



McDONALD INSTITUTE CONVERSATIONS

# Far from the Hearth

Essays in Honour of Martin K. Jones

Edited by Emma Lightfoot, Xinyi Liu & Dorian Q Fuller

Far from the Hearth



*(Above) Martin Jones at West Stow, 1972 (with thanks to Ian Alister, Lucy Walker, Leonie Walker, and West Stow Environmental Archaeology Group); (Below) Martin Jones in a millet field, Inner Mongolia, 2010. (Photograph: X. Liu.)*





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Cover image: *Foxtail millet field near Xinglonggou, Chifeng, China, photographed by Xinyi Liu, September 2014.*

Edited for the Institute by James Barrett (*Series Editor*) and Anne Chippindale.

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## *Acknowledgements*

The initial idea of editing this volume grew out of a conversation between Xinyi Liu and Graeme Barker at St John's College, Cambridge in June 2016. The editors subsequently discussed the provisional layout of the volume. By April of the following year, our list of agreed contributors was complete. Abstracts followed, and the chapters themselves soon after. First of all, the editors would like to pay tribute to our 36 authors, whose excellent work and timely contributions made it all possible.

For the last two-and-a-half years, the volume has been known as 'Fantastic Beasts' in order to keep it a secret from Martin. As we enter the final stage, we wish to extend our thanks to all who have ensured Martin remains blissfully unaware, including Lucy Walker, and we offer her our sincere thanks. We are extremely grateful to Harriet Hunt, Diane Lister, Cynthia Larbey and Tamsin O'Connell, who are kindly

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*Xinyi Liu, Emma Lightfoot and Dorian Fuller  
August 2018*

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## Foreword

The 28-year term of Martin Jones as the first George Pitt-Rivers Professor of Archaeological Science witnessed, and in part created, a transformation in the fields of environmental and biomolecular archaeology. In this volume, Martin's colleagues and students explore the intellectual rewards of this transformation, in terms of methodological developments in archaeobotany, the efflorescence of biomolecular archaeology, the integration of biological and social perspectives, and the exploration of archaeobotanical themes on a global scale. These advances are worldwide, and Martin's contributions can be traced through citation trails, the scholarly diaspora of the Pitt-Rivers Laboratory and (not least) the foundations laid by the Ancient Biomolecules Initiative of the Natural Environment Research Council (1989–1993), which he chaired and helped create. As outlined in Chapter 6, Martin's subsequent role in the bioarchaeology programme of the Wellcome Trust (1996–2006) further consolidated what is now a central and increasingly rewarding component of archaeological inquiry. Subsequently, he has engaged with the European Research Council, as Principal Investigator of the Food Globalisation in Prehistory project and a Panel Chair for the Advanced Grant programme. As both practitioner and indefatigable campaigner, he has promoted the field in immeasurable ways, at critical junctures in the past and in on-going capacities as a research leader.

The accolades for Martin's achievements are many, most recently Fellowship of the British Academy. Yet it is as a congenial, supportive—and demanding—force within the Pitt-Rivers Laboratory that the foundations of his intellectual influence were laid. Here, each Friday morning, the archaeological science community would draw sticks to decide who would deliver an impromptu research report or explore a topical theme. Martin is among the most laid-back colleagues I have worked with, yet simultaneously the most incisive in his constructive criticism. As a provider of internal peer-review he was fearless without being unkind. The themed Pitt-Rivers Christmas parties were equally impactful—on one occasion Alice Cooper appeared, looking ever so slightly like our professor of archaeological science.

