On the relevance of the European Neolithic

R. Alexander Bentley, Michael J. O'Brien, Katie Manning and Stephen Shennan

Antiquity / Volume 89 / Issue 347 / October 2015, pp 1203 - 1210
DOI: 10.15184/aqy.2015.98, Published online: 09 October 2015

On the relevance of the European Neolithic

R. Alexander Bentley[1], Michael J. O'Brien[2], Katie Manning[3] & Stephen Shennan[3]

Sustainability, culture change, inequality and global health are among the much-discussed challenges of our time, and rightly so, given the drastic effects such variables can have on modern populations. Yet with many populations today living in tightly connected geographic communities—cities, for example—or in highly networked electronic communities, can we still learn anything about societal challenges by studying simple farming communities from many thousands of years ago? We think there is much to learn, be it Malthusian pressures and ancient societal collapse, the devastating effects of European diseases on indigenous New World populations or endemic violence in pre-state societies (e.g. Pinker 2012). By affording a simpler, 'slow motion' view of processes that are greatly accelerated in this century, the detailed, long-term record of the European Neolithic can offer insight into many of these fundamental issues. These include: human adaptations to environmental change (Palmer & Smith 2014), agro-pastoral innovation, human population dynamics, biological and cultural development, hereditary inequality, specialised occupations and private ownership.

Whether the Neolithic is considered part of the Anthropocene (Smith & Zeder 2013) or part of the 'Palaeoanthropocene' (Foley *et al.* 2013), it was the stage in which humans became active shapers of the Earth system. Archaeological evidence from multiple continents suggests that prehistoric land management may, until recently, have been vastly underestimated (e.g. Gartner 2001; Bliege Bird *et al.* 2008; Heckenberger & Neves 2009). Ruddiman's (2013) hypothesis—that increases in atmospheric carbon dioxide around 8000 years ago and methane about 5000 years ago were anthropogenic, caused by forest clearance, livestock pastoralism and early rice irrigation—can be more specifically tested using archaeological data (e.g. Fuller *et al.* 2011; Kaplan *et al.* 2011). In continental Europe, however, there is little evidence for intensified land clearance prior to the Bronze Age, about 3750 years ago (Bradshaw 2004; Berglund *et al.* 2008). This is because the small-scale intensive cultivation of the *Linearbandkeramik* (LBK) is effectively invisible in pollen diagrams (e.g. Bogaard 2014; Lechterbeck *et al.* 2014). In a Neolithic with a small population size and ephemeral environmental impact (Bogucki 1993; Zimmermann *et al.* 2009), "whole areas may indeed have been subject to only episodic and intermittent occupation for centuries if not millennia after the adoption of agriculture" (Scarre 2000: 828).

Debate

[1] *Department of Comparative Cultural Studies, University of Houston, 233 McElhinney Hall, Houston, TX 77204, USA (Email: rabentley@uh.edu)*
[2] *Department of Anthropology, University of Missouri, Columbia, MO 65211, USA*
[3] *Institute of Archaeology, University College London, London WC1H 0PY, UK*

ANTIQUITY 89 347 (2015): 1203–1210 doi:10.15184/aqy.2015.98

Even if the extent of Neolithic land clearance was not substantial everywhere (McMichael *et al.* 2012), debate concerning the modern Malthusian limits of the planet (Rockström *et al.* 2009; Barnosky *et al.* 2012; Ehrlich & Ehrlich 2013; Hughes *et al.* 2013) makes relevant study of prehistoric population growth. The occurrence of the Neolithic on multiple continents reveals how fertility rates vary over very long timescales in the kinds of small-scale subsistence communities that fundamentally inform the evolutionary study of modern fertility (Mace 2008; Bocquet-Appel 2011). For decades the view has been that agriculture initiated higher fertility in Neolithic Europe, effectively enabling steady population growth for all those subsequent millennia (Bocquet-Appel 2011). Although occurring at vastly different rates, both ancient and modern cereal domestication has increased yields, nutrition content and climatic resilience of domestic crops (Dayton 2014).

