These questions must be answered before caspase inhibition can be considered as a target for anti-Alzheimer's drugs. The road to treatment and prevention of Alzheimer's disease is, therefore, still very long. But treatment of other neurodegenerative diseases — such as Huntington's disease — may be available much sooner, because the mechanism of neuronal cell loss is better understood, and it can be mimicked in animal models. □

Christian Haass is at the Adolf Butenandt Institute, Department of Biochemistry, Ludwig-Maximilians-University, Munich 80336, Germany.
e-mail: haass@as200.zi-mannheim.de

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Earth science

Excursions in geomagnetism

C. G. Langereis

The intensity of Earth's magnetic field varies on timescales varying from seconds to many tens of millions of years. Secular variation in the field, in terms of 100–1,000 years, can be estimated from historical records. But identifying variation on longer timescales requires continuous palaeomagnetic records from much deeper in the past, and in 1996 Guyodo and Valet[1] provided an analysis of 17 palaeointensity records going back 200,000 years. They integrated them into the so-called 'Sint-200' composite curve, which has since served as a standard. But it still covers only a comparatively brief period of Earth history.

As described on page 249 of this issue[2], Guyodo and Valet have now produced a new 'stack' of globally distributed records. They have analysed 33 records of relative palaeomagnetic intensity spanning the past 800,000 years, and have constructed the Sint-800 composite; the age models of all the records (which had already been normalized with appropriate correction factors) were refined by applying the same reference curves, thereby increasing the correlation between them. The much longer time span of Sint-800 allows insight into the longer-term behaviour of the geomagnetic field — in particular, into the putative effect of climate on magnetic intensity, and into the nature and occurrence of short 'excursions' during the past 780,000 years. This is the period known as the Brunhes Chron, during which the polarity of Earth's magnetic field is as it is now; the excursions are departures from the dipole field that are considerably larger than those seen in secular variation, and sometimes even attain opposite polarity.

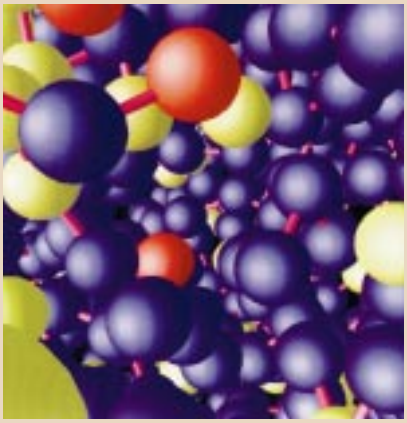
For some time there was speculation as to a causal relationship between Earth's magnetic field and phenomena such as climate variation and faunal extinctions. For instance when, in the 1970s, records of climatic change became available, it was proposed that change in magnetic intensity

Statistical physics

Glasses go critical

Why is polystyrene brittle but polyethylene rubbery? At room temperature, the first is a glassy material whereas the second is more like a highly viscous fluid. At least, that's the easy answer. But what, exactly, is a glass? Phenomenologically, it is a liquid that has 'jammed up' — cooled without freezing until translational molecular motion is arrested. But the transition from liquid to glass poses a deep theoretical problem; indeed, the deepest and most interesting in solid-state theory, according to Philip Anderson in 1995. Elsewhere in this issue (*Nature* 399, 246–249; 1999), Sharon Glotzer and co-workers establish a link between this transition and the critical phenomena familiar from equilibrium statistical physics.

The glass transition is a transformation not between globally stable equilibrium states but between metastable states: a supercooled liquid and a disordered solid. This, then, is the fundamental difficulty — the glass transition is of a dynamical nature, representing the point at which molecules become localized and relaxation times become very long. Yet the critical phenomena most studied in statistical physics — that is, the second-order phase transition as one passes through a critical point such as the Curie point of a ferromagnet — are transitions between



equilibrium states, for which a static, thermodynamic description is sufficient. How to reconcile the dynamical character of the glass transition with a thermodynamic picture has recently been an issue of wide interest (see, for example, S. Sastry *et al. Nature* 393, 554–557; 1998). The key seems to be the relationship between the topographic character of the energy landscape of the system and the way in which this is explored as the system evolves from one configuration to another.

