Mishima and colleagues' extensive analysis[2] documents a direct link between cell-cycle regulatory proteins and a key change in the structure of the mitotic spindle. Nevertheless, data just published by another group[6] indicate that our understanding remains incomplete. Surprisingly, these investigators show that deleting the CDC14 gene in *C. elegans* does not result in detectable defects in assembly of the central spindle, chromosome segregation or cytokinesis. Instead, mutant worms lacking CDC14 undergo extra, non-lethal cell divisions during larval development, apparently because a protein that is unrelated to ZEN-4 cannot be dephosphorylated. At least in *C. elegans*, then, CDC14 is not required for cell division. One must conclude that dephosphorylation is either not necessary for cell division or can be accomplished without CDC14. No doubt we can expect further chapters in this intriguing story. ■

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Palaeoclimatology

Fresh angle on the polar seesaw

Trond M. Dokken and Kerim H. Nisancioglu

During the last glacial period, climatic variation in the Northern and Southern Hemispheres was evidently linked. Modelling work points to freshwater discharge into the North Atlantic as a driving factor.

Climate during the period from 60,000 to 25,000 years ago, referred to as Marine Isotope Stage 3, was exceptionally variable. Ice-core records from Greenland suggest that the Northern Hemisphere underwent a series of rapid warming episodes, each followed by gradual cooling. The Southern Hemisphere had a similar climate pattern, but with relatively slow warming and less extreme temperatures. These so-called Dansgaard–Oeschger (DO) events occurred several times during this period, but the physical processes behind the timing and amplitude of the recorded temperature changes are unclear. On page 851 of this issue, Knutti and colleagues[1] present a conceptual model suggesting that discharges of fresh water into the North Atlantic had a larger part to play than was previously thought.

The relative timing of the climate changes in each hemisphere can be investigated by using variations in methane content to synchronize the timescales of changes in the ice cores taken from Greenland and Antarctica. And it seems that the temperature swings in the two hemispheres were offset, with changes in Antarctica preceding those in Greenland by just over a millennium[2]. This out-of-phase relationship between the two hemispheres has been invoked as evidence for a bipolar climate 'seesaw'[3], where cooling in the Northern Hemisphere is balanced by warming in the Southern Hemisphere (Fig. 1).

In general, the ocean's meridional overturning circulation (MOC) transports heat northward in the dense salty water near the surface of the Atlantic. As the water approaches the Norwegian–Greenland seas it cools and sinks into the deep ocean, where it is carried back south. According to the classical seesaw model, DO events are caused by a disruption of this circulation, resulting in cooling in high northern latitudes and a build-up of heat in the Southern Hemisphere[4,5]. One prime suspect for the cause of this disruption is a freshening of the surface ocean in the North Atlantic and the Nordic seas caused by massive releases of melt water from the surrounding ice sheets. Such a freshening would reduce the density of the water and prevent the northward limb of the MOC from sinking. The MOC would recover once the surface density increased again, and the Northern Hemisphere would then warm rapidly, drawing heat from the Southern Hemisphere.

The classical seesaw model assumes an anti-phase relationship between temperature changes in the north and south, with no time lag. But studies of Antarctic and Greenland ice cores[6] and model simulations[7] suggest that the anti-phase changes in Antarctic temperature lag those recorded in Greenland by 400–800 years. Based on these results, Stocker and Johnsen[8] introduced a revised model — the thermal bipolar seesaw — in which temperatures in the two hemispheres are out of phase, but with a lead of Greenland over Antarctica. In this model, the Southern Ocean acts as a heat reservoir that takes time to warm or cool, with a timescale that matches the estimated lag between the hemispheres.

But simulations based on the thermal seesaw model, although improved, still fail to match the temperature record deduced from the ice cores. So Knutti and colleagues[1] have now updated this model to improve the timing and shape of the simulated temperatures. They used a climate model that simulates processes in both the ocean and the atmosphere, and find that, in addition to disturbing the MOC, fresh water from Northern Hemisphere ice sheets might have amplified the temperature response in the Southern Hemisphere by another, more direct mechanism. They find evidence of anomalous transport of heat from the North to the South Atlantic Ocean in response to a large freshwater perturbation at high northern latitudes.