New evidence, however, indicates that Neolithic populations fluctuated through millennial-scale cycles of population growth and decline (Zimmermann *et al.* 2009; Shennan *et al.* 2013). In Britain and Ireland, pollen evidence suggests forest clearance by growing numbers of farmers from about 6000 years ago (Whitehouse *et al.* 2014; Woodbridge *et al.* 2014), followed by a decline in both population and human impact approximately 5500 years ago. It was not until late in the fifth millennium BP that population levels and associated land clearance were renewed. In continental Europe, the abundance of radiocarbon dates from the Neolithic—over 13 000—enable their use as a statistical proxy for population size through time, which demonstrates a recurrent pattern of population boom and bust following the introduction of farming into Europe (Shennan *et al.* 2013; Timpson *et al.* 2014). As more such finely resolved time-series data become available, abrupt changes may resolve themselves and we can perhaps determine if there were early warning signs in the lead up to these critical transitions (Scheffer *et al.* 2009).

Between cycles of population growth and decline (Shennan *et al.* 2013; Timpson *et al.* 2014), population bottlenecks will have had a considerable impact on the genetic and cultural diversity of subsequent growth periods, with strong selective pressures acting on populations. Nutrition, disease resistance, climatic adaptations and group alliances will have affected survival rates during these population bottlenecks. Although Neolithic farmers were shorter than Mesolithic hunter-gatherers, had bad teeth and suffered from farming-related diseases (Jackes *et al.* 1997; Holtby *et al.* 2012; Bickle & Fibiger 2014), the Neolithic still provided a selective advantage for those biologically evolved for adult lactose tolerance and carbohydrate digestion (Itan *et al.* 2009, 2010; Laland *et al.* 2010). If dairy farming constituted its own evolutionary niche in the European Neolithic (Laland *et al.* 2010; Gerbault *et al.* 2011; O'Brien & Laland 2012; O'Brien & Bentley in press), lactose-tolerant lineages may have emerged as an increased proportion of the population. As a result, the modern European digestive system is partly a legacy of Neolithic dairy farming and cereal production. These ancient origins may yield insight into the breakdown of the insulin-regulatory system that underlies modern diabetes and obesity.

Ownership of food production fundamentally changed in the Neolithic; this has contemporary relevance as the world debates who 'owns' new, genetically modified crops (Eisenstein 2014). While the landscape of Mesolithic Europe was probably communal for hunting and gathering (e.g. boar, aurochs, deer, eggs, fish, shellfish, hazelnuts, medicinal plants), Neolithic farmers cultivated their crops (wheat, barley, peas, flax, opium poppy) in plots that were probably owned by specific households or lineages and intensively managed for long periods (Bogaard 2004; Lüning 2005; Bogaard *et al.* 2011). With the evolution of land ownership, the Neolithic was clearly a watershed phase in the origins of socio-economic inequality (Shennan 2011a; Pringle 2014). Although evidence for ascribed status among European Neolithic burials has been recognised for some time (e.g. Nieszery 1995; Jeunesse 1997), new evidence is accumulating for differential access to resources. Ownership of cattle is likely to have signified wealth or status, and owners of large dairy herds probably had a selective advantage over smaller owners or non-owners. Wealth was therefore another likely factor in Neolithic survival, and livestock wealth usually predicts better reproductive success in terms of surviving children (e.g. Holden & Mace 2003). Neolithic farmers also raised pigs, sheep and goats, but cattle produced valuable milk, as well as meat, hides and traction (Bogucki 1993; Vigne & Helmer 2007; Salque *et al.* 2013). If livestock herding was a hereditary specialisation (e.g. Bogucki 1993), as suggested by isotopic studies of Neolithic skeletons (Bentley *et al.* 2008), then this selective advantage would have favoured wealthy, lactose-tolerant, cattle-owning lineages for generations, especially during population bottlenecks.

This amounts to a theory of niche construction among Neolithic dairy farmers (Brock *et al.* in press), and even though testing this hypothesis requires more prehistoric data than currently exists, each year brings increasingly sophisticated lines of evidence from Neolithic contexts (e.g. Skoglund *et al.* 2012, 2014; Bollongino *et al.* 2013; Brandt *et al.* 2013, 2015; Lazaridis *et al.* 2014). Some of the most detailed source material comes from the Neolithic village of Vaihingen, Germany, where palaeobotanical evidence, combined with an extensive analysis of ceramic decoration, suggests that different family lineages had access to different portions of land for cultivation or stock keeping (Bogaard *et al.* 2011). Ceramic analysis across groupings of houses has led Strien (2010) to argue that different 'clans' and lineages within Vaihingen were signalled by decoration on pottery and by lineage-specific craft techniques and raw material sources. Bogaard *et al.* (2011) propose that certain groups had access to more local, and presumably valuable, resource patches, whereas others had to travel farther afield for their subsistence needs. This is consistent with isotopic evidence from LBK sites from eastern France to Austria, which suggests that males buried with polished stone adzes had access to more local resources than those without (Bentley *et al.* 2012).

