changes to the Red List due to changing knowledge rather than to changing levels of extinction risk[11]. They also use these back-cast data to calculate error around the current Red List Index value due to genuine but as yet undetected changes in status. Finally, they provide a weighting for the index based on extinction probabilities, through which it becomes largely driven by actual extinctions. Although this gives narrower biodiversity coverage (because the contribution of most species towards this weighted index is negligible), it may provide a better measure of the loss of irretrievable genetic diversity.

As an immediate step for the assessment of progress towards the 2010 target, we suggest that the next meeting (in February 2005) of the Subsidiary Body for Scientific, Technical and Technological Advice to the convention should add the Red List Index to the other eight indicators already recommended for immediate testing. The index then needs expansion in coverage across other taxonomic groups. All mammal and amphibian species are currently being assessed, and Red List Indices for these will be available by 2010. Efforts to assess reptiles, fish and plants are also in progress but will require significant support to produce timely results. Moreover, a sampled Red List Index is under development, with the aim of providing an index that is taxonomically as well as geographically comprehensive. Similarly, the other eight indicators proposed for testing need considerable work to better inform progress towards the 2010 target.

Although we need to be able to measure progress (or lack thereof) towards the 2010 target, the more pressing need is to ensure funding and implementation of those conservation activities needed to actually achieve a significant reduction in the rate of biodiversity loss. Ultimately, an improvement in the Red List Index will require urgent investment in the conservation of species facing a high risk of extinction and of the habitats where they occur. ■

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Solar physics

Spots from rings

Paula J. Reimer

An ingeniously constructed record of sunspot activity shows that the current episode is the most intense for several thousand years. But that does not let us off the anthropogenic hook of global warming.

Dark spots or 'blemishes' on the face of the Sun (Fig. 1) were recognized from the early seventeenth century, and have since been identified as places where strong magnetic fields emerge from the Sun's surface. Data on sunspot numbers provide the longest observational record of solar activity. But that record is too short to document changes in activity occurring on timescales longer than the recognized cycles of 11- and 88-year periods, or to support claims for a connection between solar activity and Earth's climate on centennial to millennial timescales.

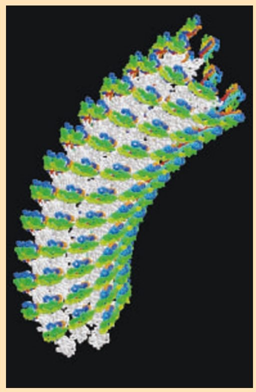
On page 1084 of this issue, however, Solanki *et al.*[1] describe how they have produced a reconstruction of sunspot number for the past 11,000 years. They have done so by connecting a series of models based on well-established physics, taking as their data the concentration of the carbon isotope ^{14}C found in tree rings, which provides windows on atmospheric and solar trends at known points in time.

The reconstruction shows that the current episode of high sunspot number, which has lasted for the past 70 years, has been the most intense and has had the longest duration of any in the past 8,000 years. Based on the length of previous episodes of high activity, the probability that the current event will continue until the end of the twenty-first century is quite low (1%).

Each model used in the reconstruction makes a step in connecting the tree-ring ^{14}C record[2] to sunspot number using parameters that were fixed by independent measurements (direct or indirect). Carbon-14, and some other isotopes such as the beryllium isotope ^{10}Be, are formed from the bombardment of the atmosphere by cosmic-ray particles. The ^{14}C in the atmosphere is converted to $^{14}CO_2$ and incorporated into the tree rings as they form; the year of growth can be precisely determined from dendrochronology. Production of cosmogenic isotopes is high during periods of low solar magnetic activity. But during the Sun's active phase (with

Molecular motors

Smooth coupling in *Salmonella*



Bacteria such as *Salmonella typhimurium* move by the action of their flagella. Depending on the direction of rotation, flagella either act singly, causing uncoordinated tumbling, or clump together into a single helical propeller for straight-line swimming. The 60-nm-long hook that joins the flagellar filament to its motor in the bacterial cell wall must thus bend through as much as 90° in a millisecond or less, all the time rotating at up to 300 revolutions per second. Elsewhere in this issue (*Nature* **431,** 1062–1068; 2004), Fadel A. Samatey *et al.* describe how they determined the atomic structure of this super-flexible universal joint, and thereby how it achieves such a feat of engineering.

The hook is a hollow tube assembled from 11 chains, or protofilaments, of a single protein, called FlgE. These protofilaments are stacked together with a slight helical twist that changes slightly with the direction of rotation.

Samatey *et al.* made their model by first determining the structure of the central region of FlgE by X-ray crystallography at a resolution of 1.8 Å. This was then fitted into the lower-resolution images of isolated, straight hooks as seen by electron microscopy. The final curved hook (shown here with individual protein chains coloured from blue through to red) emerged by computer simulation of the squashing and stretching of individual protofilaments.