Glotzer and her colleagues take a somewhat different approach, by focusing on correlations in the atomic motions of the glass-forming medium, in this case a polymer. At a critical point, correlations between the interacting particles develop a range much longer than the extent of the intermolecular forces. Take ferromagnetism: as the temperature is lowered through the Curie point, the spins on each magnetic particle become aligned. At the critical point itself, the correlation length of a spin becomes infinite — the spin is sensitive not just to the alignments of its near neighbours but to all others in the system.

Can such a diverging length scale be identified for the glass transition? The simulations by Glotzer and co-workers show that there seems to be a divergence in a dynamical length scale at the glass transition, namely the distance over which monomer displacements on the polymer chains are correlated. This is illustrated in the picture, a snapshot of the polymer very near the glass transition in which monomers that are moving in a correlated fashion are coloured similarly. (Red and yellow denote high mobility, and purple low mobility.) Related to this length scale is a dynamical variable that behaves like the static order parameter that characterizes equilibrium critical phenomena (the magnetization, in the case of a ferromagnet). In other words, it may be possible to mould the well-established conceptual framework of critical phenomena to the case of glass formation.

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could cause change in climate (nobody knew how: there was just a nice correlation). But it soon became evident that this idea stemmed from a failure to take account of variations in the amount of material magnetized, for instance through the availability of magnetic minerals which is largely under climatic control[3]. Because of this we now know that the intensity of the natural magnetization in sediments must be normalized by appropriate correction factors[4].

This procedure is thought to largely remove climatic influences from the palaeomagnetic record, and the remaining traces of climatic influence are usually taken to be insignificant in perturbing the true geomagnetic signal. Supporting evidence for the geomagnetic origin of the Sint-200 composite came from a stacked record of cosmogenic ^{10}Be in sediments[5]. This radionuclide is produced in the Earth's atmosphere, and its production depends on the degree of shielding by the Earth's magnetic field.

It has also been argued that both the Sint-200 and the ^{10}Be stack record are not entirely free of climatic influence[6]. Nonetheless, there was almost general agreement that any trace of climate is probably caused by insufficient normalization. That consensus was abruptly shaken by a paper by Channell *et al.*[7], published last year. Spectral analysis of two relative palaeointensity records from the North Atlantic showed apparent correlations with periodic variations in the eccentricity of Earth's orbit (100,000-year period) and in its obliquity (41,000-year period). The eccentricity component was ruled out by normalization, but not the obliquity one. Channell *et al.* therefore concluded that their record provides evidence that the Earth's obliquity influences geomagnetic field intensity, with a period of around 41,000 years. They suggested that this is caused by the effect of obliquity on precessional angular velocity and hence on precessional forces in the Earth's core.

Does this hypothesis take us back to the early 1970s? Not according to Guyodo and Valet[2]. They performed a spectral analysis of Sint-800, comparing every 400,000-year-long interval, in steps of 100,000 years, over their entire record, and found no evidence of any dominant stable periodicity in palaeomagnetic intensity. This, however, is no doubt a debate that will run for some time.

Another feature of Sint-800 is the occurrence of many intervals of low geomagnetic intensity. Low intensities of Earth's dipole favour the incidence of geomagnetic excursions, both in direction and intensity, because the non-dipole contribution of the field becomes significant. But it is not clear whether excursions should be considered as increased secular variation or as aborted reversals; and because of the imprecision of published excursion ages, it has even been speculated that excursions correlate with climate, for example with cold periods[8].

Guyodo and Valet[2] use a compilation of astronomically dated, globally occurring excursions[9], and find that they provide an excellent match with lows in geomagnetic intensity, particularly if the field is below 50% of its present strength. Moreover, they clearly show that there is no correlation with climate, effectively killing the idea that geomagnetic excursions are related to climate.