The tendency for cattle ownership to co-occur with patrilineal kinship (Holden & Mace 2003) may also provide a framework for the archaeological, archaeogenetic and linguistic evidence favouring patriliny and livestock ownership in the European Neolithic (Bogucki 1993; Cavalli-Sforza 1997; Eisenhauer 2003; Bentley *et al.* 2008, 2012; Bogaard *et al.* 2011). Patriliny would have been conducive to the growth of hereditary inequality over time, as males endeavoured to retain resource access within their lineages. These patrilineages may have become specialised stock-keepers and cultivators (Bogucki 1993; Eisenhauer 2003; Vigne & Helmer 2007; Bentley *et al.* 2008). If women made pottery with lineage-dependent decorative styles learned from their mothers (Strien 2010), distinctive pottery design motifs may track the residential movement of women (Claßen 2009).

In terms of Neolithic society and technology, the relatively low-level, fluctuating populations may have resulted in founder effects (Shennan 2000). The related archaeological discussion of population size and cumulative culture (Henrich 2004; Powell *et al.* 2009;

Shennan 2011b; Bentley & O'Brien 2012) is echoed by a new economic theory that twenty-first century populations will lead new technologies, which are capable of keeping pace with environmental demands (Malakoff 2013). This, in turn, feeds back into the origins of inequality. Social memory, which was so resilient in Neolithic societies (Hodder & Cessford 2004), may leave legacies in modern populations, such as the suggestion that millennia of rice agriculture in China brought about more holistic and collective social norms than the wheat-intensive Neolithic of Europe (Talhelm *et al.* 2014), or that norms associated with the prehistory of plough-use continue to affect modern fertility (Alesina *et al.* 2011).

Insights into cooperation are demonstrated in how the exchange of foodstuffs mitigates the risk of seasonal uncertainty between different regional systems. If climate fluctuations undermined the stability of Neolithic societies (Gronenborn 2007), the disruption of exchange may have been as important as reduced productivity. These may provide important lessons for the twenty-first century regarding the effects of global warming on food supply (e.g. Battisti & Naylor 2009), the increased likelihood of warfare (Hsiang *et al.* 2013) or a reduction in labour capacity (Dunne *et al.* 2013).

More generally, the detailed regional diversity of the material and cultural data from Neolithic Europe—including burial practices, pottery decorations, stone tools, craft techniques and raw material sources (Modderman 1988; Lüning *et al.* 1989; Gronenborn 1999)—makes for an excellent testing ground of culture evolutionary process, including the neutral theory of 'cultural drift' (Shennan & Wilkinson 2001; Bentley & Shennan 2003), variations of which are now applied widely to contemporary phenomena, even Twitter (Gleeson *et al.* 2014). Similarly, concepts of cumulative culture, tested in the Neolithic and before, underlie theories of modern innovation and the combinatorial possibilities of technology (Hausmann & Hidalgo 2011).

Archaeology is increasingly playing a significant role in these debates as we begin to learn from the early agricultural societies where so many trends began. The role of people in changing global environments and climate has become an issue of massive concern. Human diets have never been subject to closer scrutiny, and the links between genetic patterns and subsistence practices are becoming ever clearer. The consequences of a human population that is heading towards ten billion members are unknown. Will a new equilibrium be reached, or will we see a repeat of the boom-and-bust patterns visible in prehistory but on a much larger scale because of the strength of global interconnections? Are we doomed to ever-greater inequality as a result of the increased concentration of resources in fewer hands? The continuing relevance of the Neolithic has never been more apparent.

