at a positive *y* reading; or that the trapping might have happened a million years ago. The demonized system's differential equations are so time-asymmetric as to make them globally not uniquely time-invertible. Forwards in time the Maxwell scheme has uniquely defined trajectories.

Maddox may be right in thinking Maxwell's tongue was in his cheek, but his text has been mostly interpreted otherwise. At least Maxwell seems to have wanted to get people to think in terms of statistical mechanics by fabricating a contrafactual whimsy.

PAUL A. SAMUELSON
*Department of Economics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA*

SIR—Maddox, in his discussion of the possibility of breaching the second law of thermodynamics (*Nature* **345**, 109; 1990) raises an issue which deserves more than cursory attention. If Maxwell's demon could act effortlessly to allow more energetic particles to pass from one cavity A to another B, while restricting flow from B to A to less energetic particles, then one could transfer heat up a temperature gradient to cause B to be hotter than A. The question is important because our search for a pollution-free energy source would soon be solved for ever if an army of Maxwell's demons could be put to such use on a commercial scale.

Because we regard photons as carriers of energy and see them as a kind of particle travelling at the speed of light, we hardly need rely on the intelligence of Maxwell's demons to open and close a shutter across a hole between the two cavities. Instead it is sufficient to place a convex mirror located in cavity A and positioned away from but facing the hole. The focusing action of this mirror will ensure that those photons transfer heat from A to B until the walls of cavity B are at a higher temperature than the walls of cavity A.

This should suffice as an apparatus which will breach the second law of thermodynamics. Textbook teaching declares that "In nature heat is never found to proceed up a temperature gradient of its own accord". From this, the textbooks advance to a statement of the law according to which it is impossible for any machine to abstract heat from the coldest body of its surroundings and convert this into useful work surplus to that needed to power the machine. Maxwell's demon can affect that self-accord of the heat transfer and this causes one to wonder if that demon does really do any work in controlling the shutter. But with the mirror discharging this physical task, it is assuredly not doing work itself and those photons proceed up that temperature gradient by their own accord as they bounce from the mirror surface. In principle, therefore, there just has to be a failure of the second law of thermodynamics.

Maddox, in his editorial on mechanical engines driven by light (*Nature* **342**, 13; 1989), suggested that "it would be more than just fun if somebody were to build one". The practical implications are enormous but they highlight the need to develop a miniature thermoelectric power converter which could be incorporated between cavities A and B in a stratified system containing a large superficial heat radiating surface with numerous cavities and numerous mirror focusing elements so that a significant net power per unit volume can be generated.

What is so fascinating about this proposal is that such an energy device would not be subject to the Carnot efficiency limit. All the heat fed into the system to sustain the temperature of cavity A would emerge as electricity even though it might cycle several times between cavity A and cavity B, going one way thanks to the focusing power of the mirror and the other way as heat 'loss' through the thermoelectric converters. The efficiency of the heat-to-electricity conversion of the thermoelectic power converter is not a factor limiting what has just been said. It is just that the greater this efficiency, the smaller the volume of the structure needed for a given power output and so the smaller the capital expense incurred.

H. ASPDEN
*Department of Electrical Engineering, University of Southampton, Southampton SO9 5HN, UK*

SIR—Maddox's article (*Nature* **345**, 109; 1990) does not mention two issues which, it seems to me, are inseparable from any such discussion.

First, the traditional assumption is that the partition operated by the demon must be frictionless so that no energy is lost as heat during operation of the partition. Maddox does not mention that the partition must also be massless if work is not to be done in opening and shutting the partition. But how can a massless partition impart momentum to those molecules whose passage it seeks to prevent? (Conversely, if the partition has no rest mass, then it must be travelling at the speed of light relative to the demon, creating an absurd situation.)

Second, I recognize that Maddox's discussion was intended to focus on the statistical interpretation of the information theoretical aspects of the problem. The discussion is based entirely upon classical concepts. But what of the quantum-mechanical implications of the demon's ability to 'see' which molecules are travelling faster (or slower) than the average? To 'see' a molecule, the demon must exchange quanta with the molecule, thereby altering the states of both the molecule and the demon in accordance with the uncertainty principle. The assumptions underlying Maxwell's demon are *a priori* inconsistent with quantum mechanical reality.

LEE H. KRONENBERG
*Lee Biomolecular Research Laboratories Inc., 11211 Sorrento Valley Road, San Diego, California 92121, USA*

**Scientific Correspondence**

Scientific Correspondence is intended to provide a forum in which readers may raise points of a scientific character. They need not arise out of anything published in *Nature*. In any case, priority will be given to letters of fewer than 500 words and five references. □

# No ecosystem shift

SIR—Fanning[1] suggested that atmospheric inputs of fixed nitrogen have shifted the surface ocean waters, in parts of the North Atlantic and North Pacific, from nitrogen to phosphorus limitation. Such a change represents a large perturbation of these ocean ecosystems and requires investigation. Here we wish to make two points that we believe argue that the case for such a shift is not proven.

Several years of monthly measurements of nitrate and phosphate concentrations are available from station S in the Sargasso Sea (ref. 2 and references therein; A.H.K., unpublished data). This area lies downwind of the North American continent in an area where atmospheric inputs might be expected to have their greatest effect, although we have previously argued that on an annual average their magnitudes are small compared to internal recycling[3]. We have analysed recent data for the period April 1985–November 1988 using the same criteria as Fanning, because our methods and detection limits are similar to those reported in the

| Class | Number of samples | % of total |
|---|---|---|
| Nitrate undetectable | 126 | 24 |
| Phosphate undetectable | 46 | 9 |
| Nitrate and phosphate undetectable | 307 | 59 |
| Nitrate and phosphate detectable | 42 | 8 |

521 water samples collected at station S (32° 10′N, 64° 30′W) in the upper 100 m (approximately the average euphotic zone depth) April 1985–November 1988 have been classified as only nitrate undetectable, only phosphate undetectable or nitrate plus phosphate undetectable using the criteria presented by Fanning (1). An additional class in which nitrate plus phosphate are both detectable covers mostly the period of winter overturn.