Daisyworld

Our understanding of the world is a product of our personal experiences, our culture and the kind of 'infrastructure of ideas' (the web of pictures) we live in. Ideas can take a long time to be accepted and become part of our world view. Just think how long it took to accept that the Earth is not the centre of the universe. If new knowledge and insights is to have meaning in our lives we must be careful to avoid framing it in terms of 'outdated' or inaccurate ways of thinking. This may entail re-evaluating some deep-rooted beliefs and it might be both difficult and painful. It might also be fun and invigorating. My father once related to me the time when he was a kid and read popular science magazines. He still remembers how amazed he was to find out that there were more than just a handful of galaxies, maybe even a hundred. Today we think there might be more than one hundred billion! It seems we have to be careful with making definitive statements about our world.

A perspective that takes the whole as its starting point and questions whether the whole can be accurately described in terms of it constituent parts is sometimes called holism. Some scientists do not like this approach as it can be difficult to reconcile with the scientific method. There is an ongoing debate in learned circles about the apparent conflict between holism and reductionism, with elaborate arguments that describe the merits and faults of either perspective. This is not a helpful debate because it splits scientific enquiry into two distinct parts which appear irreconcilable. It is not a universal conflict however, it is simply a choice of perspective or approach. Even in science there is a great deal of emotion involved in debating, and sometimes the ideal of objectivity takes a back seat to winning the argument. But it is also necessary to be discussing these concepts because the quarrel over words like holism and reductionism reflects in a great many other theories that define our world.

A good example is the famous Gaia theory, first conceived by James Lovelock and Lynn Margulis. This elegant theory is based on observations of the Earth's highly dynamic and changing atmosphere and posits that the role of the entire biota in the self-regulating Earth system is to keep the planet 'fit for life' by regulating atmospheric composition. This theory grew out of a systems approach that recognised that the Earth metabolises much in the same way as other living systems do. Like my body works in such a way as to keep my internal temperature close to 37 ^{o}C, so does the Earth regulate to be habitable to the life-forms that dominates its surface. The theory has received intense criticism (as should any scientific theory) and some scientists have charged Gaia theory with being essentially unscientific. This is because it was perceived (wrongly) to be teleological, i.e. that it stated that the Earth self-regulates with the *predetermined purpose* of being habitable to life, and that it is impossible to prove Gaia theory by conventional scientific methods. Self-regulation cannot be observed in one single mechanism, if the sum is more than its parts you cannot 'prove' something at the greater level by testing at the lower level. Gaia cannot be subjected to the standard test of falsification. How could you prove such a theory to be wrong? It is either correct or it is correct.

The debate surrounding Gaia reveals much about the environment in which new theories emerge today, and some criticism of the theory seems to be far from motivated by a desire to arrive at an objective or accurate description of the Earth system. Part of the reason why Gaia is hard to accept for some scientists is that it is not a straightforward matter how the self-regulating or stabilising effects emerge in the process of evolution. Gaia suggests that there is a much stronger connection between organism and environment than many Darwinists are prepared to admit (Lovelock suggests a systemic Darwinian evolution for self-regulating mechanisms). Lovelock's strong opinions on politics and his use of Gaia as a metaphor to advocate a contraction of economic activity on the scale of World War II may not have helped further his scientific concepts either. It is not our intention to engage in those discussions or to take a stance on either side of the debate, this simply serves as an example of how even in science we get tangled up in the use of words. Science is not a hermetically sealed sphere of its own but one that constantly interacts and feeds on social paradigms as well. Maybe we should care less about whether we can attach the label 'right' or 'wrong' to a theory and more about its explanatory power and consistency with observations. Gaia theory has provided various accurate predictions about the climate system as well as a credible explanation of how planetary self-regulation works. In order to corroborate his claim that the Earth has the capacity for self-regulation (which is now a generally accepted theory), Lovelock developed a model he called Daisyworld. This is the last concept we will explore before we turn to see how the Earth system works and the ways in which our global climate operates.