References

ALESINA, A., P. GIULIANO & N. NUNN. 2011. Fertility and the plough. *American Economic Review: Papers & Proceedings* 101: 499–503. http://dx.doi.org/10.1257/aer.101.3.499

BARNOSKY, A.D., E.A. HADLY, J. BASCOMPTE, E.L. BERLOW, J.H. BROWN, M. FORTELIUS, W.M. GETZ, J. HARTE, A. HASTINGS, P.A. MARQUET, N.D. MARTINEZ, A. MOOERS, P. ROOPNARINE, G. VERMEIJ, J.W. WILLIAMS, R. GILLESPIE, J. KITZES, C. MARSHALL, N. MATZKE, D.P. MINDELL, E. REVILLA & A.B. SMITH. 2012. Approaching a state shift in Earth's biosphere. *Nature* 486: 52–58. http://dx.doi.org/10.1038/nature11018

BATTISTI, D.S. & R.L. NAYLOR. 2009. Historical warnings of future food insecurity with unprecedented seasonal heat. *Science* 323: 240–44. http://dx.doi.org/10.1126/science.1164363

BENTLEY, R.A. & M.J. O'BRIEN. 2012. Cultural evolutionary tipping points in the storage and transmission of information. *Frontiers in Psychology* 3: 1–14. http://dx.doi.org/10.3389/fpsyg.2012.00569

BENTLEY, R.A. & S.J. SHENNAN. 2003. Cultural transmission and stochastic network growth. *American Antiquity* 68: 459–85. http://dx.doi.org/10.2307/3557104

BENTLEY, R.A., J. WAHL, T.D. PRICE & T.C. ATKINSON. 2008. Isotopic signatures and hereditary traits: snapshot of a Neolithic community in Germany. *Antiquity* 82: 290–304. http://dx.doi.org/10.1017/S0003598X00096812

BENTLEY, R.A., P. BICKLE, L. FIBIGER, G.M. NOWELL, C.W. DALE, R.E.M. HEDGES, J. HAMILTON, J. WAHL, M. FRANCKEN, G. GRUPE, E. LENNEIS, M. TESCHLER-NICOLA, R.-M. ARBOGAST, D. HOFMANN & A. WHITTLE. 2012. Community differentiation and kinship among Europe's first farmers. *Proceedings of the National Academy of Sciences USA* 109: 9326–30. http://dx.doi.org/10.1073/pnas.1113710109

BERGLUND, B.E., T. PERSSON & L. BJÖRKMAN. 2008. Late Quaternary landscape and vegetation diversity in a north European perspective. *Quaternary International* 184: 187–94. http://dx.doi.org/10.1016/j.quaint.2007.09.018

BICKLE, P. & L. FIBIGER. 2014. Ageing, childhood, and social identity in the early Neolithic of central Europe. *European Journal of Archaeology* 17: 208–28. http://dx.doi.org/10.1179/1461957114Y.0000000052

BLIEGE BIRD, R.B., D.W. BIRD, B.F. CODDING, C.H. PARKER & J.H. JONES. 2008. The "fire stick farming" hypothesis. *Proceedings of the National Academy of Sciences USA* 105: 14796–801. http://dx.doi.org/10.1073/pnas.0804757105

BOCQUET-APPEL, J.P. 2011. When the world's population took off: the springboard of the Neolithic demographic transition. *Science* 333: 560–61. http://dx.doi.org/10.1126/science.1208880

BOGAARD, A. 2004. *Neolithic farming in central Europe*. London: Routledge.

– 2014. Framing farming: a multi-stranded approach to early agricultural practice in Europe, in A. Whittle & P. Bickle (ed.) *Early farmers: the view from archaeology and science*: 181–96. Oxford: Oxford University Press.

BOGAARD, A., H.-C. STRIEN & R. KRAUSE. 2011. Towards a social geography of cultivation and plant use in an early farming community: Vaihingen an der Enz, south-west Germany. *Antiquity* 85: 395–416. http://dx.doi.org/10.1017/S0003598X00067831

BOGUCKI, P. 1993. Animal traction and household economies in Neolithic Europe. *Antiquity* 67: 492–503. http://dx.doi.org/10.1017/S0003598×00045713

BOLLONGINO, R., O. NEHLICH, M.P. RICHARDS, J. ORSCHIEDT, M.G. THOMAS, C. SELL, Z. FAJKOŠOVÁ, A. POWELL & J. BURGER. 2013. 2000 years of parallel societies in Stone Age Central Europe. *Science* 342: 479–81. http://dx.doi.org/10.1126/science.1245049

BRADSHAW, R.H. 2004. Past anthropogenic influence on European forests and some possible genetic consequences. *Forest Ecology and Management* 197: 203–12. http://dx.doi.org/10.1016/j.foreco.2004.05.025

