

Elementary cycling

Cycles of Life: Civilization and the Biosphere

by Vaclav Smil

Scientific American Library/W.H. Freeman: 1997. Pp. 221. \$32.95, £19.95

Mike Whitfield

If the whole of the Earth's history were compressed into a day, the residence times of most of the essential elements in the atmosphere, oceans and biosphere would be measured in fractions of a second. Only by parsimonious recycling and careful reutilization of elements could life persist and evolve in the face of such dynamic change. Smil's book addresses the biological cycling of just three elements — carbon, nitrogen and sulphur — which are essential to life and are effectively recycled in soluble waterborne compounds as well as in gases.

When dealing with terrestrial and atmospheric cycles, the book is authoritative and detailed, and is a pleasure to read. The way the cycles work, the evolution of our understanding of their intricacies and the interfer-

ence of civilization in their functioning are traced in clear language, and with beautifully presented diagrams and photographs. Nicely drawn dioramas or complex and intricate flowcharts illustrate the global cycles themselves. Frustratingly, fluxes and reservoir sizes are given only on subsets (Antarctic carbon cycle or Chinese agricultural nitrogen cycle) that are atypical of the global system.

A readily digestible analysis is provided of such complex issues as soil and water acidification and the fertilization of terrestrial plant growth by industrially released carbon dioxide and oxides of nitrogen. The folly of reaching for technofixes to alleviate such problems is emphasized most tellingly in an account of the intensification of the acid-rain problem in the United States that resulted from concerted efforts to clean up power-station discharges.

The author is less sure footed when dealing with the marine system. This is unfortunate because the oceans cover two-thirds of the Earth's surface, and for the first eighty per cent of the Earth's history provided the only environment of any significance. The role of the oceans in the carbon cycle is given fullest coverage, though even here the treatment is

oddly skewed at times. For example, the focus on the Antarctic carbon cycle leaves the false impression that, globally, birds and mammals form the main route for the transfer of carbon dioxide from the oceans to the atmosphere, and that only ten per cent of the carbon dioxide fixed by phytoplankton passes through the bacterial system.

The marine cycling of nitrogen gets short shrift. It is not included in a neatly presented history of our understanding of the nitrogen cycle, and the only mention within the chapter called "Reactive Nitrogen in the Biosphere" is an unexplained link between nitrate discharge and the crown-of-thorns starfish plague on the Great Barrier Reef. The production of dimethyl sulphide in the oceans is mentioned, but there is no overall budget for the global sulphur cycle to allow its impact to be assessed. Furthermore, its involvement in influencing cloud albedo over the open oceans, a matter of intense study and debate, is dismissed as unimportant, even in the preindustrial world, for the rather odd reason that burning vegetation also generates cloud-condensation nuclei. These criticisms are alleviated to some degree by an excellent treatment of the prob-

In retrospect chosen by Keith Stewart Thomson

Natural Theology; or Evidences of the Existence and Attributes of the Deity Collected from the Appearances of Nature

by the Reverend William Paley
(1802)

The alternative concepts to evolution are teleology and the argument from design, which is the proposition that the intricacies of nature and the supposed perfection of an organism's adaptation to the conditions of its existence (a darwinian term) are evidence of the operation of a First Cause, God the Creator. Paley's classic exposition of this subject has enjoyed almost as many editions and readers as Darwin's *On the Origin of Species*. Not that the argument from design was original to Paley; indeed a contemporary reviewer even asked why another work on this subject was necessary (*Edinburgh Review*, vol. 1, 1802–1803). As an undergraduate, Darwin himself was impressed by Paley's logic, although not unconditionally ("I did not at that time trouble myself about Paley's premises").

Natural theology is not so much a religious argument against the rising sciences of the early nineteenth century as a marshalling of scientific evidence against various forms of atheistic materialism. Paley's targets are David Hume, unitarians, deists and other free-thinkers including Buffon and, of course, Erasmus Darwin, and all notions that the natural world is the product of chance or the blind workings of laws and principles.

The trouble with Paley's argument is not its

form, and certainly not its brilliant opening syllogism: a watch is found on the ground, "we perceive... that its several parts are framed and put together for a purpose...(and) the inference, we think, is inevitable, that the watch must have had a maker." Therefore complex organisms must also have had a maker. (A similar argument was made by Cicero in *De Natura Deorum*.)

Paley must next imagine that a watch could be found that contained within it the makings of more watches ("... a complex adjustment of lathes, files, and other tools evidently and separately calculated for this purpose"), and now the downhill slide begins. Just as a hypothesis that explains everything explains nothing, so a Creator who has created everything has created too much. The First Cause cannot have unintended consequences, so Paley is left wriggling on his self-imposed hook: why did God create pain and suffering, war, pestilence and famine? (For Darwin, the heartbreaking death of his daughter Annie turned him against religion as much as any science.)

Paley, writing as a scientist rather than a theologian, takes some of his answers from Thomas Malthus (*An Essay on the Principle of Population*, 1798). For example, the malthusian inevitability of poverty "necessarily imposes labour, servitude, restraint". This natural cause of class structure forms a convenient argument against all kinds of disturbing movements of self-improvement. Where Malthus argued that utopian communities were impossible, Paley has to argue that we (blessed are the poor, indeed) live in one.

Malthus explains the harsh exigencies of the natural world, and Paley's works (which Darwin studied intently and partially memorized) thus gave Darwin an early (and unacknowledged) exposure to Malthus on population and key arguments such as 'superfecundity' in nature and the struggle for existence ("that system of natural hostilities").

Paley's complaints about Erasmus Darwin's transformism are familiar: "... a total lack of evidence. No changes, like those which the theory requires, have ever been observed." However, in his incisive articulations of the arguments for the Creator, Paley (like Lyell later) lays out a template which, if inverted, becomes a programme for the investigation of transmutation.

These remarkable passages were intended as irony: "... A countless variety of animals might have existed, which do not exist... unicorns and mermaids, sylphs and centaurs... nations of human beings, with more or fewer fingers and toes than ten... we may modify any one species many different ways, all consistent with life, and with actions necessary to preservation, although affording different degrees of conveniency and enjoyment to the animal..." Imagine this being read by Robert Chambers, whose *Vestiges of the Natural History of Creation* (1844) in many ways broke ground for Darwin, and who was hexadactyl!

Keith Stewart Thomson is University Distinguished Scientist in Residence at the New School for Social Research, 65 West 11th Street, New York, New York 10011, USA.