Indirect effects of an oil spill

SIR—We were monitoring the population of south polar skuas (*Catharacta maccormicki*) near the US Antarctic research station at Palmer Station when the Argentine Navy ship *Bahia Paraiso* ran aground on 29 January 1989 (see ref. 1). The wreck spilled one million litres of diesel and jet fuel near large seabird colonies (more than 30,000 birds; W.R. Fraser, personal communication) at the height of the breeding season. During the spill, diving birds (penguins and shags) died from fouling and toxicity, and there was an unprecedented[2,3] reproductive failure in south polar skuas, in which all young died within a 3-week period during the spill. Skua nestlings had normal growth rates during the spill, showing no evidence of infection, fouling or toxicity[4,5], such as the haemorrhagic gastroenteritis seen in shag nestlings. We suggest that fouling disrupted the normal parental behaviour of south polar skuas and indirectly caused the reproductive failure.

Whereas the skuas frequently foraged in oil slicks and acquired a light diesel coating, we did not see oiled skuas in their territories. Our observations of a captive bird suggest that skuas require two days of bathing to clean themselves, substantially longer than their normal shift away from the nest[6]. Lapses in nest attendance by adults became common during the spill (frequency of occurrence: 3% before, 31% during, $\chi^2 P<0.01$) and left young vulnerable to predation by other skuas[2]. Although not observed before the spill, predation was the only known cause of death during the spill and coincided with lapses in nest attendance. Adult pairs were commonly seen defending their territories after losing their young.

Our hypothesis of the cause of the reproductive failure is strongly supported by comparison of south polar skuas with other sympatric species. Reproductive failure was not seen either in the non-cannibalistic species that encountered oil (Adelie penguins *Pygoscelis adeliae*, blue-eyed shags *Phalacrocorax atriceps*, southern giant petrels, *Macronectes giganteus*), or in cannibalistic species that were not oiled (brown skuas, *Catharacta lonnbergii*). Like south polar skuas, brown skuas are opportunistic cannibals and are fiercely territorial. But unlike south polar skuas, which feed mainly at sea, brown skuas feed in penguin colonies[2], and hence are less likely to become oiled. While south polar skuas suffered reproductive failure during the spill, brown skuas apparently had normal reproductive success.

The short-term effects of the *Bahia Paraiso* spill on this and other populations of seabirds at Palmer Station were unexpected. Instead of minor negative effects on all seabird species, we saw a range of short-term effects varying from catastrophically negative to neutral and, perhaps, positive — the giant petrel population has produced 30% more young this year (W.R. Fraser, personal communication) in part, perhaps, because of the abundance of food after the spill. Direct toxicity and fouling caused mortality in penguins and shags, the two species which neither foraged in oil slicks nor ate contaminated prey, but which became fouled when diving through oil. These deaths provided abundant food for avian scavengers. By satiating scavengers, which also prey on the fledglings of other seabirds, the oil spill may have conserved productivity in some species.

In a small spill, where the direct effects of oil are not uniformly catastrophic, indirect effects become apparent. The events at Palmer Station emphasize the importance of behavioural and ecological interactions in determining the immediate effects of oil on species. Although these factors may be understood *post hoc*, correctly predicting the effects of oil on species may be difficult.

ZOE A. EPPLEY
MARGARET A. RUBEGA
Department of Ecology and Evolutionary Biology, University of California, Irvine, California 92717, USA

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Deuterium on Venus

SIR—Bertaux and Clarke[1] place an upper limit of 300 rayleighs (2σ) on the deuterium Lyman-α emission from the disk of Venus, viewed near maximum elongation by the International Ultraviolet Explorer (IUE). They then deduce the column density of deuterium in the upper atmosphere of Venus above 110 km and construct models for deuterium with this columnar abundance to compare with one of hydrogen, obtained from a radiative transfer analysis of Pioneer Venus short ultraviolet data[2]. They conclude that the upper limit to the D/H ratio at 100 km is $(3.6 \pm 1.5) \times 10^{-3}$ and claim that this conflicts with an interpretation of ion-composition data that identifies the mass-2 ion in the night-time ionosphere as D^+ rather than H_2^+ (refs 3–5). They also argue that this D/H ratio may also hold in the bulk atmosphere, rather than the ratio of $(1.6 \pm 0.2) \times 10^{-2}$ obtained by mass spectrometry[6].

