Adult bone-marrow cells were also thought to be a source of replacement heart muscle cells, but recently it was found that they cannot develop into cardiac cells[10,11]. However, several small-scale clinical studies suggest that they may improve cardiac function when transplanted immediately after a heart attack. Although it is unclear how this might work, and most studies did not include a control patient group, no detrimental effects were observed in patients receiving their own bone marrow in the heart. For this reason, there have been calls to set up large-scale, controlled clinical trials[12,13] using bone marrow, without extensive experiments in animals first.

Regenerating heart muscle by cardiac transplantation therapy is an ambitious goal, but with the current developments, it holds more than an abstract promise. ■

Christine L. Mummery is in the Hubrecht Laboratory and the Interuniversity Cardiology Institute of the Netherlands, University Medical Centre, Uppsalalaan 8, 3584 CT Utrecht, The Netherlands.
e-mail: christin@niob.knaw.nl

1. Nadal-Ginard B., Kajstura, J., Leri, A. & Anversa, P. *Circ. Res.* **92,** 139–150 (2003).
2. Condorelli, G. *et al. Proc. Natl Acad. Sci. USA* **98,** 10733–10738 (2001).
3. Laflamme, M. A., Myerson, D., Saffitz, J. E. & Murry, C. E. *Circ. Res.* **90,** 634–640 (2002).
4. Laugwitz, K.-L. *et al. Nature* **433,** 647–653 (2005).
5. Kehat, I. *et al. Nature Biotechnol.* **22,** 1282–1289 (2004).
6. Beltrami, A. P. *et al. Cell* **114,** 763–776 (2003).
7. Oh, H. *et al. Proc. Natl Acad. Sci. USA* **100,** 12313–12381 (2003).
8. Messina, E. *et al. Circ. Res.* **95,** 911–921 (2004).
9. Menasche, P. *et al. J. Am. Coll. Cardiol.* **41,** 1078–1083 (2003).
10. Murry, C. E. *et al. Nature* **428,** 664–668 (2004).
11. Balsam, L. B. *et al. Nature* **428,** 668–673 (2004).
12. Strauer, B. E. *et al. Circulation* **106,** 1913–1918 (2002).
13. Wollert, K. C. *et al. Lancet* **364,** 141–148 (2004).

Climate change

Let all the voices be heard

D. M. Anderson and C. A. Woodhouse

It's a tough job to excavate trustworthy records about past temperatures from the palaeoclimate archives. The application of a fresh approach, in the form of wavelet analysis of the data, is a step forward.

Records of temperature during the past two millennia provide clues to the natural variation we might expect in the future. They also support attempts to partition recent warming into natural and anthropogenic components, and to measure the sensitivity of climate to greenhouse gases in the atmosphere. Such long records come only from natural archives, for example tree rings, ice cores and other 'proxy' evidence, and interpreting them has generated spirited debate. The crux of the issue is how much warmer or colder the average temperature has been in several century-long intervals of the past 2,000 years, the two most intensively studied intervals being the Medieval Warm Period (about AD 1200–1400) and the Little Ice Age (AD 1600–1850). Could we be in for one of these natural swings in the future? If so, how large would it be?

On page 613 of this issue[1], Moberg *et al.* present a multi-proxy reconstruction of annual temperature for the Northern Hemisphere for the past 2,000 years. Such a reconstruction is not new in itself, but it is unique in the way that the authors consider the information encoded in proxies of different temporal resolution. They use a clever statistical approach, based on 'wavelets'[2], to combine the climate information preserved in different proxies at different scales, and generate a reconstruction that reflects variability on scales ranging from the annual to the multi-centennial. In effect, the different scales of information in the proxies are voices of different frequencies, and the aim is to hear them clearly.