BRANDT, G., W. HAAK, C.J. ADLER, C. ROTH, A. SZÉCSÉNYI-NAGY, S. KARIMNIA, S. MÖLLER-RIEKER, H. MELLER, R. GANSLMEIER, S. FRIEDERICH, V. DRESELY, N. NICKLISCH, J.K. PICKRELL, F. SIROCKO, D. REICH, A. COOPER, K.W. ALT & The Genographic Consortium. 2013. Ancient DNA reveals key stages in the formation of central European mitochondrial genetic diversity. *Science* 342: 257–61. http://dx.doi.org/10.1126/science.1241844

BRANDT, G., A. SZÉCSÉNYI-NAGY, C. ROTH, K.W. ALT & W. HAAK. 2015. Human paleogenetics of Europe—the known knowns and the known unknowns. *Journal of Human Evolution* 79: 73–92. http://dx.doi.org/10.1016/j.jhevol.2014.06.017

BROCK, W.A., M.J. O'BRIEN & R.A. BENTLEY. In press. Validating niche-construction theory through path analysis. *Archaeological and Anthropological Sciences.*

CAVALLI-SFORZA, L.L. 1997. Genetic and cultural diversity in Europe. *Journal of Anthropological Research* 53: 383–404.

CLASSEN, E. 2009. Settlement history, land use and social networks of early Neolithic communities in western Germany, in D. Hofmann & P. Bickle (ed.) *Creating communities: new advances in central European Neolithic research*: 95–110. Oxford: Oxbow Books.

DAYTON, L. 2014. Blue-sky rice. *Nature* 514: S52–54. http://dx.doi.org/10.1038/514S52a

DUNNE, J.P., R.J. STOUFFER & J.G. JOHN. 2013. Reductions in labour capacity from heat stress under climate warming. *Nature Climate Change* 3: 563–66. http://dx.doi.org/10.1038/nclimate1827

Debate

EHRLICH, P.R. & A.H. EHRLICH. 2013. Can a collapse of global civilization be avoided? *Proceedings of the Royal Society B* 280: 20122845. http://dx.doi.org/10.1098/rspb.2012.2845

EISENHAUER, U. 2003. Jüngerbandkeramische residenzregeln: Patrilokalität in Talheim, in J. Eckert, U. Eisenhauer & A. Zimmermann (ed.) *Archäologische Perspektiven: Analysen und Interpretationen im Wandel*: 561–73. Rahden: Leidorf.

EISENSTEIN, M. 2014. Against the grain. *Nature* 514: S55–57. http://dx.doi.org/10.1038/514S55a

FOLEY, S.F., D. GRONENBORN, M.O. ANDREAE, J.W. KADEREIT, J. ESPER, D. SCHOLZ, U. PÖSCHL, D.E. JACOB, B.R. SCHÖNE, R. SCHREG, A. VÖTT, D. JORDAN, J. LELIEVELD, C.G. WELLER, K.W. ALT, S. GAUDZINSKI-WINDHEUSER, K.-C. BRUHN, H. TOST, F. SIROCKO & P.J. CRUTZEN. 2013. The Palaeoanthropocene—the beginnings of anthropogenic environmental change. *Anthropocene* 3: 83–88. http://dx.doi.org/10.1016/j.ancene.2013.11.002

FULLER, D., J. VAN ETTEN, K. MANNING, C. CASTILLO, E. KINGWELL-BANHAM, A. WEISSKOPF, L. QIN, Y.-I. SATO & R.J. HIJMANS. 2011. The contribution of rice agriculture and livestock pastoralism to prehistoric methane levels: an archaeological assessment. *The Holocene* 21: 743–59. http://dx.doi.org/10.1177/0959683611398052

GARTNER, W.G. 2001. Late Woodland landscapes of Wisconsin: ridged fields, effigy mounds and territoriality. *Antiquity* 73: 671–83. http://dx.doi.org/10.1017/S0003598×00065273

GERBAULT, P., A. LIEBERT, Y. ITAN, A. POWELL, M. CURRAT, J. BURGER, D.M. SWALLOW & M.G. THOMAS. 2011. Evolution of lactase persistence: an example of human niche construction. *Philosophical Transactions of the Royal Society B* 366: 863–77. http://dx.doi.org/10.1098/rstb.2010.0268

GLEESON, J.P., D. CELLAI, J.-P. ONNELA, M.A. PORTER & F. REED-TSOCHAS. 2014. A simple generative model of collective online behavior. *Proceedings of the National Academy of Sciences USA* 111: 10411–15. http://dx.doi.org/10.1073/pnas.1313895111

