Earth and Life

Daisyworld: Self regulation

Voice Over

But Daisyworld's sun is still getting hotter and soon the black daisies find it hard to cope, whilst the white ones stay cool. The white flowers soon outnumber the black ones and Daisyworld becomes whiter and whiter. The white planet can reflect the increasing solar radiation and stay cool, but the sun gets hotter still. Eventually the planet gets too hot and even the white daisies can't cope. Daisyworld dies.

James Lovelock

In a way Daisyworld resembles a living organism. I know biologists hate me for suggesting such a thing, but it does, and perhaps the way in which it most resembles it is that it can die. If the Sun gets too hot for Daisy, the star gets too hot for Daisyworld, then even a total cover with light-coloured daisies is insufficient to keep the planet cool enough for them to survive. And the moment some of them start dying darker, bare ground is exposed, and then again with explosive, positive feedback the temperature zooms upwards, far beyond the range of toleration of any kind of life, so it dies.

Voice Over

22.5 Celsius is the optimum growth temperature for both black and white daisies. The black daisies work with the Sun and warm the planet. We call this positive feedback. White daisies work against the Sun and cool the planet. We call this negative feedback. In Daisyworld we're concerned with the combined effects of both positive and negative feedback. This graph represents the temperature of Daisyworld based on changes in solar luminosity alone, without the influence of the daisies. If we now add the daisies we get this curve which shows both positive feedback from the black daisies, and negative feedback from the white ones. Together they regulate the planet's temperature, producing a stable environment, despite the changes in solar radiation.

James Lovelock

I see Gaia theory as a theory of Evolution in which in no way discards Darwin's great vision, but includes also the geological evolution of the Earth and couples the two together tightly. What emerges from the synthesis of these two older systems are such properties as self-regulation, that's to say the regulation of the climate and the chemical composition of the Earth, so that it is always a fit place for life.

Voice Over

The Daisyworld model is a very general one and you can play all manner of games with it. So let's make it more realistic by giving the daisies a few problems. For example, we could introduce rabbits to feed on the daisies. At first the rabbits would try to eat up all the daisies but as the daisies became scarcer the rabbits would starve, so the rabbit population would decline as a result. If then the daisy population recovers, this will be followed by a recovery in the rabbit population. This is another example of a positive and negative feedback system which balances out over time. So if the rabbit population fluctuates like this - the daisies correspond like this. During the population cycles there appear to be runaway increases or decreases in the number of rabbits or daisies, but when measured over a long time a balance or equilibrium has been achieved between the number of daisies growing and the number of rabbits supported by them. This balance means that the rabbits have little effect on the long-term wellbeing of Daisyworld. The same long-term balance will eventually be achieved, even if we introduce further biological perturbations. We could, for instance, introduce foxes to prey on the rabbits, or a plague to kill off a high percentage of the daisies, or competition between daisies of different colours, or whatever perturbations we may care to invent.

James Lovelock
Biologists' critics in the early days suggested that if there appeared on Daisyworld a grey-coloured daisy that didn't use energy making light or dark pigment, it would have an advantage and take over the whole scene, and regulation would collapse; they called this a cheat. I took them seriously and I made a Daisyworld model in which a grey-coloured daisy was included, and to make things harder for the black and white ones I taxed them 5% of their gross rate for making pigment. It was most instructive when the model was run – the dark and light-coloured daisies flourished, just as before; the grey ones flourished as well, although interestingly not quite so well as the dark and light ones. You see it's really quite simple. When it's very cold, only dark daisies are fit to grow; light and grey ones cannot. When it's very hot, only light daisies are fit to grow; the dark and grey ones cannot. So the grey daisies have their place.

Voice Over
The effect of feedback is a zone of quite remarkable planetary temperature stability in the face of quite massive changes in solar radiation. As the output of the sun varies, so the black and white daisies simply respond to changing conditions, but in doing so they regulate the temperature. The process is entirely automatic; it's just an emergent property of the system.

James Lovelock
The most important conclusion I would draw from Daisyworld modelling is that it demonstrates that a system such as Daisyworld can self-regulate without there being any purpose, foresight, or planning, or anything built into the system beforehand that would make it do so. The other most important thing I would single out from it, which I'd add on to that, is that Daisyworld is the mathematical basis of Gaia theory and the explanation of everything that I mean by Gaia.