Using DNA to Reveal Information about Past Cultural Landscapes

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The genetic information contained in the cells of our bodies—and in those of plants, animals, and other organisms in our environment—can be considered a material record of the past. The DNA that encodes this genetic information represents a molecular genealogy that captures aspects of our unique individual histories and our shared human journeys. In this article, I provide an overview of the ways in which the field of genetics can contribute to emerging conceptions and understandings of past cultural landscapes.

Heritability is the key attribute of DNA that affords us a view into the past. However, different types of DNA are passed from parent to child in different ways. Human cells contain two main types of DNA: mitochondrial DNA and nuclear DNA. Mitochondrial DNA is located in the mitochondrion—part of the cell devoted to energy conversion—and it is inherited strictly through the maternal line, from mother to child. In contrast, nuclear DNA is found in the cell's nucleus—a specialised DNA-protecting compartment—and is inherited from both parents. The exception is the Y-chromosome, which is usually only possessed by males. Despite being nuclear DNA, the Y-chromosome is inherited through the paternal line, from father to child. As a result, the DNA of a single individual can potentially provide information about their direct line of maternal ancestry (mitochondrial DNA), direct line of paternal ancestry (Y-chromosome), and their broader family relationships (the other 'autosomal' nuclear DNA).

Genetic information can be used to trace the ancestry of living people back over thousands of years. These lines of ancestry can illuminate major events in human history. A good example of this principle is the role that genetic data have played in establishing a 'recent' African origin for all living humans. When tracing back the genetic ancestry of any two individuals, eventually a point of coalescence is reached—their common ancestor—beyond which their lines of ancestry are identical. On average, when comparing the ancestry of any two non-African individuals this common ancestor is reached fewer generations in the past compared to an African and non-African individual, or two African individuals. This pattern is consistent with the descent of non-African humans from a single ancestral population that migrated out of Africa tens of thousands of years ago. However, we are greatly limited in the level of detail about past cultural landscapes that can be obtained by only tracking the ancestry of living individuals.

While genetic information from living individuals strongly supports an African origin for modern populations around the world, it reveals much less about the exact routes of migration and other events that occurred along the way. This is because lines of ancestry drawn from living individuals, and their common ancestors, cannot be directly linked to specific locations or ancient cultures. Further, by comparing only living individuals we remain blind to the stories of individuals and populations who left no living descendants—possibly encompassing entire past groups of people. Fortunately, these limitations can be addressed by obtaining genetic information—'ancient DNA'—directly from the remains of deceased individuals, revealing vanished lineages. However, while ancient DNA is a powerful tool, it can be challenging to obtain and has limitations of its own.

Death of an organism does not result in the immediate disappearance of its DNA. Instead, chemical processes and decomposition by bacteria and fungi gradually dilute and damage the DNA. Eventually the DNA vanishes, but DNA entombed within bones and teeth—at least those that have been protected from the elements and high temperatures—can often survive for tens of thousands of years. However, the highly degraded nature of this ancient DNA makes it vulnerable to contamination, so precautions must be taken by researchers to avoid accidentally transferring their own DNA to remains via shed hair and skin, sweat, or saliva. Even then, the diluted quantities of ancient DNA make it much more expensive to study compared to DNA from modern individuals. Fortunately, advances in DNA sequencing technology over the past decade have drastically reduced the costs associated with ancient DNA research, throwing open the door to more widespread adoption of genetic information in studies of landscape archaeology.

At a local scale, ancient DNA can be used to determine the relationship between long-deceased individuals. This can provide information about family structure and burial practices. For example, Schroeder et al. (2019) used ancient DNA to investigate the relationships of 15 individuals uncovered in a 5000 year-old mass grave in Poland. These data revealed that the individuals mostly belonged to one extended family—all the men shared a paternal lineage (the same Y-chromosome type) and were likely brothers, half-brothers, or cousins, while maternally inherited mitochondrial DNA indicated that their mothers were also among the buried individuals. The authors pointed to perimortem skeletal injuries and suggested these indicate a rival group massacred the family. But the DNA analysis was able to show that biologically closely related kin were placed next to each other in the grave, implying that the people who buried these 15 individuals knew or were otherwise able to identify immediate (social) family groups (siblings, or mothers and their children) within the extended family. The DNA results clarified that genetic relationships informed the choices made in the placement of individuals in the mass grave.

At a broader scale, ancient DNA can be used to help track the movement of groups of ancient peoples. This can assist investigations of potential relationships between the movements of people and changes observed in styles of artefacts or cultural traditions identified across extensive regions. For example, the origin of the 'Corded Ware' archaeological 'culture' in Central Europe has been a long-standing question in the study of European archaeology. The 'Corded Ware culture' shares aspects of material culture with another archaeological 'culture' grouping, labeled the Yamnaya and identified with people who lived in the Pontic-Caspian steppe region. Prior to the advent of ancient DNA research, it was impossible to test whether this similarity in the material cultures of Yamnaya and Corded Ware resulted primarily from mass human migration or from non-demographic transmission of a cultural package. Haak et al. (2015) showed that the genetic ancestry of individuals associated with Corded Ware cultural materials was closely linked to that of people associated with Yamnaya cultural materials, suggesting that a mass migration of people from the steppe played a major role in the expansion of their cultural practices across Central Europe. The authors also speculate that this migration might be the mechanism by which Indo-European languages spread into Europe. Thus, ancient DNA from human remains has an important role to play as an independent line of evidence for testing archaeological ideas and understandings based on other material records.