Martin's roles as a research leader extended to several stints as head of the Department of Archaeology, chairing the Faculty of Archaeology and Anthropology and serving as a long-term member of the Managing Committee of the McDonald Institute for Archaeological Research. Having started his professional career as an excavation-unit archaeobotanist in Oxford, he was a long-standing proponent of the highly successful Cambridge Archaeological Unit. In the wider collegiate community, he is a Fellow (and was Vice-Master) of Darwin College and was the staff treasurer of the Student Labour Club. In all roles he fought valiantly and often successfully for the interests of his constituency. His capacity to fight for deeply held priorities while recognizing the value of diverse perspectives was of utmost importance. His nostalgic enthusiasm for the debate with archaeological science that was engendered by the post-processual critique is one signal of an underlying appreciation of plurality. His active support for the recent merger of the Divisions of Archaeology and Biological Anthropology, within our new Department of Archaeology, is another. As a scientist (Martin's first degree, at Cambridge, was in Natural Sciences) he values the peer-reviewed journal article above all scholarly outputs, yet has authored as many highly regarded books as a scholar in the humanities. His *Feast: Why humans share food* has been translated into several languages and won Food Book of the Year from the Guild of Food Writers. He views academia and society as a continuum, campaigning for archaeobotanical contributions to global food security (e.g. by promoting millet as a drought-resistant crop) and working with world players such as Unilever to encourage archaeologically informed decisions regarding food products.

That Martin's achievements and influence merit celebration is clear. That his colleagues and students wish to honour him is equally so. Yet does the McDonald Conversations series publish *Festschriften*? This is a semantic question. As series editor I am delighted to introduce a collection of important papers regarding the past, present and future of archaeobotany, representing its methodological diversity and maturity. That this collection concurrently pays respect to a treasured colleague is a very pleasant serendipity.

Dr James H. Barrett

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## Chapter 9

# Agriculture is a State of Mind: The Andean Potato's Social Domestication

Christine A. Hastorf

How far have we come in understanding agricultural origins and domestication? A long way in the past 30 years. We can now discuss both morphological and genetic relationships, intended and unintended processes (Fuller *et al.* 2014; Larson *et al.* 2014). We have learned that different plants had very different selection histories; we know that some wild and domestic interactions have continued over time, creating a diversity in domesticates that was not envisioned when this discipline began. As the book *Documenting Domestication* (Zeder *et al.* 2006) notes, there were/are many paths to domestication, some narrow, some broad, some fast, but most slow. It has been a long-entwined process that continues today, not just with genetically modified crops, but in many farmers' fields. With the multi-dimensional work of archaeologists through botanical and faunal morphological evidence, landscape and tool evidence and the genetic work on domesticates and their wild progenitors, we are rapidly expanding our data and insights on the dynamic temporal and spatial placement of domestication and agricultural origins in their cultural contexts.

It is in this context that I discuss here some ideas about the social, cultural and ontological points of view that accompanied the process of domestication and how both plants and people reacted to one another, each training the other to help them along in their life success. As people entered a new environment, they clearly sought out and engaged with plants and animals that they were familiar with, that were similar to those that they knew, those that tasted like and smelled like the plants or animals they were used to. They also would alter and construct the environment so that they could work with it in ways they understood. People moved across the landscape foraging on plants that they were familiar with on a daily basis. This activity was goal directed and innovative, as the knowledge of growth habits, yield, processing and all that it took to make the living things edible was transmitted throughout

the groups that roamed across the landscapes. This continual interaction with the world around them meant that, as in all ecology, people were altering and adjusting as they went, as were the plants and animals (Laland & Sterelny 2006). This continual process intensified as groups focused on specific locations and on specific resources. Part of people's success was cooperation and a sense of mutual responsibility, in that people did not live or move around alone, but worked together in small groups. Nor did they rage at the environment. As with all animals living in the wild, there is a give and take, a coping with the constraints and potential of the resources at hand, a sense of extracting as well as protecting. People were no different. As they increasingly returned to the same places, they learned more intimately about some specific plants and animals that they focused on, and in turn were a focus for the plants and animals. Over the generations, both the people and the ecological niches altered together. Certain resources were encouraged, others were diminished. Such foraging promoted general cooperation amongst people, evident still in communities around the world. This human agency in non-human evolution is seen most obviously in the process of domestication, as the plants and animals change enough for a co-dependence to develop that is often irresistible and irreversible. People have to care for the plants and/or animals and the plants and animals have to give yields to sustain their caretakers. The form of these interactive co-dependent histories varies by environmental setting.

