rotator phases. This is the first observation of such phases induced by any type of direct metal–metal bonding. Above the transition temperature the materials have been shown by polarized microscopy to be crystalline (with the individual molecules having cross-sectional areas typical of alkyl chains) but gentle mechanical pressure can deform them.

The new gold-based rotator phases are unique in that mesogenic (liquid-crystal) properties are induced in the absence of traditional mesogenic units such as aromatic rings. It remains to be seen whether these properties will lead to useful applications, perhaps in the areas of liquid-crystal and sensor technology. ■

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Archaeology

Out in the cold

John A. J. Gowlett

Humans are very adaptable: during the last ice age, they apparently lived within the Arctic Circle. The discovery suggests that, although cold, the region was probably not covered in ice at the time.

Archaeological finds described by Pavlov and colleagues on page 64 of this issue[1] show for the first time that humans were present north of the Arctic Circle almost 40,000 years ago, in the last ice age. The idea of people living in a land gripped by an ice age goes back to nineteenth-century France, but the new finds extend both the geographic and the temporal range of the phenomenon. The results should also rekindle debate about the effects of the climate on the movements of early human populations.

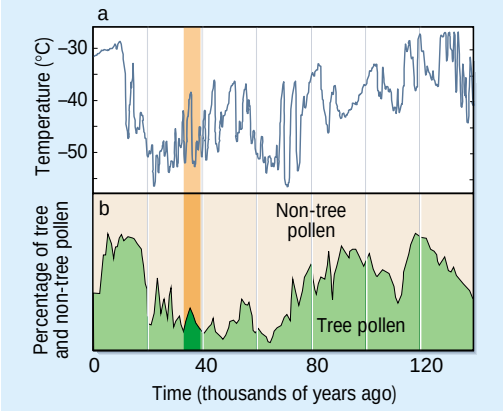

Figure 1 **Climate and early human populations. Pavlov *et al.*'s finds from Mamontovaya Kurya[1] are dated to the period shown by the orange shading. This is set against the backdrop of:** a, **the temperature record of the last ice age, obtained from analysis of Greenland ice cores such as GRIP2 (ref. 7); and** b, **the pollen record from Lake Kopais, Greece[13]. These and other findings suggest that the ice sheets of the last glaciation were, most of the time, fairly restricted on the northeastern flank, allowing people (Neanderthals or early modern humans) to settle there. (The timescale is only approximate for** b.**)**

Pavlov *et al.*[1] carried out fieldwork at a site in the Russian Arctic known as Mamontovaya Kurya, which dates to Middle to Upper Palaeolithic times, some 35,000–40,000 years ago. Their finds comprise various stone tools and over a hundred mammalian bones, as well as a mammoth tusk bearing cut marks that were apparently made by tools. The age of the tusk was determined by a radiocarbon-dating technique known as accelerator mass spectrometry, illustrating the power of this technique for dating artefacts directly rather than by the age of the sediments in which they are found.

It is not possible from these finds to determine whether they were left by Neanderthals or by some of the first modern humans in Europe, but this is equally true of most contemporary artefacts further south. In the broader scheme of things, knowing who made the tools is less important than simply knowing that someone was adapted to the cold conditions. This is significant because all evidence from recent foragers (such as Inuit or Siberian Yukaghir) suggests that adaptation to northern climes requires high levels of technological and social organization.

That said, it would be interesting to know whether these people were Neanderthals or early 'anatomically modern' humans. If they were Neanderthals, this provides further support — along with their anatomical adaptations and the height and remoteness of many of the sites at which Neanderthal artefacts have been found — of the Neanderthals' rugged durability and extensive capabilities[2]. Their high degree of meat-eating, indicated by recent studies of stable carbon and nitrogen isotopes in bone[3], also suggests a specialized socioeconomic adaptation, perhaps developed over a long period in environments rich in animals but limited in plant resources.

If, on the other hand, these ice-age people were modern humans, then this is evidence of a remarkably rapid advance to the north — modern humans had only just set foot in the southeast of Europe. Pavlov *et al.*[1] incline towards this view — the nearest archaeological finds to the south, along the Pechora River near the Urals[4,5], are allied more closely with those Upper Palaeolithic traditions associated with modern humans than with the Middle Palaeolithic toolkits more commonly associated with Neanderthals.

The bones and artefacts found at Mamontovaya Kurya suggest that the northeast must have been relatively dry and ice-free in this period of the ice age. These finds are one outcome of a major interdisciplinary study that has also shown that, for most of the time, the ice sheets of the last glaciation were far more restricted on their eastern flank than is sometimes suggested. Support for the existence of large ice-free areas also comes from Finland[6], where direct radiocarbon dating of key evidence — this time a series of mammoth teeth — establishes the presence of large animals between 22,000 and about 40,000 years ago. The existence of large animals implies that the environment was steppe-like, consisting of open grassland.

Icy cold, however, it was. Temperature estimates derived from variations in the ^{18}O content of Greenland ice cores such as GRIP2 (at a latitude of about 72° north) show wild fluctuations throughout the middle of the last glaciation[7] (Fig. 1), but it was always at least 10 °C colder than today. The dominant feature of the time from 60,000 to 30,000 years ago was a series of saw-toothed temperature fluctuations of up to 15 °C. Similar temperatures were found in intensive research across north-central Europe, using indicators such as beetle remains and pollen as proxy evidence[8]. These indicate an average annual temperature of −1 °C in the Netherlands from 50,000 to 41,000 years ago, with the coldest month being at least 10 °C below this[9].