Wavelet analysis is a powerful tool, already in use throughout science and engineering, and it is used here to extract, and then combine, the variance preserved in different proxies. The approach is both elegant and appropriate, providing a means of surmounting known limitations of the palaeoclimate archive. High-frequency (multi-year to multi-decade) variance is often blurred in all but the highest-fidelity ice or sediment records, and low-frequency (century-scale) variance is not usually well preserved in high-resolution tree-ring reconstructions, particularly those assembled from short overlapping series (the 'segment-length' curse[3]).

Using wavelets, the authors reconstruct a time series of Northern Hemisphere mean-temperature change from a suite of proxy records — hearing the high-frequency voices preserved in tree rings and the low-frequency voices retained in marine and lake sediments and other records. As a method of time-series analysis, wavelets offer several advantages, and are notably free from the assumption of stationarity (unchanging mean and variance) that makes most methods unsuitable for palaeoclimate time series.

The authors themselves recognize several shortcomings. The limited number of long tree-ring series available provides only a rough estimate of annual- to decadal-scale temperature variability in the Northern

NATURE

100 YEARS AGO

The excavations [of Stonehenge] produced clear evidence touching the mode of erection… (1) The ground on the site it was to occupy was removed, the chalk rock being cut into in such a manner as to leave a ledge, on which the base of the stone was to rest, *and a perpendicular face rising from it, against which as a buttress* one side would bear when set up. From the bottom of this hole an inclined plane was cut to the surface, down which the monolith which had already been dressed was slid until its base rested on the ledge. (2) It was then gradually raised into a vertical position by means first of levers and afterwards of ropes. The levers would be long trunks of trees, to one end of which a number of ropes were attached… (3) As the stone was raised, it was packed up with logs of timber and probably also with blocks of stone placed beneath it. (4) After its upper end had reached a certain elevation, ropes were attached to it, and it was then hauled by numerous men into a vertical position, *so that its back rested against the perpendicular face of the chalk which had been prepared for it.*
From *Nature* 9 February 1905.

50 YEARS AGO

"Symposium on Genetics of Population Structure." Besides six papers, the Proceedings of the Symposium contain short comments by Dobzhansky, Lerner and Epling, the conclusions by Buzzati-Traverso and the scholarly but delightful address of thanks by Haldane… Scossiroli reported on the results of selection for bristle number in *Drosophila* populations after heavy X-ray irradiations… there occurred a spectacular response to selection in the 'high' direction but not in the 'low' one… It could be that X-ray-induced inheritable variation is mainly in the direction opposite to that for which natural selection had to work harder— a point well worth investigation at the threshold of the atomic age… The summing up… clearly showed how far the classic theoretical framework of population genetics has led… This change in outlook is essentially a shift of emphasis from the single gene to the integrated systems of chromosomes, the genotypes of the individuals and the whole gene pool of populations.
From *Nature* 12 February 1955.

Hemisphere; the impact of this shortcoming on the reconstruction has not been assessed. Only rudimentary spatial averaging was applied, considering neither the spatial representativeness of each proxy nor the difference in the quality of the records as temperature proxies. But these shortcomings do not compromise the main conclusions, and can be addressed in future work.

The results reveal substantially more variance at the century scale, and an amplitude of change equal to about 1 K (about the same as the borehole reconstructions[4], and double the estimate based principally on tree rings[5]). Moberg and colleagues' reconstruction is consistent with results published earlier this year[6] suggesting that tree-ring and other proxies produced with regression-based calibration methods commonly underestimate the amplitude of change.

What have we learned from the palaeo record of the past 2,000 years? Most tree-ring and high-resolution multi-proxy reconstructions show that Northern Hemisphere mean temperatures have varied about 0.5 K over the past millennium (temperatures were 0.5 K colder during the Little Ice Age relative to the 1961–90 mean). In contrast, reconstructions using boreholes[4], and recent modelling analyses[6], reveal a larger amplitude, close to 1.0 K. The results from Moberg *et al.* support the larger amplitude; even without the elegant mathematics, direct inspection of their compilation of low-frequency records indicates that the temperature change was about 1 K in many places.

