apparent paradox that typical studies of selection do not have the statistical power necessary[7,8] to detect selection that appears unrealistically strong[1]. Unfortunately, this paradox will not be resolved simply by accumulating more data of the same ilk, as all reviews identify problems with our current methods[1,4,7,8]. How, then, are we to obtain a good handle on the true power of selection in nature?

Evolutionary biologists will have to resolve this uncertainty by determining how best to measure and judge the strength of selection, and by conducting more robust studies of selection. Meanwhile, we are only deluding ourselves that we have a good handle on the typical power of selection in nature. Once we do, we can begin to investigate how humans are changing selection pressures, and whether populations and species will be able to adapt accordingly. ■

Andrew P. Hendry is in the Redpath Museum and Department of Biology, McGill University, Montreal, Quebec H3A 2K6, Canada.
e-mail: andrew.hendry@mcgill.ca

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Planetary science

Saturn's mixed magnetosphere

Fran Bagenal

When interplanetary shock waves hit the Cassini spacecraft and then Saturn in January 2004, it presented a unique opportunity to study the planet's magnetosphere and to compare it with that of Earth.

Saturn can be considered as the geometric mean of Earth and Jupiter in terms of the strength and extent of its magnetic field. Three papers in this issue — by Clarke *et al.*[1], Kurth *et al.*[2] and Crary *et al.*[3] — describe the response of Saturn's magnetosphere to changes in the solar wind as observed by NASA's Cassini spacecraft and the Hubble Space Telescope (HST). The authors conclude that some aspects of the behaviour of Saturn's magnetosphere are similar to the behaviour of Earth's magnetosphere, some to that of Jupiter's and some are unique. Studies of Saturn's magnetic field and how it is driven by the solar wind are interesting in their own right, but they also allow researchers to compare different planetary magnetospheres and to test our understanding of Earth's system by applying the same principles to different conditions.

Earth's magnetic field forms a cavity in the solar wind — the stream of electromagnetic radiation and charged particles that flows outwards from the Sun. Earth's magnetosphere extends roughly 10 times the planet's radius towards the Sun and many hundreds of Earth radii away from the Sun, in a 'magnetotail' stretching downstream of Earth in the solar wind. Jupiter is much larger than Earth (by a factor of 11), and its magnetosphere is also vast, extending 50–100 jovian radii on the dayside, with a magnetotail that stretches out to its orbit distance. Saturn's magnetosphere (Fig. 1, overleaf) is an intermediate case, extending about 20 Saturn radii towards the Sun (Saturn's radius is 9.4 times that of Earth).

Most of the material in Earth's magnetosphere is a plasma of protons and electrons that has leaked in from the solar wind. By contrast, the magnetospheres of Jupiter and Saturn are mainly fed by plasma sources of heavy ions from their satellites.

The three papers[1–3], beginning on page 717, describe observations of magnetosphere dynamics at Saturn. In Earth's magnetosphere, plasma circulates in a flow pattern that is primarily driven by the coupling of the planetary magnetic field to the solar wind. Within about 15° of the poles, Earth's magnetic field is directly connected to the solar wind. At lower latitudes the magnetic field topology is closed, with magnetic field lines connected at both ends to the planetary dynamo. At the outer boundary of the magnetosphere — the dayside 'magnetopause' — small regions of closed magnetic field couple to the solar magnetic field (which is swept towards the planet by the solar wind) in a process called magnetic reconnection. Once coupled to the solar wind, these tubes of magnetic flux are swept back over Earth's poles and down the magnetotail where they reconnect to closed field lines — as they must, to conserve the total magnetic flux from the planet.

The stresses associated with this process of coupling solar wind and magnetosphere drive electrical currents between the magnetopause and the ionosphere (the ionized upper part of the planet's atmosphere), leading to radio and auroral emissions. The terrestrial aurorae form in rings around Earth's magnetic poles, at the boundaries

NATURE

100 YEARS AGO

What mutation is in biology, conversion is in psychology, and revolution in sociology. It may be said that to assume such parallels is merely to beg the question, but I think that the apparent parallelism cannot be without significance… If the supposed analogy is a valid one, it appears to follow that mutability is due to the same general causes as ordinary variability (just as change of opinion and reform are due to the same general causes as conversion and revolution), but that there is this difference — mutability represents an explosion of energy, as it were, in a given direction, and therefore differs from ordinary variation somewhat as the firing of a gun differs from the explosion of a loose heap of powder… [T]he chance of mutations succeeding from the first is comparatively remote, though such a thing is quite possible; but since they are the result of general causes, the sort of changes the mutations exhibit are likely to come about in due course, just as the sort of changes represented by a revolution are likely to prevail ultimately, though the revolution itself may appear to fail. T. D. A. Cockerell
From *Nature* 16 February 1905.