GRONENBORN, D. 1999. A variation on a basic theme: the transition to farming in southern Central Europe. *Journal of World Prehistory* 13: 123–210. http://dx.doi.org/10.1023/A:1022374312372

– 2007. Beyond the models: 'Neolithisation' in Central Europe. *Proceedings of the British Academy* 144: 73–98. http://dx.doi.org/10.5871/bacad/9780197264140.003.0005

HAUSMANN, R. & C.A. HIDALGO. 2011. The network structure of economic output. *Journal of Economic Growth* 16: 309–42. http://dx.doi.org/10.1007/s10887-011-9071-4

HECKENBERGER, M.J. & E.G. NEVES. 2009. Amazonian archaeology. *Annual Review of Anthropology* 38: 251–66. http://dx.doi.org/10.1146/annurev-anthro-091908-164310

HENRICH, J. 2004. Demography and cultural evolution: why adaptive cultural processes produced maladaptive losses in Tasmania. *American Antiquity* 69: 197–214. http://dx.doi.org/10.2307/4128416

HODDER, I. & C. CESSFORD. 2004. Daily practice and social memory at Çatalhöyük. *American Antiquity* 69: 17–40. http://dx.doi.org/10.2307/4128346

HOLDEN, C.J. & R. MACE. 2003. Spread of cattle led to the loss of matrilineal descent in Africa: a co-evolutionary analysis. *Proceedings of the Royal Society B* 270: 2425–33. http://dx.doi.org/10.1098/rspb.2003.2535

HOLTBY, I., C. SCARRE, R.A. BENTLEY & P. ROWLEY-CONWY. 2012. Disease, CCR5-32 and the European spread of agriculture? A hypothesis. *Antiquity* 86: 207–10. http://dx.doi.org/10.1017/S0003598X00062554

HSIANG, S.M., M. BURKE & E. MIGUEL. 2013. Quantifying the influence of climate on human conflict. *Science* 341: 6151. http://dx.doi.org/10.1126/science.1235367

HUGHES, T.P., S. CARPENTER, J. ROCKSTRÖM, M. SCHEFFER & B. WALKER. 2013. Multiscale regime shifts and planetary boundaries. *Trends in Ecology & Evolution* 28: 389–95. http://dx.doi.org/10.1016/j.tree.2013.05.019

ITAN, Y., A. POWELL, M.A. BEAUMONT, J. BURGER & M.G. THOMAS. 2009. The origins of lactase persistence in Europe. *PLOS Computational Biology* 5(8): e1000491. http://dx.doi.org/10.1371/journal.pcbi.1000491

ITAN, Y., B.L. JONES, C.J. INGRAM, D.M. SWALLOW & M.G. THOMAS. 2010. A worldwide correlation of lactase persistence phenotype and genotypes. *BMC Evolutionary Biology* 10: 36. http://dx.doi.org/10.1186/1471-2148-10-36

JACKES, M., D. LUBELL & C. MEIKLEJOHN. 1997. Healthy but mortal: human biology and the first farmers of western Europe. *Antiquity* 71: 639–58. http://dx.doi.org/10.1017/S0003598X00085379

JEUNESSE, C. 1997. *Pratiques funéraires au Néolithique ancien. Sépultures nécropoles Danubiennes 5500–4900 av. J.-C.* Paris: Éditions Errance.

KAPLAN, J.O., E.C. ELLIS, W.F. RUDDIMAN, C. LEMMEN & K.K. GOLDEWIJK. 2011. Holocene carbon emissions as a result of anthropogenic land cover change. *The Holocene* 21: 775–91. http://dx.doi.org/10.1177/0959683610386983

LALAND, K.N., J. ODLING-SMEE & S. MYLES. 2010. How culture shaped the human genome. *Nature Reviews Genetics* 11: 137–48. http://dx.doi.org/10.1038/nrg2734

LAZARIDIS, I., N. PATTERSON, A. MITTNIK, G. RENAUD, S. MALLICK, K. KIRSANOW, P.H. SUDMANT *et al.* 2014. Ancient human genomes suggest three ancestral populations for present-day Europeans. *Nature* 513: 409–13. http://dx.doi.org/10.1038/nature13673

LECHTERBECK, J., K. EDINBOROUGH, T. KERIG, R. FYFE, N. ROBERTS & S. SHENNAN. 2014. Is Neolithic land use correlated with demography? *The Holocene* 24: 1297–307. http://dx.doi.org/10.1177/0959683614540952

LÜNING, J. 2005. Bandkeramische Hofplätze und absolute Chronologie der Bandkeramik, in J. Lüning, C. Frirdich & A. Zimmerman (ed.) *Die Bandkeramik im 21 Jahrhundert*: 49–74. Rahden: Leidorf.