Here I want to investigate this relationship of environmental maintenance and food production through one important and understudied domesticated crop, the potato tuber (*Solanum* spp.), domesticated in the South American highlands, well south of the Neotropical nexus where many plants were domesticated (Piperno & Pearsall 1998; Piperno *et al.* 2017). Focusing on this now globally important staple from the Andean region of South

America, the edible *Solanum* tuber-bearing species' difficult archaeological visibility and relatively poor preservation make them one of the least known staple crops in the archaeological record, although the genetics are helping us get a better sense of the timing and location of this plant-human interaction history. The macrobotanical record will never yield a detailed account of all root and tuber use, as what people harvest and eat is watery storage tissue that often lacks a preservable supportive structure. We can, however, surmise that geophytes in general were the focus of much gathering interest and engagement since their earliest encounter, perhaps even more so than grains, as they were harvestable throughout the year, whereas grains tend to mature once a year. Digging for roots is a very old food tradition, surely being one of the main forms of food gathering of our hominid scavenging/gathering ancestors as well as successful foragers (Veth *et al.* 2017). Cooking and the control of fire is a form of transformation that goes back to either around 1.9 million years ago, as Wrangham (2009) suggests, or 200,000–300,000 years ago, as Brace (1995, 578) proposes.

Once fire was harnessed and cooking could occur with gathered foods, bitter roots and tubers would have become even more important, as cooking can break down large compounds and detoxify some of the alkaloids in tubers, coordinating with the human stomach and tooth changes to keep an edible diet available (Johns 1990). This subterranean collection strategy, along with cooking, followed migrants out of Asia across the Pacific and the American continents. We should not be surprised that the earliest inhabitants of South America were seeking out edible roots and tubers to eat, engaging with these taxa quite intensively in all ecological niches where they were encountered. And what a collection of tubers they found in South America. We now know that there were many tuberous plants that have responded to human engagement across that continent, some having become global foods even before the Age of Exploration (Mann 2011), such as the sweet potato (*Ipomoea batatas* [L.] Lam.), and others at the start of it, as with the potato (*Solanum* spp.), manioc (*Manihot esculenta* Crantz) and arrowroot (*Canna indica* L.). There are also geophytes that were locally domesticated in the highlands of South America that only recently travelled outside South America, such as oca (*Oxalis tuberosa* Molina), ulluco (*Ullucus tuberosus* Caldas), mashua (*Tropaeolum tuberosum* Ruiz and Pavón) and maca (*Lepidium meyenii* Walp.). Why these domestic geophytes have been received differently by the world is an interesting cultural, symbolic, haptic, economic and even ontological question, but here I want to focus only on the potato

and how it was domesticated and spread throughout western South America, as a particularly productive example of ongoing geophyte domestication and the role that people's social relations have played in its success and expansion.

Today, landraces of potato range from Chile to Colombia, whereas their wild relatives have a much wider distribution throughout much of South America and north up to the southern US border (de Haan & Rodriguez 2016; Hawkes 1990; Spooner *et al.* 2004).

An explanatory framework proposed to address how and why potatoes became not just domesticated and farmed throughout the high Andean mountain regions, but became a staple crop there, is a complex but important question, weaving together biological and cultural processes. Morphological and genetic discussions of domestication are incomplete if our agricultural definitions do not include human engagement. Geophytes reproduce asexually through cloning or seed potatoes in this case, which either sprout during the new planting cycle from the tubers in the sediment, or are harvested, stored and replanted the following growing season. While sexual reproduction through seed planting is known today, it is very rare (de Haan & Rodriguez 2016). To model tuber domestication and the associated human decisions and agricultural processes that created it, in this paper I focus on the importance of *exchange* and *social relations* as a crucial element in the domestication process and the spread of potato production.

