the hot surface. Furthermore, the cooling rate can be calculated from the time it takes the drop to evaporate.

Previous studies have raised the Leidenfrost temperature by incorporating hierarchical structures into the surface to be cooled. Such structures combine nanometre-sized features designed to draw (or wick) liquid to the hot surface with sparse, micrometre-sized textures that act as vents to prevent vapour from lifting the droplet[4,5]. This combination can raise the Leidenfrost temperature by hundreds of degrees, yet as the surface temperature increases, the amount of vapour produced also increases, and this can disrupt the process of drawing liquid to the surface. Designs that decouple the venting and wicking help[5], but at sufficiently high surface temperatures, the vapour accumulates in the wicking region, limiting performance.

To engineer a surface design that achieves high cooling rates at record-high temperatures, Jiang and colleagues fused an insulating mesh between thermally conductive micropillars (Fig. 1b). The mesh is made from silicon dioxide fibres that absorb water droplets and draw them towards the steel micropillars, where the liquid vaporizes. The vapour then escapes through U-shaped channels lying beneath the mesh.

Architecturally, this design is similar to the hierarchical structures developed previously[5]. However, a key difference is that heat conducts quickly between the steel base and pillars, but slowly in the mesh membrane. This mismatch is crucial, because it means that the vapour is generated where the pillars and mesh meet, where it cannot interfere with the absorption of liquid by the mesh. Indeed, Jiang and colleagues demonstrated that, when they removed this feature by making both the membrane and pillars thermally conductive, the surface was effectively cooled to temperatures of up to 500 °C — consistent with the limits of previous designs[4,5] — but not beyond this point.

By introducing the mismatch in conductivity, Jiang and colleagues showed that their surface could be spray cooled from ultrahot temperatures in excess of 1,100 °C. This value is particularly relevant, because 1,100 °C is around the temperature at which a material undergoing the boiling crisis recovers the ability to cool in response to internally generated heat. This achievement indicates that the surface might avoid the boiling crisis, rather than merely delaying it. The authors also demonstrated that their design could be applied to curved and flexible surfaces, opening up the possibility of retrofitting existing heat exchangers and pipes.

Finally, Jiang *et al.* combined mechanistic modelling with numerous systematic experiments, enabling them to form and verify predictions for the parameters of their design. This is the most influential contribution of the study, because it provides in-depth understanding of how these parameters affect the cooling rate, and can therefore guide future improvements.

Increasing the peak cooling rate would be one such improvement. The team's modelling suggests that this could be achieved by increasing the mesh pore size (to draw the liquid to the pillars more quickly) and deepening the channels (to speed up the removal of the excess vapour). In applications for which overheating is a concern, it would also be preferable to have the cooling rate increase sharply with temperature instead of remaining constant, as it does in the current design. Small modifications, such as a non-uniform mesh or channels of varying depth, might enable such a sharp increase by passively adjusting the flow of water and steam as the temperature increases.

Taken together, Jiang *et al.* have demonstrated an innovative approach and a clear understanding of their system, both of which are certain to inspire future cooling strategies.

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Archaeology

A grave matter of ancient kinship in Neolithic Britain

Neil Carlin

An investigation into the nature of genetic connections between individuals interred in the same chambers of an ancient tomb in Britain about 5,700 years ago sheds light on kinship in an early society. **See p.584**

Archaeologists have long suggested that the placement of human remains in tombs during the Stone Age of northwestern Europe reflects one of the ways in which kinship was created and negotiated. Biological descent is presumed to have played a part, but relatively few cases of close genetic relationships have previously been uncovered from these tombs. This is partly because only a couple of studies have investigated the genetic lineage of multiple burials from the same site. Now, an innovative study of a chambered tomb at Hazleton North in southwestern Britain has analysed the genomes of 35 out of at least 41 people, including 22 adults, buried there over the course of a century. On page 584, Fowler *et al.*[1] reveal notable information about the social relationships between these individuals, who lived around 5,700 years ago. The authors' findings provide a uniquely high-resolution, multigenerational and spatio-temporal analysis of the connections between the people who were interred together in the monument.