50 YEARS AGO

***Amazon Head-Hunters*. By Lewis Cotlow. The author of this book is a New York insurance broker whose hobby is travelling in lands inhabited by primitive races… Between 1940 and 1949 he made several expeditions to the north-west of the South American continent… These are the areas inhabited by the Choco, Colorado and Yagua Indians, and include also the very isolated country of the Jivaro Indians, who are especially known for their custom of drying and shrinking the heads of their enemies… Mr. Cotlow was able to become very friendly with several of their chiefs, and they informed him of the number of heads which they had taken during their lives. He brings out forcibly the fact that the relatives of a man slain in battle are in honour bound to kill his killer and to shrink his decapitated head. The relatives of this victim must retaliate in the same manner, so that inter-community warfare is almost continuous. The author describes fully the method of shrinking a head. Unfortunately, he did not actually see it carried out, since at the time of the raid he was stricken with dysentery.**
From *Nature* 19 February 1955.

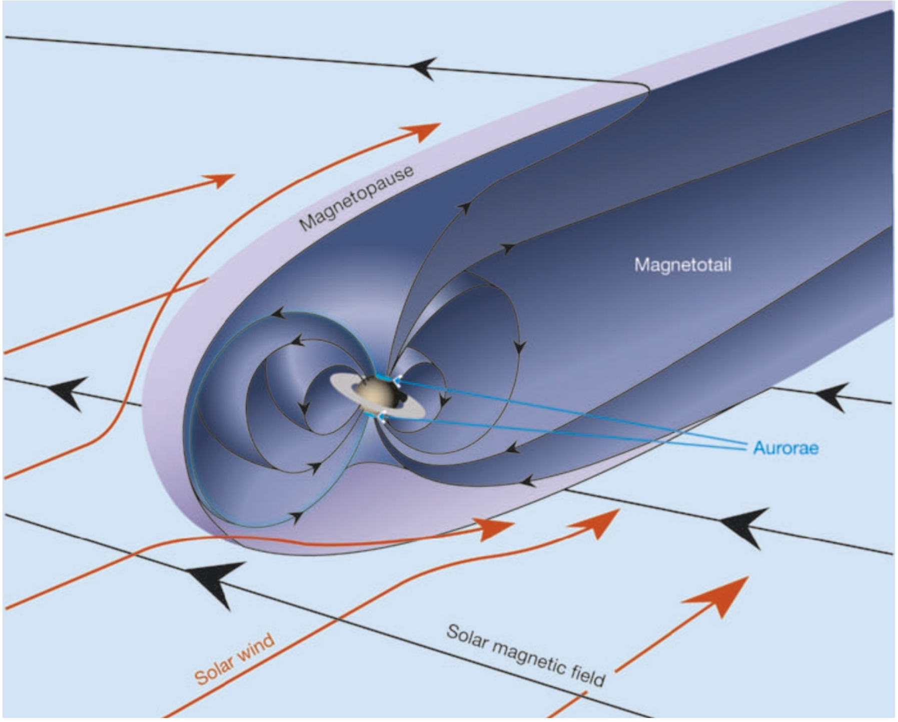

Figure 1 **Saturn's magnetosphere. The planet's magnetic field forms a cavity in the solar wind that extends roughly 20 Saturn radii towards the Sun and stretches several hundreds of radii away from the Sun in a magnetotail. The size of the planet and rings are exaggerated by a factor of two. Clarke *et al.*[1], Kurth *et al.*[2] and Crary *et al.*[3] report observations showing that, as occurs around Earth, the solar wind influences the auroral emissions and dynamics of the magnetosphere, but also that the controlling factors are different from those at Earth.**

between regions of open and closed magnetic field. The orientation of the solar magnetic field is important for magnetic reconnection and therefore strongly modulates dynamical activity and auroral emissions.