Human remains are not the only source of ancient DNA with relevance to landscape archaeology—genetic information can also be obtained from refuse or objects made from plants or animals. These data can reveal information about diet, subsistence strategies, trade, and movement. For example, coastal middens in New Zealand document the past use of marine resources by early Māori. However, the variety of cetaceans (whales and dolphins) represented in these sites has been unclear due to anatomical similarities between species and the cultural practice of modifying bones to create objects. Ancient DNA from these middens allowed Seersholm et al. (2018) to identify several cetaceans—including fin whale and orca—that had never previously been reported from an archaeological context in New Zealand, expanding knowledge about the breadth of early Māori subsistence practices. Similar insights can be gained from plant remains—Jensen et al. (2019) obtained genetic data from a piece of 5700-year-old 'chewing gum' (actually chewed birch pitch) from a site in Denmark, which revealed not only the ancestry of the individual who chewed it, but also provided genetic evidence for a prior meal comprising duck and hazelnuts.

Genetic information not only allows the identification of individual species of plant and animal—as above—but potentially also the geographical source of those organisms. For example, there was a well-documented European trade in walrus ivory from the ninth through to the seventeenth century. The exact origin of the ivory is documented less well and several major sources are possible—Greenland, the Canadian Arctic, or the Barents Sea. By tracing the genetic ancestry of ancient traded ivory and modern walruses, Star et al. (2018) found that the geographical source of walrus ivory changed through time. However, they also found that between c. 1125 and 1400 CE, the walrus ivory in Europe may have come exclusively from Norse Greenland. Application of genetic methods can also identify the origin of other goods, including domestic animals and crops, and thereby reveal networks of cultural exchange. In some cases, this may overturn previously accepted interpretations—indeed, genetic information has recently confirmed that modern and prehistoric domestic horses do not descend from those associated with peoples with a Botai material culture from Central Asia, where the earliest archaeological evidence for horse husbandry some 5500 years ago is found, but from another as yet unidentified source (Gaunitz et al. 2018).

Among the most exciting opportunities presented by ancient DNA is the prospect of obtaining information about occupation from locations with no other material record. It has recently been demonstrated that genetic information can be recovered directly from ancient sediments, revealing the past presence of humans or other organisms even in the absence of physical remains. For example, Zavala et al. (2021) obtained mitochondrial DNA from sediments corresponding to stratigraphic layers spanning over 100,000 years from Denisova Cave in southern Siberia. These genetic data show that at various times Denisova Cave was intermittently occupied by two groups of archaic hominins—Neanderthals and Denisovans—as well as anatomically modern humans. Importantly, in many of these stratigraphic layers there are no skeletal remains nor stone tools that would otherwise suggest occupation. This may indicate something about the mode of occupation and source of DNA—perhaps the site was only used ephemerally and DNA originates from excrement or shed skin and hair. Or perhaps occupation was more intensive and other evidence of occupation has simply disappeared over time, with DNA originating from micro-particles of degraded bone and tooth. Either way, it is clear that genetic information from ancient sediments potentially represents an extraordinary source of data for landscape archaeology.

The potential of genetic information from ancient sediments extends beyond establishing occupation—it encompasses entire cultural landscapes, including the environmental conditions under which occupation occurred. In addition to humans, Zavala et al. (2021) also identified the presence of DNA from other large mammals in the sediments from Denisova Cave, including camels, horses, bears, and hyenas. The relative abundance of DNA from these other species also appears to change between stratigraphic layers, hinting at changing environmental contexts of human occupation. Beyond mammals, ancient plant DNA can also be obtained directly from sediments, either complementing data from pollen and phytolith records or providing novel insights in the absence of other data. For example, Seersholm et al. (2020) used plant DNA in sediments from Hall's Cave in Texas, USA, to demonstrate the continuous presence of hackberry and oak in the environment immediately outside the cave throughout the Younger Dryas cooling event (12,900–11,700 cal BP), while other plant species—such as walnut—disappeared temporarily. Importantly, while pine pollen has been detected in Hall's Cave, Seersholm et al. (2020) failed to detect any pine DNA—consequently, the pine pollen is likely to be aeolian-derived and not from the immediate environment outside the cave. Genetic information therefore has a unique niche among the range of techniques available to archaeologists.

'Landscape archaeology' as defined in this Element draws in all dimensions of the broader spatial contexts of past human lives. In this article, I have described how genetic information—especially ancient DNA—can feed into that overarching goal. However, the disciplinary intersection of genetics and more traditional archaeological methods is still relatively new, and geneticists must ensure that they engage ethically with the present-day communities affected by their research (Ávila-Arcos et al. 2022). Conscientious and equitable genetic research has an important role to play in the future of landscape archaeology—I am excited for the new insights to come.

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