Instead, we have a fascinating new hypothesis, formulated by Gubbins[10], that relates excursions to processes in the Earth's core. The Earth's main magnetic field stems from electric currents in the liquid, iron-rich outer core. These currents derive from convective fluid flow, with a typical overturn time of about 500 years. The magnetic field of the solid inner core can change only by diffusion of the field[11], which has a timescale of about 3,000 years. The inner core thus stabilizes the geomagnetic field.

Gubbins[10] proposes that excursions occur when the geomagnetic field reverses in the liquid outer core but not in the solid inner core. The influence of the inner core delays full reversal of the field, during which time the original polarity may establish itself in the outer core. Gubbins argues that the short duration of excursions, 10,000 years or less[9], is consistent with the estimated diffusion time. Moreover, the large number of excursions since the last full polarity reversal 780,000 years ago, as discovered by Lund *et al.*[12] in high-resolution magnetic records from the western North Atlantic, agrees with the order-of-magnitude difference between dynamical timescales in the core.

Clearly, the Gubbins hypothesis[10] requires confirmation from much longer records, while at the same time a good estimate of excursion duration requires records that are accurately dated and of high resolution. Many excursions are not observed simply because they don't last long — more often than not, the geomagnetic signal may be distorted, or even lost, for example by post-depositional alteration of the rock after it has been magnetized. Excursions are most frequently observed during the Brunhes Chron (normal polarity, 0–780,000 years), a period that is sampled by many sedimentary cores of limited depth range. One problem with the preceding Matuyama Chron (reversed polarity, 780,000–2,580,000 years) is that it is difficult to show that normal polarity excursions are not caused by overprinting by the present-day (normal polarity) field.

So Guyodo and Valet's new, high-resolution composite of Earth's geomagnetic field tells us a great deal. From Sint-800, it now seems unlikely that geomagnetic field intensity has been influenced by Earth's orbit, or that geomagnetic excursions are related to climate; and we also have support for the new hypothesis[10] that excursions and dipole fields of low intensity are an inherent property of the geodynamo. What next? We will learn a lot more on the road to Sint-2,000. □

C. G. Langereis is in the Paleomagnetic Laboratory 'Fort Hoofddijk', Faculty of Earth Sciences, Utrecht University, Budapestlaan 17, 3584 CD Utrecht, The Netherlands.
e-mail: langer@geo.uu.nl

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Cell biology

Snail mail to the nucleus

Iain W. Mattaj and Elena Conti

Many macromolecules constantly move between the nucleus and cytoplasm of eukaryotic cells. Nuclear proteins and cytoplasmic RNAs, for example, must be transported from where they are made to where they act. Transit occurs via nuclear-pore complexes — large assemblies which span the nuclear envelope membranes, that separate the nucleus from the cytoplasm. Transport is mediated by receptor proteins, which shuttle between the nucleus and cytoplasm carrying cargo in one direction (Fig. 1). These receptors — known as importins and exportins — mostly belong to the importin-β protein family[1], and have also been called karyopherins. On pages 221 and 230 of this issue, Cingolani *et al.*[2] and Chook and Blobel[3] describe the structures of two different import receptors.

All members of the importin-β family interact with the GTP-bound form of a small GTPase called Ran. When Ran•GTP binds to importins, it causes release of the cargo (Fig. 1a); in contrast, exportins bind to their cargo only in the presence of Ran•GTP (Fig. 1b). The direction of transport depends on the concentration of Ran•GTP, which needs to be high in the nucleus and low in the cytoplasm[1]. But how does binding of Ran•GTP affect the conformations of the receptors — and, so, their ability to interact with cargo? The two new receptor structures[2,3], one with bound cargo and the other with Ran•GTP, provide the first insights into this conformational switch.

Cingolani and colleagues[2] studied