Yet, despite this newly detailed backdrop, recent archaeology-based discussion about the Neanderthals has not — with certain exceptions[10] — been concerned primarily with climate. The emphasis has been on chronology, population movements, and the nature of cultural contact (if indeed there was any) between Neanderthals and incoming modern humans (Box 1, overleaf). There has been good reason to focus on the cultural changes that occurred in the past 40,000 years, as this time period includes the more rapid developments of the Upper Palaeo-

Box 1 Neanderthal prehistory

Neanderthals are the best known group of early hominids; they lived in Europe and parts of Asia, and survived until about 30,000 years ago. Hominid specimens from about 300,000 years ago already had some characteristics of Neanderthals, but it is not known how much further back their roots go. Some early humans entered Europe at least 800,000 years ago, but later technological innovations shared with other regions suggest that new populations may have entered the continent.

Better known are the later, 'classic Neanderthal' specimens from the last glaciation. The features of these Neanderthals, who were around from about 100,000 to 30,000 years ago, are more uniform than those of than earlier populations, suggesting that there may have been a population crash (with a subsequent 'bottleneck') around the start of this period[15]. All Neanderthals were strongly built, with long, low crania and large faces. Damage to their skeletons attests to the fact that their lives were hard. If they were as carnivorous as seems likely, they would have had many encounters with dangerous prey.

After 150 years of debate, and despite a steady flow of new knowledge, the Neanderthals' position alongside anatomically modern humans remains uncertain[16]. The means by which Neanderthals were eventually replaced by modern humans is fiercely contested, as is the degree of genetic separation. Many specialists see Neanderthals as a distinct species, contributing little to either the gene pool or the culture of later populations. But modern human and Neanderthal remains, genetics and tool traditions all show intriguing continuities[17].

Less controversial is the new willingness to admit that Neanderthals had qualities that showed their 'humanity'. For example, Neanderthals are contenders for the first display of caring behaviour: a crippled individual at Shanidar in Iraq was clearly sustained by the support of others. But it is not easy to pick out behavioural patterns that were distinctive of Neanderthals — burials, bone-based tools and symbolism are all found earlier in populations of anatomically modern humans. The continued debate over the relationship between Neanderthals and modern humans is stimulating, but should not mask enormous advances in dating, genetics and other forms of analysis. **J.A.J.G.**

lithic era and falls within the range of radiocarbon dating. Climate change has seemed less important because different Neanderthal populations successfully made distinct adaptations to different regions[11], and these adaptations remained roughly the same for 200,000 years[12].

But climate may have its moment again. The dramatically spiky record from ice cores in the interval from 60,000 to 40,000 years ago, together with pollen evidence, implies that steppe environments moved up and down rapidly from southeast Europe to the far north, and suggests that climate change could have been crucial in promoting population movement and cultural change. In 'warmer' parts of the ice age, as Pavlov *et al.*[1] show, fauna-rich steppe environments and humans apparently reached the Arctic. During colder intervals, wooded environments gave way to steppe even in Greece[13]. In the Last Glacial Maximum, 20,000 years ago, conditions were so ferociously cold that even modern humans were driven down towards the south of France[14]. Indirectly, such responses may help to explain the southward expansion of Neanderthals into the Middle East around 60,000 years ago, and (perhaps) the similar spread of Upper Palaeolithic Aurignacian human populations around 30,000 years ago.

The new finds[1] show that humans had a hold on the north, if only for a short time. Although there are questions to be answered, the artefacts illustrate both the capacity of early humans to do the unexpected, and the value of archaeologists researching in unlikely areas. ■

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Daedalus

Pay for the Internet

The collapse of many Internet dotcom companies reflects the deep unease of many consumers at trusting their credit-card numbers to the insecurity of the Internet. How, then, to bring alive the Internet's commercial potential? Micro-payments have somehow not taken off. Daedalus reckons that a consumer will trust to the Internet what he might lose on a bet — maybe US$50 or so. Rogue sites that charge more than this, in one or many payments, must be discouraged.

DREADCO Financial Services is therefore inventing a special low-limit card or cheque for Internet use. Their small limit cannot be overexploited, so the risk is low. It may feature an exact cut-off negotiated automatically with the company beforehand.

Thus the great dream — that of our own personal library from the Internet — would come true at last. The big publications, like *Nature* and *The Times*, will continue as before, for those who need them. But people who visit their websites, and those of all other publications too, will note those articles that seem interesting, and amass them for small proportional payments, controlled by the DREADCO card. A software 'gopher' could do this or haggle over it all the time. It would store its haul on a hard disk, a vast improvement on a stack of old papers. Occasionally you might glance at the screen to see what you had caught, and you could print out your results. Those for whom citations are magical, in support of personal glory, would relish the chance to amass them. The whole media scene would be one vast newspaper or magazine, with perfect indexing, no wasted time, and maybe the deletion of items no longer of interest.

Why doesn't this happen now? The academic media are deeply divided about how freely to release their papers onto the Internet, or what time delay to adopt before doing so. But once most publishers had taken the plunge, the worth of any delay would soon be shown by market forces, clear to everyone. Daily newspapers would lose value in a few days, and weeklies in a few weeks; academic journals of more lasting value should hold that value longer. Daedalus reckons that when a journal has amassed more citations than it quotes itself, its value starts to decay. But journal publication would remain useful, partly because editorial scrutiny weeds out the nonsense, and partly because anyone specializing in the area is better off subscribing to the journal. David Jones