Daisyworld is a two-component system, consisting of a dark species of daisies and a white one. We can think of Daisyworld as a planet orbiting a star that warms up as it gets older, much like our own Sun. The temperature at the surface of the planet also depends on its albedo – this is affected by the kind of daisy that grows on the planet because the dark daisies absorb sunlight and the white ones reflect it. Daisies will grow only in a certain temperature range, from 5 ºC to 40 ºC with an optimal temperature of 22 ºC. As the star becomes warm enough to heat the surface of Daisyworld above 5 ºC daisies begin to grow. Dark daises are favoured over white daisies because they absorb more sunlight and make the surface warmer and so raise the temperature toward a better level for daisy growth. At the end of the first growing season there are many more dark ones. This continues throughout the following seasons, a strong positive feedback exists between daisy growth (hence albedo) and Daisyworld temperature. When the temperature rise above the optimum level for daisy growth the white daisies compete for space, and as they grow in numbers they begin to cool the planet because of their high reflectivity. This alters the temperature through a negative feedback, there is now a negative coupling between surface albedo and temperature. Eventually a steady state between dark and white daisy coverage is reached, at which point the surface albedo and temperature is close to the level optimal for daisy growth.

Computer models of Daisyworld have introduced neutral coloured daisies, rabbits that live off the daisies, foxes that live off the rabbits as well as global catastrophes that wipe out a large part of the daisy population. All models show that the strong couplings between the species living on Daisyworld, allowing for positive and negative feedback, generate an overall stabilising effect on planetary temperature that can resist significant perturbations. But when the heat output from the star approaches 40 ºC and becomes so large that even the high albedo produced by maximum white daisy coverage is not enough to cool the system, deserts spread across Daisyworld and the system spirals out of control. Once the stabilising effect of negative feedback fails the system rapidly disintegrates. Daisyworld shows how a climate system can evolve to suit the preferences of its inhabitants. The daisies in this system regulate the temperature without a set goal for regulation – self-regulation is a feature of the system that emerges at the level of the whole and does not require a predetermined goal or purpose.

Daisyworld is a brilliant example of the ways in which climate science and the study of natural systems have furthered our collective understanding of the world we inhabit. Although the world may appear to operate according to the Cartesian split between mind vs. matter and human vs. nature this is not necessarily so. Strangely enough, this is only true as long as we believe it is true and organise our actions accordingly. But science has long been showing us that our world cannot be described by simple logic. Our world is full of circularity and a kind of circular logic is needed if we are to describe it accurately. A system that operates on the basis of feedback is not modelled very well by an attempt at employing logic because the dimension of time decides what is cause and effect in a sequence of self-repeating patterns. Cause becomes effect becomes cause. In short, the sum is more than the parts. Living systems show a remarkable ability to remain at a quasi equilibrium state in a condition of constant internal change. This is a feature that the Earth shares with us and one that have led some people, including James Lovelock, to liken our planet to an organism. Whether this is strictly true in terms of the definitions of life that we have inherited is open for debate. It is certainly a better metaphor than that of the machine. It might imbue the Earth and its ecosystems with respect and intrinsic value, rather than the conventional view of nature as another form of capital, a resource which is there for us to exploit. But we must not forget what our metaphors signify. Equating people with a plague, as Lovelock does, all too easily translates into the very rhetoric that makes our world look dangerous and gloomy.

Like the picture of Earth from space represents technological advances it is also a story of a mental advance, a story of our expanding collective consciousness. Science plays a lead character in this story and it probably plays more than one: the young and adventurous traveller as well as the old grandfather deaf and blind in his dusty archives. The real hero in the story is likely to be Curiosity, that formidable character that science, philosophy, spirituality, invention and creativity all share. This mental advance shows a picture of an interconnected and interdependent universe out of which solar systems, living planets, nature and people, with all their habits and talents, grow. It is also a picture of a planet where all living things take part and contribute to the continued existence of a habitable environment.