Are the different proxies equally trustworthy and problem-free? Probably not. But the authors have taken a fruitful approach by attempting to combine information from different proxies in a way that uses the unbiased climate information found in each of them. Is it appropriate to consider change averaged over entire hemispheres? The emphasis of many palaeoclimatologists is shifting instead towards the identification of regional patterns of change. Many of the studies incorporated by Moberg *et al.* had that purpose — for example, even though the global climate system is interconnected, the tropical monsoon regions may have undergone different changes from those experienced by the high Arctic or the west Pacific.

The approach pioneered by Moberg *et al.* will serve equally well as a strategy to evaluate past climate change in each of these regions by combining information from different proxies. Indeed, the challenge for palaeoclimate researchers — and their funding agencies — is to produce multi-proxy reconstructions at the appropriate regional scale so that all of the voices can be heard. ■

D. M. Anderson and C. A. Woodhouse are in the Paleoclimatology Branch, National Climatic Data Center, Boulder, Colorado 80305-3328, USA.
e-mail: david.m.anderson@noaa.gov

1. Moberg, A., Sonechkin, D. M., Holmgren, K., Datsenko, N. M. & Karlén, W. *Nature* **433,** 613–617 (2005).
2. Torrence, C. & Compo, G. P. *Bull. Am. Meteorol. Soc.* **79,** 61–78 (1998).
3. Cook, E. R., Briffa, K. R., Meko, D. M., Graybill, D. A. & Funkhouser, G. *Holocene* **5,** 229–237 (1995).
4. Pollack, H. N. & Smerdon, J. E. *J. Geophys. Res.* **109,** doi:10.1029/2003JD004163 (2004).
5. Mann, M. E. & Jones, P. D. *Geophys. Res. Lett.* **30,** doi:10.1029/2003GL017814 (2003).
6. Von Storch, H. *et al. Science* **306,** 679–682 (2004).

Palaeoecology

Down to the woods yesterday

Peter D. Moore

What were European forests like following the last ice age and before the advent of agriculture? The pollen record in Ireland provides a unique perspective from which to examine ideas on the question.

The past may be a foreign country, and a pretty inaccessible one at that. But it does not deter people from exploring it. One of the objects of conservation is to retain or recreate primeval habitats, but this can only be achieved with sound knowledge of the structure and composition of past ecosystems, and the factors that sustained them.

Temperate deciduous forests (Fig. 1) are an example of such a habitat, and palaeoecologists are constantly probing the mists of time to answer some difficult questions — just how dense was the canopy of forests before the advent of agriculture, and what part did large grazing animals play in maintaining clearings and open conditions? This is a controversy that is of more than academic interest, and the latest foray, published by Fraser Mitchell in the *Journal of Ecology*[1], seeks to assure us that the forests were dense and that big grazers played a limited role in woodland dynamics.

The technique of pollen analysis, developed in the early twentieth century, revealed a progressive invasion of forest over western Europe[2]. In the mid-Holocene, between 8,500 and 5,500 radiocarbon years ago (BP), trees dominated the rain of pollen that fell on the lakes and bogs, where the pollen became preserved in stratified layers. Analysts interpreted this abundance of tree pollen as indicative of closed-canopy forest that had re-established itself following the last glacial retreat and then covered most of the landscape.

There were some puzzling features, however, such as the presence of 'non-arboreal pollen', the pollen of herbaceous plants, especially grasses and sedges, that persisted through the supposed closed-forest period. These open-habitat indicators became much more abundant as agricultural activities took hold and early farmers began to clear the forests around 5,500 BP. But the bogs and lakes where the pollen accumulated had their own local vegetation that included herbaceous plants, so their presence in the pollen record of the 'closed-forest' period was not regarded as surprising.

However, there are two additional aspects

R. CUMMINS/CORBIS

Figure 1 **Tree story in Europe. Pollen grains preserved in ancient lake sediments show that even before the advent of agriculture there were gaps in the forest. But were large grazing mammals responsible?**