

tized pulsar in supernova 1987A might nevertheless be detectable. The low-magnetic-field millisecond pulsars would be weak sources in our scaling.

F. C. MICHEL  
C. D. DERMER

Department of Space Physics and  
Astronomy,  
Rice University, PO Box 1892,  
Houston, Texas 77251, USA

1. Sturrock, P. A. *Astrophys. J.* **164**, 529 (1971).
2. Arons, J. *Astrophys. J.* **248**, 1099 (1981).
3. Cheng, A. F., Ruderman, M. & Sutherland, P. *Astrophys. J.* **203**, 209 (1976).
4. Cheng, K. S., Ho, C. & Ruderman, M. *Astrophys. J.* **300**, 500 (1986).
5. Michel, F. C. *Theory of Neutron Star Magnetospheres* (University of Chicago Press, 1991).
6. Michel, F. C. *Astrophys. J.* **383**, 808 (1991).

## Aluminium and global warming

**SIR** — The Intergovernmental Panel on Climate Change has overlooked two important greenhouse gases: CF<sub>4</sub> (CFC-14) and C<sub>2</sub>F<sub>6</sub> (CFC-116). These gases have atmospheric residence times in excess of 10,000 years and have strong absorption bands in the atmospheric window near 8 μm (ref. 1). Of the chlorofluorocarbons, the radiative forcing of CF<sub>4</sub> and C<sub>2</sub>F<sub>6</sub> during the 1980s was exceeded only by CFC-11, -12, -113 and HCFC-22 (ref. 2).

The only significant known anthropogenic source term for CF<sub>4</sub> and C<sub>2</sub>F<sub>6</sub> is primary aluminium smelting. Various fluoride compounds, including CF<sub>4</sub> and C<sub>2</sub>F<sub>6</sub>, are produced during electrolysis of alumina (Al<sub>2</sub>O<sub>3</sub>) dissolved in a molten cryolite (Na<sub>3</sub>AlF<sub>6</sub>) bath<sup>3</sup>. A small, yet unidentified, natural source of CF<sub>4</sub> is suspected. Fabian *et al.*<sup>4</sup> estimated global emission rates of 28,000 tonne CF<sub>4</sub> and 3,200 tonne C<sub>2</sub>F<sub>6</sub> per year in 1987. This suggests global average emission factors of about 1.6 kg CF<sub>4</sub> and 0.2 kg C<sub>2</sub>F<sub>6</sub> per tonne of primary aluminium production. These emission rates are consistent with aluminium industry estimates of 1.5–2.5 kg of CF<sub>4</sub> produced and emitted to the atmosphere per tonne of aluminium, and an order of magnitude or so less of C<sub>2</sub>F<sub>6</sub> (ref. 5).

Using the band strengths reported by Hansen *et al.*<sup>2</sup>, I estimate the global warming potential (GWP) to be between 10,000 and 11,000 for CF<sub>4</sub> with 100-yr integration time and without correction for the overlapping of absorption bands of CH<sub>4</sub> and N<sub>2</sub>O. F. Stordal, using a more detailed model, has estimated the 100-yr GWP of CF<sub>4</sub> and C<sub>2</sub>F<sub>6</sub> to be about 8,400 (personal communication). Lashof and Ahuja estimated that CF<sub>4</sub> was responsible for 1.7% of the total warming potential of all global anthropogenic greenhouse gas emissions in 1985<sup>6</sup>.

Average CF<sub>4</sub> and C<sub>2</sub>F<sub>6</sub> emissions are thus equivalent to the greenhouse contribution of about 15–20 tonnes of CO<sub>2</sub>

per tonne of aluminium. To the extent that CF<sub>4</sub> and C<sub>2</sub>F<sub>6</sub> are produced during electrolysis cell anode effect, considerable variation in emissions from plant to plant would be expected as the frequency of anode effect varies by at least 10-fold between smelters<sup>7</sup>.

CF<sub>4</sub> and C<sub>2</sub>F<sub>6</sub> may be the most potent greenhouse gases being emitted in large amounts. Not only do they have a very large GWP, they also cause an essentially permanent alteration in greenhouse forcing. Aluminium smelting also results in large greenhouse gas emissions from production of the electricity consumed during smelting, and from CO<sub>2</sub> produced during alumina reduction to aluminium metal. Alumina reduction, 2Al<sub>2</sub>O<sub>3</sub> + 3C → 4Al + 3CO<sub>2</sub>, results, in practice, in emissions of between 1.5 and 2.2 tonnes of CO<sub>2</sub> per tonne of aluminium. Aluminium smelters consume between 13 to 20 MWh of electricity per tonne of aluminium depending on efficiency. Greenhouse gas emissions from producing this electricity vary from at least 22 tonnes of CO<sub>2</sub> equivalent per tonne

of aluminium when the electricity is produced by a conventional coal-fired power plant to low levels for hydropower.