Unlike the situation near Earth, Jupiter's intense aurorae are caused by stresses associated with rotation rather than coupling to the solar wind. Jupiter's strong magnetic field couples profuse plasma from its moon Io to the planet's rapid spin (a 9.9-hour period). As the plasma spreads out and inflates the giant magnetosphere, strong electrical currents between the magnetosphere and Jupiter's ionosphere keep the plasma rotating (against the tendency to slow down owing to conservation of angular momentum). Observations of Saturn in 1981 by the Voyager spacecraft indicated that its magnetosphere dynamics may be similar to those of Jupiter and be driven by Saturn's fast rotation (a 10.7-hour period). However, Saturn's icy satellites are much weaker plasma sources than Jupiter's volcanic Io, making Saturn's magnetosphere less inflated, the stresses less, and the aurorae weaker. Moreover, earlier HST studies hinted that the solar wind influences the aurorae. Thus, when Cassini approached Saturn, scientists grabbed the chance to test the hypothesis that its magnetosphere dynamics and associated aurorae are controlled by the solar wind, as occurs around Earth.

For 22 days, Cassini's instruments measured the magnetic field, plasma density and plasma velocity in the solar wind while the HST and Cassini radio antennas monitored Saturn's auroral activity. Nature cooperated and provided a couple of interplanetary shock waves that passed the Cassini spacecraft on 15 and 25 January and hit Saturn's magnetosphere some 17 hours later. Clarke *et al.*[1] report HST observations of the subsequent brightening of auroral emission, and Kurth *et al.*[2] report accompanying increases in radio emission. Crary *et al.*[3] show a correlation of auroral intensity with solar-wind dynamical pressure, supporting the view that the solar wind has an Earth-like role at Saturn.

But further study showed that the solar-wind conditions that influence Saturn's magnetosphere dynamics are different from those that influence Earth's. Compression of the magnetopause by the solar wind is more important than reconnection of the solar and saturnian magnetic fields. Crary *et al.*[3] point out that at Saturn's orbit (9.5 times Earth's distance from the Sun), the solar magnetic field is fairly closely confined to the plane of Saturn's orbit around the Sun; the solar and saturnian fields are therefore largely at right angles to each other, so that the optimum conditions for magnetic reconnection are not met.

But there are further unknown complications to Saturn's magnetospheric dynamics and auroral activity: what are the effects of Titan, Saturn's largest moon, and of the 26° tilt of Saturn's southern pole towards the Sun? Studies of the terrestrial magnetosphere have shown the need for long-term monitoring to properly distinguish between the causes of various auroral effects. Cassini will make many more observations in its 75 orbits of Saturn. But the imaging spectrograph onboard the HST is no longer operational and the space telescope's future looks bleak. Furthermore, these vital but unglamorous synoptic studies of planetary magnetospheres currently have little appeal for NASA, whose science budget is being squeezed to pay for human space exploration. So it may be some time before we can follow up on these latest findings from Saturn. ■

Fran Bagenal is in the Laboratory for Atmospheric and Space Physics and the Department of Astrophysical and Planetary Sciences, University of Colorado, Boulder, Colorado 80309-0392, USA.
e-mail: bagenal@colorado.edu

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Neurodegeneration

Cellular defences destroyed

Dennis W. Choi

A lack of blood flow can kill nerve cells, by causing a massive influx of calcium ions. But what's happened to the cellular mechanisms for coping with excess calcium?

Without calcium, life would simply not be possible: it imparts strength to bones and serves as a messenger in myriad cellular processes. Underlying this ubiquitous signalling role is a 10,000-fold concentration gradient across the cell membrane, with 50–100 nM free calcium ions inside cells, separated by only a lipid bilayer from 1 mM calcium outside. Exquisitely regulated channels permit dollops of calcium to rush in across the membrane, causing localized increases in intracellular calcium levels and the activation of appropriate molecules. Yet under pathological conditions, such as a stroke, calcium can also be a killer, flooding into neurons and inducing lethal derangements. Although much has been learned about how excess calcium gets in, it has been puzzling that the mechanisms normally