To account for this, the authors propose a mechanism that invokes a fast 'wave-adjustment', by which the depth of the ocean's upper layer of warm water (thermocline water) fluctuates by a process somewhat resembling a tide. This adjustment in the Atlantic sets up a southward cross-equatorial ocean current, which transports heat from north to south during periods of massive ice-sheet dis-

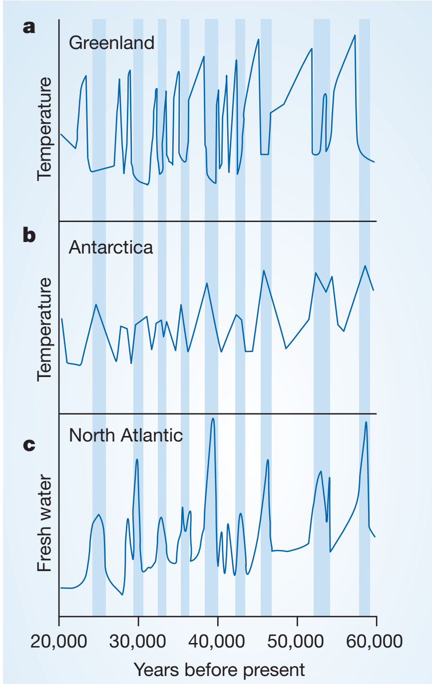

Figure 1 **Abrupt climate changes in the past glacial period.** a,b, **Simplified graphs of the temperature data retrieved from the Greenland (GRIP;** a) **and Antarctic (Byrd;** b) **ice cores. Increases in temperature in the Northern Hemisphere are balanced by decreases in the Southern Hemisphere, although the swings are slightly out of synch.** c, **A smoothed graph showing discharges of fresh water into the North Atlantic from the surrounding ice sheets, inferred from ocean sediment cores that contain glacial deposits[15]. There is a clear correspondence between periods of increased melt water in the North Atlantic and the most pronounced warming episodes in the Southern Hemisphere. This provides support for a northern trigger for the climate changes — as is assumed by the various bipolar climate seesaw models.**

charge. The authors suggest that up to a third of the southern temperature signal is due to this current, and that the remaining two-thirds is associated with the thermal-seesaw effect and changes in the large-scale MOC.

The classical bipolar seesaw and Knutti and colleagues' revised thermal–freshwater seesaw are intriguing, as they present physically based models to explain a set of observations. And indeed, the modelled temperature results fit very well with the ice-core temperature changes (Fig. 5 on page 855). To test all aspects of the new concept, however, more evidence is necessary, for example data on the strength of the overturning circulation. An obvious test for future studies would be to see how much of the variability observed in Antarctic temperature data can be explained by freshwater data from the North Atlantic.

The various versions of the bipolar seesaw model assume that climate changes in the Northern Hemisphere trigger a response in the Southern Hemisphere. And some evidence for a northern trigger is provided by the fact that observed increases in fresh water discharged into the North Atlantic follow the pattern predicted by the models relative to the ice-core temperature data (Fig. 1). However, an increasing number of calculations suggest that Antarctic temperature changes precede those in Greenland by 1,000–2,000 years[2,9]. Therefore, an alternative theory is that the trigger lies in the Southern Hemisphere. Model experiments[10–12] and ocean sediment-core data[13,14] suggest that a variety of processes in the Southern Hemisphere might have provoked changes in the MOC. These include changes in the strength of westerly winds and the circumpolar current; changes in Southern Ocean density structure; and gradual warming triggered by a shift in the main source of water entering the South Atlantic, either via the warm Indian Ocean or the cold Pacific Ocean.