The potato has evolved the way it has due not only to the diverse Andean landscape and the wild species and genetic manipulation through pollination, but also through the actions of trading, sharing and exchanging the tubers between growers. If Andean people did not regularly carry and exchange the tubers, the plants would not have become as robust, and the tubers would not have become as varied or maintained their yields as much as they have. These results are reflected in the diverse variety of *Solanum* tubers present in the highlands today (Brush *et al.* 1980; 1992; de Haan & Rodriguez 2016; Hawkes 1990; Spooner *et al.* 2014; Zimmerer 1991).

There are debates as to how to classify the diversity of the potatoes growing throughout the Andes and beyond. Agronomists' and botanists' estimates of the number of cultivated species have ranged from one to eight. Many categorizations are in the literature, but I choose to follow the work of Huamán and de Haan of the International Potato Center and Spooner of the USDA. These scholars propose that there is one major domestic potato species: *Solanum tuberosum* L. They base this on several criteria, but mainly due to the ease of the different potato plants within this species'

abilities to interbreed with each other throughout the region, allowed by their genetic similarities. In addition, there have been a range of landraces categorized that carry the diversity of this food source throughout diverse geographies, climates and temperatures (de Haan *et al.* 2007; Huamán & Spooner 2002; Spooner *et al.* 2004; 2014). The two main domestic groups in *S. tuberosum*, the *S. tuberosum* Chilotanum group and the *S. tuberosum* Andigenum group (de Haan & Rodriguez 2016), and the three other cultivated species, *S. ajanhuiri* Juz. & Bukasov, *S. juzepcsukii* Bukasov and *S. curtilobum* Juz. & Bukasov, often called bitter potatoes, together contain over 5000 landraces (Brush 1980; de Haan *et al.* 2007). Additionally, c. 100 wild *Solanum* species are recognized and studied (Spooner *et al.* 2014).<sup>1</sup> Bitter potatoes are classed as such because they yield in much cooler and higher locations and require more processing to become consumable, due to their higher levels of alkaloids. These are the tubers that are freeze-dried and/or fermented for longer-term storage. Both modern hybrids and landraces are grown by farmers through the Andean region today, most often by small landholders.

For some time, there has been a debate as to the number of independent domestication locations of *Solanum tuberosum*, due to its widespread production. Recent genetic work by Spooner and colleagues, however, suggests there was only one domestication location for *S. tuberosum* from within the northern *S. brevicaulis* wild species complex (Spooner *et al.* 2014). Based on the genetics of field collections, they identified the root cultivar for the domesticate *S. tuberosum* Andigenum to have come out of stock from the northern Titicaca Basin. As the domesticate spread north and south over time, it continually hybridized with wild *Solanum* plants across the high central Andean mountains, creating a great diversity in the genetic stock via the landraces. This single origin location focuses our attention on the greater Titicaca region for the genetic origin of the potato and for the engagement with this species by the residents at least by Late Archaic times (6000–2000 BC: Rumold & Aldenderfer 2016).

This recent genetic work, in addition to assessing morphological and growth patterns, has allowed this team to identify the single origin of these domestic races. While it may have begun there, genetically the original stock stemming from the *S. brevicaulis* complex interbred with many wild *Solanum* plants and over 8000 years generated many varieties that have adapted to the diverse and different ecological conditions across western South America. This new model makes us focus more on the importance of trade than did the earlier domestication model of multiple

domestications throughout the highlands (Hawkes 1990). That model supported only local selection and engagement with different potatoes across the region. The new Huamán/Spooner model includes genetics and more clearly supports the agency of people moving and trading potatoes continuously east and west, north and south, actively creating new niches for the potato to prosper in.

Propagation is completed through planting curated seed potatoes, usually by opening up a small hole and dropping in one or two small healthy potatoes. This form of cropping has created the raw diversity we see still across the centre of origin and the robusticity of this now globally important geophyte. How did this happen and how was a clonal food plant maintained and even diversified over the past 6000 years of its domesticated life? – through informal and formal seed-potato exchange.