This modelling showed that the hook's mechanical properties result from a combination of flexibility and rigidity at the molecular level. Individual protofilaments can grow and shrink in length by as much as 50% through flexing of a hinge that joins the two major domains of FlgE. However, the interlocking of adjacent subunits prevents the protofilaments from sliding against each other. The flagellar hook can thus bend but not twist, allowing efficient transmission of force from motor to propeller. **Christopher Surridge**

SPL

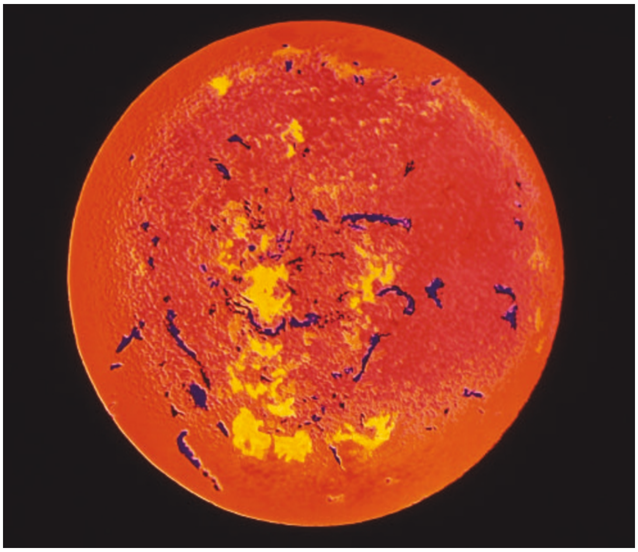


Figure 1 **Solar blemishes. This is a false-colour image of the face of the Sun, with sunspots as black patches. In the work discussed here, Solanki *et al.*[1] have produced a reconstruction of sunspot number going back 11,000 years.**

high sunspot number), the more intense solar wind — the ions streaming out from the Sun — deflects charged particles so that fewer of them enter Earth's atmosphere.

Solanki and colleagues' first step was to determine the rate of ^{14}C production using the tree-ring record of atmospheric ^{14}C concentration after removing the long-term trend in Earth's magnetic field, which modulates the cosmic-ray flux. The concentrations of ^{14}C in the atmosphere may also be affected by variations in ocean circulation, because carbon is partitioned between the atmosphere, the ocean and the biosphere. But there is no evidence of major oceanic variability over the past 11,000 years, and carbon fluxes in the biosphere are not sufficient to cause large changes in atmospheric ^{14}C.

The second step was to calculate the cosmic-ray flux from the data for ^{14}C production, by 'inverting' a model of the transport and modulation of galactic cosmic rays within the envelope of the solar wind; model inversion means working backwards from the answer to find the necessary input to produce that answer. Solanki *et al.* then reconstructed the Sun's open magnetic flux — the magnetic field that extends into the interplanetary medium — from a model of the effect of the open magnetic flux on the transport of galactic cosmic rays. Finally, a model describing the evolution of the open magnetic flux for a given sunspot number was inverted to produce estimates of sunspot number. Within well-defined limits of uncertainty, the series of models reproduce the observed record of sunspots extremely well, from almost no sunspots during the seventeenth century to the current high levels.

Climate variability on centennial to millennial timescales is documented in many palaeoclimate records going back at least as far as the end of the last glaciation, some 12,000 years ago. Whether solar activity is a dominant influence in these changes is a subject of intense debate[3–6]. The exact relationship of solar irradiance to sunspot number is still uncertain[7,8], but the reconstructed sunspot number will nonetheless provide a much-needed record of solar activity. This can then be compared with palaeoclimate data sets to test theories of possible solar–climate connections, as well as enabling physicists to model long-term solar variability. A better understanding of the mechanisms responsible for past climate variability will also help those using global circulation models to predict future climate change.

So does the current episode of high sunspot number imply that the Sun has had a significant role in the global warming of the late twentieth century? The answer is no. Although climate models differ in their estimation of the Sun's contribution to recent warming, even those that include spectrally varying changes in solar irradiance conclude that anthropogenic causes are the prime factor[9–12]. The high probability that this episode will end soon is not likely to cut us much slack in controlling global warming unless we reduce greenhouse-gas emissions. But because the solar influence may be more regionally variable than the effects of greenhouse gases[11], model-based predictions of regional climate change may be improved by this study. It is at the regional level that climate change will have the greatest impact on society. ■

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Evolutionary biology

Mortality and lifespan

Peter A. Abrams

How does natural selection affect lifespan? The question has exercised biologists for some years. The latest twist comes from ingenious experiments on tropical fish from different ecological backgrounds.

On page 1095 of this issue, Reznick *et al.*[1] describe how they have investigated one of the main factors that influence the evolution of an organism's lifespan. That factor is the risk of dying that a population faces as a result of environmental conditions (such as, in this case, predation). The study subjects are guppies, small tropical fish that are widely used in evolutionary studies, and the authors provide the first experimental support for the prediction that a higher environmental risk of mortality can select for inherently longer-lived organisms.

Guppies from the lower reaches of several rivers in Trinidad are subject to much higher rates of predation than those in the upper parts of the same rivers, where waterfalls block access by larger fish. In predator-free lab experiments, Reznick *et al.* found that guppies from the high-predation segments of two of the rivers lived up to 35% longer than those from low-predation segments of the same watercourse. In addition, the guppies from high-predation sites had a 40% longer reproductive span and reproduced at a higher rate. So a background of higher mortality under natural conditions has apparently led to the evolution of both a longer lifespan and a longer reproductive span. Their longest-lived fish, a female, is pictured in Figure 1.

A bit of history is required to see why this observation is surprising. Environmentally caused ('extrinsic') mortality has long been recognized as a key factor determining how natural selection moulds 'intrinsic' mortality — the death rate that a population would have under some standardized, generally benign, set of environmental conditions. Although evolution should favour lower