Individual

proteins forming channels in the neurones are opening and closing, partly at random, all the time. I think we use this and other forms of randomness in our nervous systems to ‘spin the wheel of chance’ just as the immune system ‘spins the wheel of chance’ in your DNA. Just as the immune system generates an unlimited number of DNA variations, your nervous system can harness chance to develop an unlimited repertoire of behaviour. The neural processes that generate that repertoire can then mesh with your social interactions to generate the ‘logical’ response to the situation you find yourself in. I think this is why creative activity is unpredictable in prospect but can be rationalised in retrospect.

The harnessing of chance can therefore be the means for resolving the tension between micro-level and macro-level explanations of what you decide to do. Free agency on this view is relatively independent of micro-level causes but not independent of macro-level causes. Nor would you want it to be. If you are like me, you will be quite happy to be determined in your actions by what you see as the right fit to what the situation demands, just as your immune system finds the right fit to the invading virus. The difference is that you are aware of your neural actions. You are not aware of your immune system actions.

These are the processes by which living organisms can be seen through the interdependence of order and disorder. But what about the inanimate universe?

Imagine a universe in which all matter is completely uniformly distributed. Perhaps it was like that when the universe was forming from the ‘big bang’ over 13 billion years ago. Clearly this is not the universe we now know. It is full of strange objects: circles, spirals, horseshoes, vast dust clouds of various shapes and sizes, and of course the even stranger objects in modern theories of physics, such as black holes, dark matter and dark energy. And the most wondrous objects of all: living organisms!

How did such complexity arise from what may have been uniformity and from a perhaps infinitesimally small beginning?

One answer to the origin of complexity is surprisingly simple. There are forces between

objects. Some forces, like gravity and the opposite poles of magnets, attract while others, like the positive poles of two magnets, repel. This is to find symmetry in modern science that resembles the symmetry of yin and yang in ancient science.

Because of these forces between polar opposites, if we could turn the clock back and distribute the matter of the universe evenly the particles would immediately start their dance of attraction and repulsion. As they do so they inevitably form networks of interactions. No particle would initially be in a privileged position but as they attract each other they would congregate to form clumps. Once that happens we break the symmetry of a perfectly uniform universe. Those clumps would form initially as clouds and then as stars and planets.

Breaking symmetry in an unstable system is easy. Small chance events can do the trick. Imagine a ball placed exactly at the top of a hill with a shallow enough top for the ball to have the possibility of staying put. It might stay there indefinitely if there were no chance perturbations. But the slightest wind would displace it from the peak and it would start to roll downhill all the way if it encounters no insuperable obstacles. Depending on how fine the slope is at the top it may initially move extremely slowly, but then more rapidly as it experiences steeper slopes. On the way that rolling ball may trigger many other events, such as landslides, that may in turn kill unsuspecting climbers, in turn disturbing their family and friendship structures… the list is endless. Once symmetry has broken, further events can occur simply because of the energy and matter gradients that form, and the chance encounter with other events and situations. There is a continual ‘becoming’, described by some oriental philosophers as conditioned arising. These are process with ever more possibilities arising, because each arising forms the conditions for many others.

We can see this kind of process at work in the weather systems of the sky above us. On a perfectly clear day the sky looks uniform as the apparently evenly distributed particles in the atmosphere scatter sunlight to form the uniform blue colour we see. But the stillness and uniformity mislead us. All the time the atmosphere is exchanging heat, water and gases with the oceans and continents. Convection currents arise as warmer parts rise and colder parts fall. Water particles accumulate. The interactions between them form the wide diversity of

cloud structures, from relatively simple smooth planes, to the fiendish complexity of a tornado. No one thing 'makes' the tornado. It makes itself. The forces of matter under the right conditions ensure that these structures should develop. As the complexity increases so does movement within them. They spin rapidly and rhythmically like tops. The movement in the strongest tornados is so strong that they create immense damage as they hit land and dissipate their energy in a frenzy of destruction.

From a distance above the earth they appear as spirals. So do spiral galaxies in the depths of space. These also rotate. Our whole galaxy, the one that forms the Milky Way, is rotating, so we are rotating with it, probably around a black hole at the centre of the galaxy. There are rotating structures everywhere in space as well as on the earth.

We don't need any abstruse kind of theory to explain these formations, both celestial and cosmic. The equations of Newtonian motion suffice, although relativistic effects must also be involved. A similar process creates these rotating structures in both cases. We call them, and many other self-sustaining structures of networks 'attractors'. The system tends towards these attractors, which explains the name. Note also that no particular part of the network is the cause of the attractor. The spiral and its circular motion are properties of the whole network of interactions. They attract more matter and energy to themselves. They are states of the network that attract other parts of the network until the whole network dances to the tune of the attractor. [4]

References

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