In view of the compelling reasons for taking the main mass-2 species in the upper atmosphere to be D, rather than H_2 (refs 3–5), and the agreement between the D/H ratio measured for Venus cloud drops[6] and that implied by the ionospheric analysis[3-5], it seems prudent to try to reconcile the IUE results with the large isotope ratio. I believe that the IUE data could concern the aeronomy of hydrogen in the upper atmosphere of Venus, rather than contradicting the evidence for a large D/H ratio.

There is an unacceptable inconsistency in using the hydrogen distribution constructed for the short ultraviolet radiative transport analysis on the one hand and interpreting the mass-2 species in the upper atmosphere as H_2 on the other. The atomic hydrogen distribution in the Paxton model[2] is calculated on the assumption that there is no H_2 in the upper atmosphere. If there are 10 p.p.m. of H_2 at the homopause (in contrast with 0.7 p.p.m. of H), as Bertaux and Clarke suggest, the aeronomy of hydrogen on Venus will be drastically different from that on Earth[7], contrary to their assertion. The atomic hydrogen distribution will be nothing like the one used by Paxton *et al.*, from which Bertaux and Clarke took the density at 110 km (Fig. 1). The conversion of H_2 to H will place relatively much more atomic hydrogen at high altitude, where the temperature is higher than it is at 110 km. As Paxton *et al.* emphasize, temperature-dependent scattering effects can change Ly-α emission rates by a factor as large as 2.

In view of the results of Bertaux and Clarke, it is necessary to revisit the radiative transfer calculations to determine whether the short ultraviolet results can be interpreted in terms of a hydrogen distribution in which the ratio of high- to low-altitude (and temperature) hydrogen is increased significantly. Thus, less columnar atomic hydrogen may produce the same nadir Ly-α emission rate, the

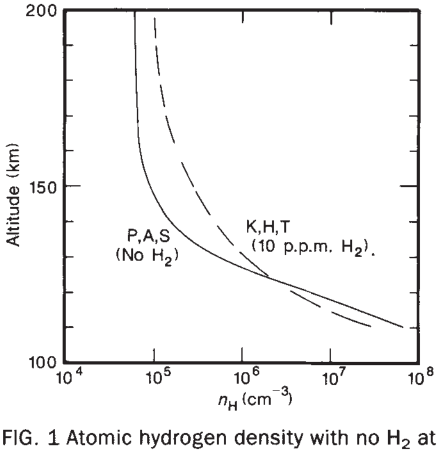

FIG. 1 Atomic hydrogen density with no H_2 at 110 km (ref. 2) and with 10 p.p.m. of H_2 at 110 km (ref. 7).

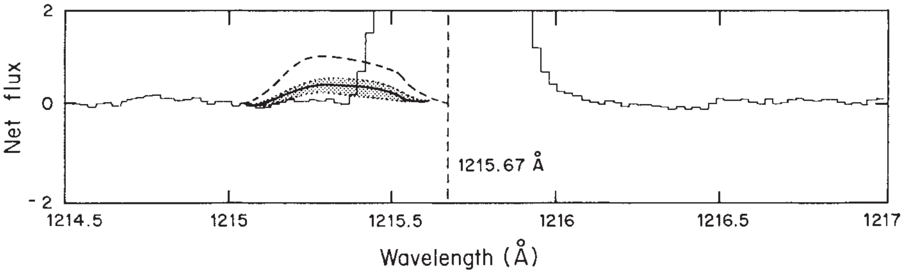

FIG. 2 Observed IUE spectrum near 1,216 Å with 2.5 kR of D Ly-α (dashed line) and 1.0 ± 0.4 kR (stippled region).

optical depth of the corresponding deuterium distribution being reduced. A significant concentration of hydrogen in the form of compounds (such as H_2 and HCl) at 110 km could cause such a change in the hydrogen altitude profile. Although ionospheric physics requires the mass-2 species to be mostly D and excludes 10 p.p.m. of H_2 at 100 km, it may allow 1 or 2 p.p.m. of H_2.

Note that the figure in the Bertaux and Clarke letter is misleading and its caption is incorrect in asserting that a D/H ratio of 1.6×10^{-2} would lead to 2.5 kR of D Ly-α. The authors mistakenly take the upward flux of hydrogen in Paxton's analysis (7.5×10^7 cm^{-2} s^{-1}) to be escape flux. Almost all this upward flux goes to support global circulation. Hence it is appropriate to treat deuterium in a one-dimensional model as carrying an analogous flux. Proper calculation of the deuterium column density gives $(3 \pm 1.2) \times 10^{11}$ cm^{-2} when the D/H ratio at 100 km is $(1.6 \pm 0.2) \times 10^{-2}$. The D Ly-$\alpha$ emission rate would then be (1.0 ± 0.4) kR, not 2.5 kR (Fig. 2). 300 R of D Ly-α would imply a D/H ratio of $(5.0 \pm 2.1) \times 10^{-3}$ at 100 km in the Paxton *et al.* hydrogen model.