LÜNING, J., U. KLOOS & S. ALBERT. 1989. Westliche Nachbarn der bandkeramischen Kultur: La Hoguette und Limburg. *Germania* 67: 355–93.

MACE, R. 2008. Reproducing in cities. *Science* 319: 764–66. http://dx.doi.org/10.1126/science.1153960

MALAKOFF, D. 2013. Are more people necessarily a problem? *Science* 333: 544–46. http://dx.doi.org/10.1126/science.333.6042.544

MCMICHAEL, C.H., D.R. PIPERNO, M.B. BUSH, M.R. SILMAN, A.R. ZIMMERMAN, M.F. RACZKA & L.C. LOBATO. 2012. Sparse pre-Columbian human habitation in western Amazonia. *Science* 336: 1429–31. http://dx.doi.org/10.1126/science.1219982

MODDERMAN, P.J.R. 1988. The Linear Pottery Culture: diversity in uniformity. *Berichten von het Rijksdienst voor Oudheidkundig Bodemonderzoek* 38: 63–140.

NIESZERY, N. 1995. *Linearbandkeramische Gräberfelder in Bayern* (Internationale Archäologie 16). Rahden: Leidorf.

O'BRIEN, M.J. & R.A. BENTLEY. In press. The role of food storage in human niche construction: an example from Neolithic Europe. *Environmental Archaeology*. http://dx.doi.org/10.1179/1749631414Y.0000000053

O'BRIEN, M.J. & K.N. LALAND. 2012. Genes, culture, and agriculture: an example of human niche construction. *Current Anthropology* 53: 434–70. http://dx.doi.org/10.1086/666585

PALMER, P.I. & M.J. SMITH. 2014. Earth systems: model human adaptation to climate change. *Nature* 512: 365–66. http://dx.doi.org/10.1038/512365a

PINKER, S. 2012. *The better angels of our nature: a history of violence and humanity*. London: Penguin.

POWELL, A., S. SHENNAN & M.G. THOMAS. 2009. Late Pleistocene demography and the appearance of modern human behavior. *Science* 324: 1298–301. http://dx.doi.org/10.1126/science.1170165

PRINGLE, H. 2014. The ancient roots of the 1%. *Science* 344: 822–25. http://dx.doi.org/10.1126/science.344.6186.822

ROCKSTRÖM, J., W. STEFFEN, K. NOONE, A. PERSSON, F.S. CHAPIN & E.F. LAMBIN. 2009. A safe operating space for humanity. *Nature* 461: 472–75. http://dx.doi.org/10.1038/461472a

RUDDIMAN, W.F. 2013. The Anthropocene. *Annual Reviews of Earth and Planetary Sciences* 41: 4–24. http://dx.doi.org/10.1146/annurev-earth-050212-123944

SALQUE, M., P. BOGUCKI, J. PYZEL, I. SOBKOWIAK-TABAKA, R. GRYGIEL, M. SZMYT & R.P. EVERSHED. 2013. Earliest evidence for cheese making in the sixth millennium BC in northern Europe. *Nature* 493: 522–25. http://dx.doi.org/10.1038/nature11698

SCARRE, C. 2000. Reply to S. Shennan, 'Population, culture history, and the dynamics of culture change'. *Current Anthropology* 41: 827–28.