> **"All those who were descended from two particular maternal lineages were found in one chamber."**

Hazleton North was constructed between approximately 3695 and 3650 BC by an early farming community, at least a century after the start of the Neolithic period in Ireland and Britain[2]. The Neolithic period was accompanied by numerous technological, cultural and social changes, such as the construction of megalithic monuments at various sites on these islands, and the introduction of cattle and cereals from continental Europe[3]. The earliest evidence for such Neolithic practices coincides with the arrival to these islands of people with distinctive genetic signatures found in continental Europe. This is where, in the case of the Hazleton North tomb, the ancestors of the deceased individuals predominantly came from.

Our knowledge of these kinds of broad-scale genetic changes in a population stems from the work of archaeogeneticists. Much of this type of analysis focuses on using ancient DNA from relatively few individuals to identify genetic-sequence clusters found across vast periods of time and space[4]. The Hazleton North work is, instead, part of a movement towards more-microscale studies of ancient DNA that analyse multiple samples from fewer sites. Such an approach provides key information about people's mobility, chromosomal sex, genetic ancestors and biological relatedness, which, together, has enabled reconstructions of prehistoric kinship.

By focusing on genome analyses of most of the people interred in a single tomb over a 100-year period, Fowler and colleagues' work considerably advances the contribution of ancient-DNA research to our understanding of the diversity of intimate relationships in a Neolithic community. Their integration of these genetic profiles with the archaeological evidence, including evidence of how people were buried, enables the reconstruction of a family tree that spans more than five generations. This highly detailed approach is necessary to reveal how both biological and non-biological relationships were understood at the Hazleton North monument, and to develop a more complete understanding of kinship beyond the limits of genealogy.

The Hazleton North tomb is an early Neolithic chambered monument known as a long cairn; tombs of this type are found across much of southern Britain. Like a small proportion of other long cairns in southwest Britain, it comprises two opposing rectangular, slab-built chambers placed back to back, but separated by and enclosed in the same long stone mound (Fig. 1). Each chamber is connected by a passage to its respective entrance in the northern or southern side of the cairn. Fowler and colleagues demonstrate that this dual architectural layout had a key role in the organization of relationships between the human remains that were successively placed in the various parts of the tomb.

These burials have not been notably disturbed, and seem to have been found in the manner in which they were buried in the Neolithic. However, there are differences between the treatment of those in the northern and southern chamber areas. For example, bones from the former showed more evidence of exposure to scavengers before their deposition than do bones from the latter. More importantly, the deliberate construction of two separate chambers and the subsequent placement of burials therein seems to have been guided by different maternal relationships.

All those who were descended from two particular maternal lineages were found in one chamber, whereas most of those from a different maternal lineage were buried in the other chamber (Fig. 1). This suggests that both the tomb's architecture and the location of particular burials in it were directly connected to kinship relations. This is a unique finding, not least because it indicates that maternal relationships were significant for configuring kin in Neolithic Britain. However, anthropologically speaking, this finding is unsurprising, given that maternal ancestry is often important even in communities configured around paternal ancestry (patrilineal societies).

Fowler and colleagues' work reveals that, overall, more biologically male than female individuals were present among the analysed burials. Furthermore, 26 of the 35 people from this tomb who were analysed genetically were biologically related on their father's side to a first degree (for example, they were parents, siblings or children) or a second degree (such as grandparents, grandchildren, uncles, aunts, nephews, nieces and half-siblings). The data reveal that burial in this tomb was closely associated with descent from a specific 'founding' male individual from the earliest generation analysed, who reproduced with four female partners.

Adult male descendants of this lineage and their adult female reproductive partners were identified in the tomb, as were two daughters who were children when they were buried. By contrast, adult daughters of this lineage were completely absent. This suggests a pattern in which men generally stayed where they were born, whereas some women moved away to form new relationships with their partner's kin, with whom they were subsequently buried. This is described as a predominantly patrilocal (or virilocal) residence pattern. However, it is possible that some adult women might not have moved elsewhere, but instead received a funerary treatment that did not result in their inclusion in this tomb.