THOMAS M. DONAHUE

Department of Atmospheric, Oceanic and Space Sciences,
Space Physics Research Laboratory,
University of Michigan,
Ann Arbor, Michigan 48109–2143, USA

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BERTAUX AND CLARKE REPLY—All the arguments presented by Donahue are sensible, but each allows room for discussion. Rather than going into the details here, we suggest another test of the presence of D atoms in the upper atmosphere of Venus. These atoms should produce an important limb brightening, just over the altitude at which CO_2 becomes transparent (horizontally) to Ly-α radiation, at about 125–130 km of altitude. This is because the D atmosphere is optically thin, whereas H atmosphere is not. With a D/H ratio of 1.6×10^{-2} and the H model proposed by Donahue, this D Ly-α brightening should amount to 1–3 kR, superimposed on the smoother H Ly-α brightening. Perhaps the data collected by the ultraviolet spectrometer on board Pioneer Venus at low altitude could be re-examined carefully for the detection of such a deuterium limb brightening.

J.-L. BERTAUX

Service d'Aéronomie du CNRS,
BP3, 91371 Verrières le Buisson, France

J. T. CLARKE

Department of Atmospheric, Oceanic and Space Sciences,
University of Michigan,
Ann Arbor, Michigan 48109, USA

Heart disease risks

SIR—Barker writes that "the geographical distribution of ischaemic heart disease is closely related to that of poor child health and development, indicated by high infant and child mortality about 70 years ago"[1]. According to this aetiological model, people born in a relatively poor area, who subsequently move to a more affluent part of Britain will experience a higher incidence of ischaemic heart disease (IHD) than those who have always lived in the more affluent area. Conversely, regardless of where they eventually settle, people born and raised in more affluent areas will suffer less adult heart disease. Migration into, and within, Britain, provides the opportunity to test the hypothesis.

The British Regional Heart Study reported[2] a strong geographical gradient in the risk of a major IHD event in 7,735 middle-aged men, living in 24 towns in England, Scotland and Wales, who were followed up between 1978 and 1986. Regardless of where they were born, men examined in Scotland experienced the highest IHD risk, whereas those examined in the south of England had the lowest. Men who were born in the relatively poor part of Britain, north of a line drawn between the Severn estuary and the Wash, but who later moved to the comparatively affluent south, experienced a risk of IHD little different from men who had always lived south of the line. On the other hand, men born in the south who moved north experienced a higher risk than those who remained in the south. Those who moved north faced an IHD risk similar to that of men who had always lived there. Furthermore, immigrants to Britain also adopted the IHD risk of the part of the country to which they moved, regardless of their birthplace.

These findings are consistent with other epidemiological studies of migrants. Between 1962 and 1966, immigrants to Australia from Italy, England and Wales had lower death rates from cardiovascular disease than Australian-born women and men[3], but death rates rose progressively with increasing length of residence. Also, between 1970 and 1972 immigrants into England and Wales had, in general, IHD mortality rates intermediate between those of their original and new country of residence[4].

Thus, environmental and cultural factors acting in adult life are of crucial importance in the development of coronary heart disease, independent of birthplace. It seems unlikely that geographical differences in IHD risk can be substantially explained by the prenatal and childhood environment.

JONATHAN ELFORD
A.G. SHAPER

Department of Clinical Epidemiology and General Practice,
Royal Free Hospital School of Medicine,
London NW3 2PF, UK

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Spin glass in a whirl

SIR—Sourlas's use of spin-glass models as error-correcting codes (*Nature* **339**, 693; 1989) is a complex way of saying something essentially very simple: that binary arithmetic, as used in most conventional computers, is multiply connected. This is in contradistinction to Gray, or reflected, binary code, which is simply connected. This means, for example, that in conventional computers five switching operations, (binary 01111 to 10000), are required in changing from the binary code for 15_{10} to the code for 16_{10}; there are thus factorial five (120_{10}) possible switching sequences. This fundamental flaw in conventional computation has been drawn to the attention of the UK Institution of Electrical Engineers in relation to the preparation of software intended for use in safety-critical situations, and also to the attention of the Combined Higher Education Software Team.

B. E. P. CLEMENT

15 Everest Drive,
Crickhowell,
Powys NP8 1DH, UK