Cement is the only primary commodity, other than fossil fuels, specifically included in conventional tabulations of sources of greenhouse gas emissions. Yet the total greenhouse contribution from primary aluminium production appears to be greater than that from cement production on a global basis and can be tens of times greater in countries with a large primary aluminium industry based on fossil-fuel-generated electricity.

DEAN ABRAHAMSON  
Humphrey Institute of Public Affairs,  
University of Minnesota,  
Minneapolis, Minnesota 55455, USA

1. Cicerone, R. S. *Science* **206**, 59–61 (1979).
2. Hansen, J., Lacis, A. & Prather, M. J. *geophys Res.* **94**, 16417–16421 (1989).
3. Grjotheim, K. *et al.*, *Aluminum Electrolysis: Fundamentals of the Hall-Héroult Process* (Aluminum Verlag, Düsseldorf, 1982).
4. Fabian, P. *et al. J. geophys Res.* **92**, 9831–9835 (1987).
5. Haupin, W. E. in *Production of Aluminium and Alumina* (ed. Burkin, A. R.) (Wiley, Chichester, 1987).
6. Lashof, D. A. & Ahuja, D. R. *Nature* **344**, 529 (1990).
7. Øye, H. A. & Huglen, R. J. *Metals* **42**, 23–28 (1990).

## Leukaemia/*Drosophila* homology

**SIR** — The sequence has recently been published<sup>1</sup> of a human complementary DNA clone encoded by a gene (designated *AML1*) that is rearranged in a translocation (t(8;21)) characterizing a subtype of acute myeloid leukaemia. No similarity was reported between the predicted polypeptide sequence and any known sequence. We find, however, that it is highly related to *runt*, one of the class of pair-rule genes that control morphogenesis in *Drosophila melanogaster*<sup>2</sup>. The region of best alignment spans 118 amino acids from positions 60–177 in *AML1* and from position 115–232 in

intron boundary. It is tempting to speculate that it may represent a functional domain. Intriguingly, the t(8;21) breakpoints seem to cluster in the intron immediately downstream of this boundary.

*Runt* encodes a nuclear protein which is likely to be a transcriptional regulator, although it does not contain any of the structural motifs recognized in such factors, or a nuclear localization signal. *AML1*, however, does contain a cluster of basic residues at position 177–182 (four residues out of six being K or R) which is a 'minimal' motif in transcription factors. This sequence would be

<i>AML1</i>	60	GELVRLTDSNPNFLCSVLPHTWRCKNTPVIAFKWVALGDVDPDGLTVIVMAGN DENYS AELR
		. . . :     . :     .     :     . :     . :     :       . :     :     . . .         . :
<i>runt</i>	115	GELAQTGSPSILCSALPNHWRSNKSPLGAFKVVIALDDWPDGLTVLVSIKCGN DENYCGELR
<i>AML1</i>	119	NATAAMKNQVAREFNDLRFVGRSGRGSFTLITVTFVTPNPQVATYHRAIKITVDGPREPR
		. . .         :                               :   .   . :     :
<i>runt</i>	174	NCTTMTKNQVAKFNDLRFVGRSGRGSFTLITVTPVQIASYSKAIKIVTVDGPREPR

Region of best alignment between human *AML1* and *D. melanogaster runt*.

*runt*. Within this region, 73% of amino-acid residues are identical, a further 23% are conservative replacements, and the percentage nucleotide identity is 68%. This is higher than the homology between the mouse proto-oncogene *int-1* and its counterpart in *Drosophila*, *wg* (54% amino-acid identity over 468 residues<sup>3</sup>) and comparable to the homology between *Drosophila* and human homeoboxes. The region of homology also includes a perfect match of the A box of a putative ATP-binding site.

The region of homology between the *Drosophila* and the human sequences stops abruptly at a conserved exon/

disrupted by the t(8;21). Thus, *AML1* seems to be a structural homologue of *runt* in man. Its role in human development, particularly in haemopoietic differentiation, remains to be established.

ANTONIO DAGA  
JANE E. TIGHE  
FRANCO CALABI

MRC Leukaemia Unit,  
Department of Haematology,  
Hammersmith Hospital,  
London W12 0NN, UK

1. Miyoshi, H. *et al. Proc. natn. Acad. Sci. USA* **88**, 10431–10434 (1991).
2. Kania, M. A. *et al. Genes & Dev.* **4**, 1701–1713 (1990).
3. Rijesewijk, F. *et al. Cell* **50**, 649–657 (1987).