Although patrilineality has been demonstrated elsewhere in the European Neolithic[5], this is the first direct, in-depth evidence for it from Ireland or Britain. It is consistent with the indirect evidence provided by two previous studies of Neolithic megalithic tombs in Britain and Ireland[6,7]. For example, the men buried in two neighbouring tombs in the west of Ireland had different Y-chromosomal genetic signatures (haplogroups) — which are passed down from father to son — that remained distinct from each other over time, although no close relatives were found in either monument[7].

The results from Hazleton North reveal that men and women had children with multiple partners, indicating that they were not monogamous. Three of the burials that were not part of the main lineage (that of the founding male individual) were of adult sons and a grandson of three women who had also reproduced with lineage-associated men. This suggests that some of the men might have adopted their partner's children from other reproductive unions. If so, this would confirm that kinship was not fixed by biology, but that it instead emerged from a range of social practices.

Although burial in the tomb was mainly structured around concepts of biological relatedness, 8 of the 35 sampled individuals are not close biological relatives or reproductive partners of anyone in the main lineage. Even so, they were found in close spatial proximity to all the others in the chambers. This suggests that these eight people were also considered to be important kin for reasons that go beyond sexual reproduction or parentage. In many societies, genetics, blood or biology are neither a determining nor a necessary factor of relatedness: people make their kin through cultural practices conducted as part of the particular context of their society, such as living, working or burying their dead

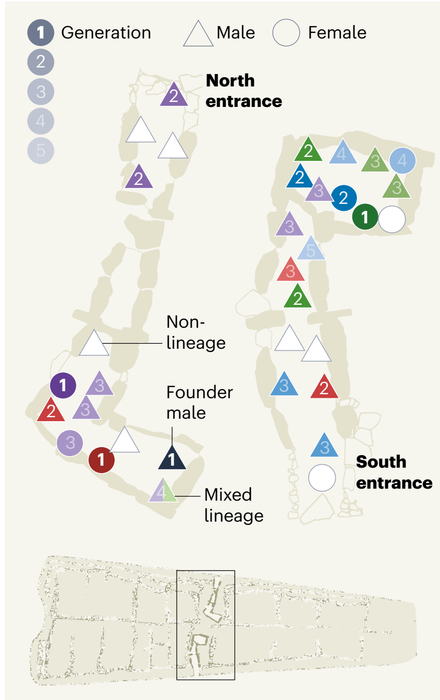

Figure 1 | Multigenerational burials in an ancient tomb. Fowler *et al.*[1] report the DNA analysis of more than 30 individuals, over 5 generations, who were buried at Hazleton North in southwestern Britain around 5,700 years ago. The authors find that one man (called the 'founder' male individual in this diagram) had children with four different women. The remains of one of these women were not found (for the lineage coloured blue). Most individuals were part of one of these four maternal lineages (each coloured differently; lighter shades of colour denote more-recent generations). Burials occurred in the northern and southern tomb compartments. Fowler and colleagues found that individuals belonging solely to two of the maternal lineages (coloured green and blue) were buried only in the southern compartment, suggesting that maternal ancestry was an important aspect of the individuals' kinship. Some individuals (non-lineage) who were not part of the four maternal lineages were also buried at this monument, raising the possibility that they formed kinship ties not based on shared ancestry.

together[8]. Indeed, a considerable strength of Fowler and colleagues' report is the nuanced way in which they consider these very issues and thereby avoid many of the problems highlighted in critiques of kinship reconstructions through ancient DNA[9]. Notably, the authors recognize that social and kinship organization are not always the same, and that the use of patrilineal descent to frame burial practices is not evidence of a male-dominated society[10].

