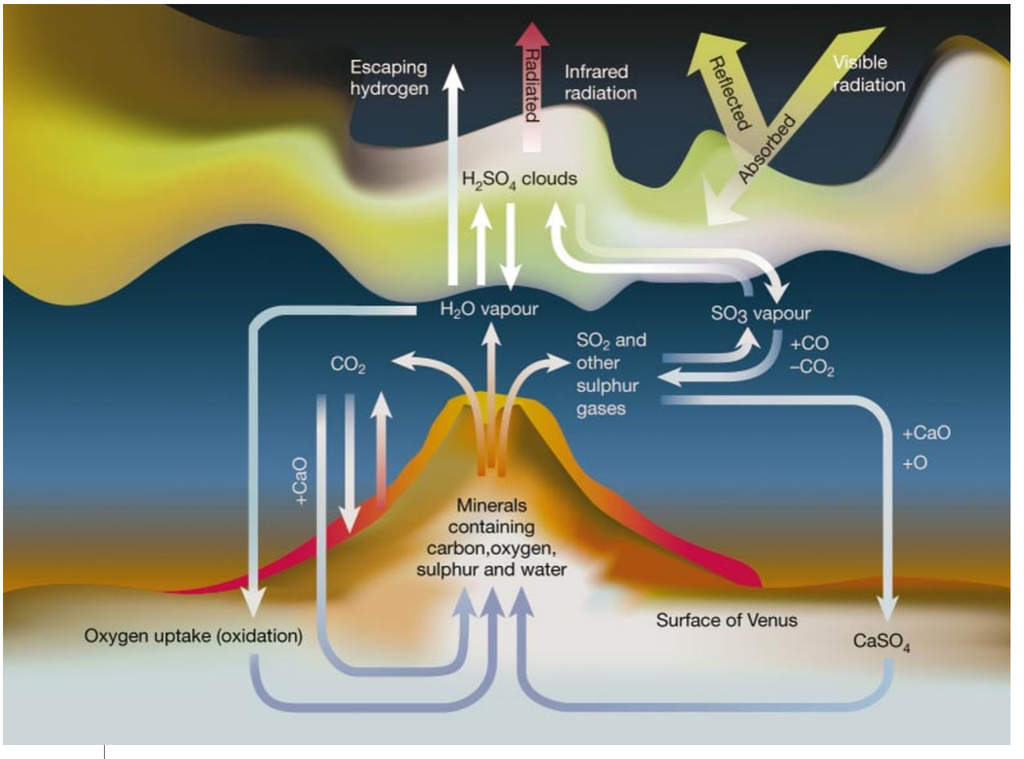

Figure 1 **Key chemical and physical processes controlling the climate of Venus over long timescales[1–5]. Venus has an atmosphere of 96.5% CO_2, which is primarily responsible for its greenhouse effect and high surface temperature. Venus also has a thick layer of sulphuric acid (H_2SO_4) clouds that reflect sunlight away from its surface, helping to cool it. The greenhouse warming is greater than the cooling effect of the clouds, making the surface of Venus much warmer than on Earth. A new numerical model developed by Bullock and Grinspoon[1] suggests that over the past 1 billion years the climate on Venus has experienced periods of both cooling and warming, largely triggered by global volcanic activity spewing out large amounts of sulphur dioxide (SO_2) and water vapour (H_2O).**

the greenhouse effect. But after this period, the Bullock–Grinspoon model indicates relatively rapid removal of excess SO_2 by reaction with carbonates and other surface rocks, so the clouds became thinner and the planet warmed by 100 K. But the warming was limited by the steady loss of H_2O as hydrogen escaped into space and oxygen was lost at the surface, allowing Venus to cool again to its current temperature.