SCHEFFER, M., J. BASCOMPTE, W.A. BROCK, V. BROVKIN, S.R. CARPENTER, V. DAKOS, H. HELD *et al.* 2009. Early-warning signals for critical transitions. *Nature* 461: 53–59. http://dx.doi.org/10.1038/nature08227

SHENNAN, S. 2000. Population, culture history, and the dynamics of change. *Current Anthropology* 41: 811–35. http://dx.doi.org/10.1086/317403

– 2011a. Property and wealth inequality as cultural niche construction. *Philosophical Transactions of the Royal Society* B 366: 918–26. http://dx.doi.org/10.1098/rstb.2010.0309

– 2011b. Descent with modification and the archaeological record. *Philosophical Transactions of the Royal Society* B 366: 1070-79. http://dx.doi.org/10.1098/rstb.2010.0380

SHENNAN, S., S.S. DOWNEY, A. TIMPSON, K. EDINBOROUGH, S. COLLEDGE, T. KERIG, K. MANNING & M.G. THOMAS. 2013. Regional population collapse followed initial agriculture booms in mid-Holocene Europe. *Nature Communications* 4: 2486. http://dx.doi.org/10.1038/ncomms3486

SHENNAN, S.J. & J.R. WILKINSON. 2001. Ceramic style change and neutral evolution: a case study from Neolithic Europe. *American Antiquity* 66: 577–94. http://dx.doi.org/10.2307/2694174

SKOGLUND, P., H. MALSTRÖM, M. RAGHAVAN, J. STORÅ, P. HALL, E. WILLERSLEV, M.T.P. GILBERT, A. GÖTHERSTRÖM & M. JAKOBSSON. 2012. Origins and genetic legacy of Neolithic farmers and hunter-gatherers in Europe. *Science* 336: 466–69. http://dx.doi.org/10.1126/science.1216304

SKOGLUND, P., H. MALSTRÖM, A. OMRAK, M. RAGHAVAN, C. VALDIOSERA, T. GÜNTHER, P. HALL, K. TAMBETS, J. PARIK, K.-G. SJÖGREN, J. APEL, E. WILLERSLEV, J. STORA, A. GÖTHERSTRÖM & M. JAKOBSSON. 2014. Genomic diversity and admixture differs for Stone-Age Scandinavian foragers and farmers. *Science* 344: 747–50. http://dx.doi.org/10.1126/science.1253448

SMITH, B.D. & M.A. ZEDER. 2013. The onset of the Anthropocene. *Anthropocene* 4: 8–13. http://dx.doi.org/10.1016/j.ancene.2013.05.001

STRIEN, H.-C. 2000. *Untersuchungen zur Bandkeramik in Württemberg*. Bonn: Habelt.

– 2010. Mobilität in bandkeramischer Zeit im Spiegel der Fernimporte, in D. Gronenborn & J. Petrasch (ed.) *Die Neolithisierung Mitteleuropas*: 497–508. Mainz: Römisch-Germanisches Zentralmuseum.

TALHELM, T., X. ZHANG, S. OISHI, C. SHIMIN, D. DUAN, X. LAN & S. KITAYAMA. 2014. Large-scale psychological differences within China explained by rice *versus* wheat agriculture. *Science* 344: 603–608. http://dx.doi.org/10.1126/science.1246850

TIMPSON, A., S. COLLEDGE, E. CREMA, K. EDINBOROUGH, T. KERIG, K. MANNING, M.G. THOMAS & S. SHENNAN. 2014. Reconstructing regional demographies of the European Neolithic using 'dates as data'. *Journal of Archaeological Science* 52: 549–57. http://dx.doi.org/10.1016/j.jas.2014.08.011

VIGNE, J.-D. & D. HELMER. 2007. Was milk a 'secondary product' in the Old World Neolithisation process? *Anthropozoologica* 42: 9–40.

WHITEHOUSE, N.J., R.J. SCHULTING, M. MCCLATCHIE, P. BARRAT, T.R. MCLAUGHLIN, A. BOGAARD, S. COLLEDGE, R. MARCHANT, J. GAFFREY & M.J. BUNTING. 2014. Neolithic agriculture on the European western frontier: the boom and bust of early farming in Ireland. *Journal of Archaeological Science* 51: 181–205. http://dx.doi.org/10.1016/j.jas.2013.08.009

WOODBRIDGE, J., R.M. FYFE, N. ROBERTS, S. DOWNEY, K. EDINBOROUGH & S. SHENNAN. 2014. The impact of the Neolithic agricultural transition in Britain. *Journal of Archaeological Science* 51: 216–24. http://dx.doi.org/10.1016/j.jas.2012.10.025

ZIMMERMANN, A., J. HILPERT & K.P. WENDT. 2009. Estimations of population density for selected periods between the Neolithic and AD 1800. *Human Biology* 81: 357–80. http://dx.doi.org/10.3378/027.081.0313

Received: 19 August 2014; Accepted: 17 November 2014; Revised: 16 December 2014