A limitation of this and many other archaeological studies is that, although the authors recognize that chromosomal sex is only one aspect of how sex and gender are biologically or culturally defined, they still use the presence of an X and a Y chromosome to indicate male/man and two X chromosomes to indicate female/woman. Using these present-day binary categories of sex and gender as if they were neutral, stable or biologically determined automatically shapes the study's results and affects their conclusions[10,11]. There is great scope for future exploration to better understand how identities, including gender, were constructed in this community by avoiding such categorizations (for example, not to presume whether any of the burials were male or female, but rather to look at how difference emerges from the treatment of each burial). Nonetheless, Fowler and colleagues have provided invaluable insights into the social practices and values of a Neolithic community, including their evidence of a combined role for patrilineal and maternal descent in creating kin relations. The big question now is whether similar results can be reproduced in future studies using the same innovative methods to further our understanding of the kinship practices associated with Neolithic tombs across northwest Europe.

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Ancient DNA

Bronze Age genomes reveal migration to Britain

Daniel G. Bradley

The genomes of hundreds of individuals who lived in Great Britain and in continental Europe during the Bronze Age provide evidence for a migration of people from the continent to southern Britain between 1000 and 875 BC. **See p.588**

Around the year 2300 BC, a man now nicknamed the Amesbury Archer was buried with exceptional riches near the ancient stone monument Stonehenge in southern England. The Amesbury Archer and the items buried with him provide a snapshot of a culture in the south of Britain that used metal and created distinctive ceramics, known as Bell Beaker pottery. This man was also an immigrant: analysis of oxygen isotopes in the enamel layers of his teeth that had formed in childhood suggested he originated from the Alps in central Europe[1]. On page 588, Patterson *et al.*[2] analyse his genome and those of hundreds of other ancient individuals buried across Britain, as well as in continental Europe, to unravel Britain's migratory past with unprecedented granularity.

For decades, the idea that large-scale migrations explained changes in a region's culture had fallen from favour[3], mostly because reconstructions of massive, unidirectional migrations were exploited by destructive political movements in the early twentieth century. The concept of migration is still a source of discussion among geneticists and archaeologists, who can ascribe slightly different meanings to the term. For archaeologists, it has usually meant a large, one-way movement during a circumscribed period of time[4]. For geneticists, it can also encompass something more subtle — a process by which the genetics of a population can be gradually altered through the movement of a few migrants at a time.

> **"The authors uncover a large-scale migration of people from continental Europe to southern Britain between 1000 and 875 BC."**

By piecing together the contributions of different ancestries to the genetic backgrounds of hundreds of pre-Roman British genomes, Patterson *et al.* clearly describe evidence of both sharp and more gradual migrations. First, the time of the Amesbury Archer marks a genetic 'turning point' in the Neolithic–Chalcolithic transition at around 2450 BC. Second, the authors uncover, for the first time, a large-scale migration of people from continental Europe to southern Britain between 1000 and 875 BC.

The Archer's genome is from the end of the Neolithic period (3950–2450 BC), when individuals in Britain uniformly had what the authors call majority 'early European farmer' (EEF) ancestry. This ancestry was carried to Europe thousands of years earlier by agriculturists from Anatolia, in what is now Turkey[5,6]. Changes in the proportion of this EEF ancestry in the British population are a powerful indicator of inward migration. From the Archer's time onwards, the proportion of EEF ancestry among British individuals drops steeply (Fig. 1). This decline is associated with what is known as the Bell Beaker horizon, when we know that the westward movement of people originating from the Pontic–Caspian Steppe in Asia, across much of northern Europe[7,8], found its way to Britain and Ireland[9,10].

Once the EEF ancestry in southern Britain was diluted, its contribution to the genetic background of individuals in that region fluctuated a little before stabilizing for around a millennium. It then rose again between 1000 and 875 BC — in the Late Bronze Age — reaching a steady state that persisted through the Iron Age, which spanned from about 800 BC to AD 43 (Fig. 1). The previously unknown change in ancestry during the Late Bronze Age is probably due to migration from the nearby continent.

Patterson and colleagues' modelling of admixture (the mixing of genetic lineages) suggest that the most likely source populations for this renewed influx of EEF ancestry derive from sites in France — although pinpointing its origins is difficult, because the regions closest to Britain remain undersampled. Indeed, the