How stable is the climate of Venus now? Maintaining current levels of SO_2, and hence clouds of sulphuric acid, requires volcanic activity. Large impacts from comets could also bring water and sulphur to Venus, but it seems that in the near future the venusian climate will be a slave to the volcanism needed to sustain current levels of H_2O and SO_2 against their loss at the surface and into space. This simple picture is complicated by the possibility that changes in surface temperature can feed back to the processes involved in volcanism, by affecting the heat flow, and hence temperatures, deep below the surface[7]. So the story will be complex.

Such models are always speculative, but Bullock and Grinspoon suggest some specific space missions and observations that could clarify the existing picture. Measurements of noble gases in the atmosphere could help quantify the flow of volatile gases from the interior into the atmosphere and space[8]. Close-up images of the surface — perhaps where the crust breaks in an impact — could reveal subsurface layers indicative of past climate change, like those seen on Mars[9]. And measurements of the flow in the atmosphere of visible and infrared radiation involved in the greenhouse effect, and the key gases involved in the chemical cycles[4], would help enormously. Stay tuned for better forecasts of the climate on Venus. ■

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1. Bullock, M. A. & Grinspoon, D. H. *Icarus* **150,** 19–37 (2001).
2. Prinn, R. G. *Scient. Am.* **252,** 46–54 (1985).
3. Von Zahn, U., Kumar, S., Niemann, H. & Prinn, R. in *Venus* (eds Hunten, D. H. *et al.*) 299–430 (Univ. Arizona Press, Tucson, 1983).
4. Prinn, R. G. in *Recent Advances in Planetary Meteorology* (ed. Hunt, G.) 1–15 (Cambridge Univ. Press, 1985).
5. Fegley, B. & Prinn, R. G. *Nature* **337,** 55–58 (1989).
6. Schaber, G. G. *et al. J. Geophys. Res.* **97,** 13257–13302 (1992).
7. Solomon, S. C., Bullock, M. A. & Grinspoon, D. H. *Science* **286,** 87–89 (1999).
8. Pepin, R. O. *Icarus* **92,** 2–79 (1991).
9. Treiman, A. H., Fuks, K. H. & Murchie, S. *J. Geophys. Res.* **100,** 26339–26344 (1995).

Daedalus

Learning to forget

Last week Daedalus contemplated the sensitivity of the brain to microwaves. He recalled brain theory, insofar as it exists. Each brain cell has many inputs (dendrites) and one main output (its axon); these are connected to other brain cells. Very plausibly, each dendrite is potentiated or inhibited by a specific protein molecule, whose configuration turns it on or off. And the shuffling of amino acids and the re-ordering of protein chains occurs at microwave frequencies. So mobile phones and microwave towers do a lot of unintended damage.

But controlled memory loss could be very welcome in psychiatry. Many people are haunted by dire memories, which prevent them re-entering places or circumstances, or make them fearful of certain normal human activities. A simple microwave irradiation, neatly erasing the damaging memory, could be gladly accepted. So DREADCO biochemists are irradiating test organisms, hoping to find that pattern of frequency or combination of frequencies that can erase a specific memory — in rats, for example, how to run a given maze.

The extension of this scheme to human psychiatry will be fraught with hazard. Fortunately, the main complaints about mobile phones refer to the loss of short-term memory only. Psychiatrists could screen mobile-phone users for the sort of information lost, and employ subjects who do not mind losing useless short-term data (perhaps certain recent breakfast menus). Furthermore, some quite worrying methods have been accepted by psychiatrists despite their potential for memory loss (electroconvulsive therapy is an example). So careful microwave-irradiation stands a good chance.

But Daedalus's main worry is the adoption of his methods by the politicos. A wide-band high-energy microwave assault on the brain might scramble all its data long before heating set in. The most convinced capitalist or advocate of human freedom could crumble before such brain-washing. Against that, how many fierce species have their hatred of humanity stored as software rather than hardware? A DREADCO selective irradiation might produce genuinely friendly lions and tigers, cheerfully accepting crocodiles and alligators. The range of tameable, tractable species could be wonderfully extended. Even the wild cat of the Scottish Highlands, said to hate everything on sight, might be converted to a purring fireside moggy.

David Jones