For now, the notion of a southern trigger for climate changes is an interesting theory that lacks a conceptual model able to explain all the observations from Antarctica and Greenland. Regardless of whether north or south leads in DO events, we need to understand better why shifts in the MOC occur. However, conflicting evidence and numerous diverse lines of argument on how the climate of the two hemispheres is linked confuse the issue. At present, we lack the necessary data from the northern and southern oceans to put palaeoceanographic constraints on the past history of MOC mode switches from this bipolar perspective. In any event, understanding the cause and effect of previous abrupt climate changes is crucial for a rational assessment of the probability of such events occurring in the future. ■

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Structural biology

Anthrax hijacks host receptor

James G. Bann and Scott J. Hultgren

An atomic picture of how anthrax toxin binds to its host's cells reveals that the toxin commandeers a host receptor protein and tricks it into helping the toxin enter the cell.

In 2001, *Bacillus anthracis* made headlines when US Senators Thomas Daschle and Patrick Leahy received letters containing anthrax spores, highlighting the urgent need for an effective treatment against the bacterium. Once exposed to *B. anthracis*, the only treatment available involves a 60-day course of antibiotics that have unpleasant side-effects[1]. The race to develop more palatable alternatives that will work at any stage of infection is now focusing on anthrax toxin, the protein complex responsible for the bacterium's lethal effects.

On page 905 of this issue, Liddington and colleagues[2] report the X-ray crystal structure of one of the anthrax toxin proteins, the protective antigen (PA), bound to its receptor from the host's cell, capillary morphogenesis protein 2 (CMG2). This work explains the structural basis of how anthrax toxin recognizes CMG2, and suggests a mechanism by which CMG2 is duped into behaving as a molecular switch that controls the transfer of anthrax toxin into the cell's cytosol, an event that ultimately proves fatal to the host.

Anthrax toxin is composed of three proteins: protective antigen (so named because it is used as a vaccine), oedema factor and lethal factor. PA is a large protein consisting of four domains (I–IV), primarily involved in targeting the toxin to host cells by recognizing CMG2. The crystal structure[2] reveals that the high-affinity binding of PA with CMG2 (ref. 3) is due partly to the involvement of a magnesium ion at the interface between them. A key aspartic acid residue

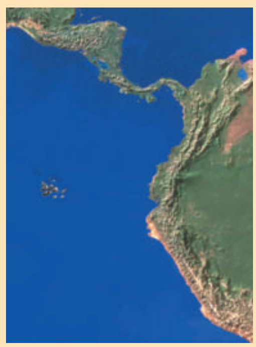
Oceanography

Islands in the stream

During the *Beagle*'s visit to the Galapagos Islands in 1835, Charles Darwin noted that the local climate was far less warm than would be expected from the islands' position on the Equator. The air-conditioning effect is due to the cooling influence of the surrounding oceans — part of which, according to C. Eden and A. Timmermann (*Geophys. Res. Lett.* **31,** L15308; 2004), arises from the very presence of the islands.

As this satellite image shows, the Galapagos are isolated in the vastness of the Pacific Ocean, lying about 1,000 km west of South America. This is nonetheless an oceanographically sensitive location, because the islands obstruct two components of a system of wind-driven ocean currents in the equatorial Pacific. The cool Southern Equatorial Current flows westwards as part of the Pacific subtropical gyre, and splits into a northern and a southern branch at the Galapagos. The subsurface Equatorial Undercurrent transports water eastwards between and beneath these two branches, and almost stops dead where it hits the islands.

Using a high-resolution numerical model, Eden and Timmermann have simulated equatorial Pacific currents with and without the Galapagos topography. The differences are significant. The islands produce



a wake-like pattern in both currents, with flow anomalies extending up to 2,000 km in an east–west direction. And as a result of stronger upwelling of cooler water from depth, sea surface temperatures just west of the Galapagos are up to 2 °C lower than they would otherwise be — hence the comparatively temperate climate.

Heike Langenberg