In the Andes, *movement of people and things—exchange* is a core tenet of social interaction, seen in inter-familial labour exchange (*ayni*), commonly called upon during most crop harvests. The movement of crops between different growing zones has long been seen as a vibrant, long-lived form of sustainability (Murra 1972; 1985). Another important related cultural tenet throughout the Andean region is reciprocity, reflected in the organization of moieties noted in many communities, where people, ideas and things are constantly moving back and forth, where balance between these two groups, like the marriage pair, keeps the community going, maintaining the responsibilities between groups and beings. Exchange and its cultural importance, I believe, has played a major role in the history of viable tuber farming, yield stability and the diverse existence of the Andean landraces.

Clone reproduction in farming narrows the gene pool and can make a crop very vulnerable to disease, as experienced in the Irish potato-blight tragedy of 1845–52, as the parasite (*Phytophthora infestans*) migrated out of Mexico into North America and then across Europe, attacking and killing field after field of plants brutally and quickly with no recourse (Kileany 1994; Messer 2000). At that time, there was only one member of the Chilotanum group present across this landscape, as one farmer after another ‘borrowed’ or purchased seed-potato clones from their landlords and neighbours, essentially reproducing the same plant across Ireland. Robusticity comes from diversity; because a cloned plant has increased vulnerability from new parasites, other activities must be enacted to sustain the crop yield, in addition to selecting seed tubers from the harvest. The main pressure is to avoid the late blight (*Phytophthora infestans*) and the potato

tuber moth (*Phthorimaea operculella*) (Giraldo *et al.* 2010). Farmers have to provide new varieties regularly into the farming system to maintain robusticity. This is brought about primarily by growing varieties in different locations as well as continually moving them around through exchange with other producers, thus maintaining and expanding diversity.

More so than for grain crops, this requirement of exchanging seed tubers between farmers is the state of mind I refer to in my title, as once there was a commitment to tending and harvesting potatoes, cultivators had to add new tubers into their fields regularly, lowering the capacity for pests to spread and thus increasing the capacity for viable yields. While the above-ground infestations are difficult enough to control, the parasites that attack subterranean storage tissues are much harder to deal with. Agricultural sustainability required more than hunters and herders carrying tubers to new places. With the commitment to regular potato consumption, farmers had to enhance the tuber's environment and increase clonal diversity. Encouraging diversity was accomplished by gathering first wild tubers and then landraces that people liked the taste of and planting them in new locations. As people moved around the landscape, this activity would have spread the landraces. Once people moved from cultivation to farming, territoriality and less regular movement transpired. A shift to exchange had to occur, as new territories were no longer as accessible. With dependence and commitment to eating potatoes, regular seed-potato movement and trade had to be socially encouraged to maintain diversity, as those who did not engage in such activities saw their yields diminish.

It is well known amongst highland farmers that good potato yields come from several actions: 1) planting potatoes after a fallow cycle of one to several years, hence their name, *la preciosa*—potatoes require more nutrients than other highland crops; 2) regularly trading for new seed potatoes from other zones, hoodwinking the local worms and bugs; 3) grazing their animals (camelids in the past, but today also sheep and cows) on the fields, or bringing their dung to the fields, so that these nutrients can be added to the soil; and 4) mimicking wild potato growth habitats by planting a range of different varieties in the same field (Brush *et al.* 1981). After a long fallow cycle when the nematodes in the soil have diminished, the conditions for tuber growth are again optimal through digging holes with a foot plough (*chakitaklla*), and plough or tractor to place several seed-tubers underground in the created holes, not by scattering.

Potato plants and their tubers are now incredibly diverse, with thousands of viable, edible landraces.

This variability is created through geography, climate, soil diversity, growing multiple races in one field and the wild species that exist across the highland landscape. Tuber exchange across the landscape was critical for the early propagators of the potato, as the traded tubers moved into new conditions, maintaining viability by escaping from local nematodes and other predators. To maintain potato yield and fertility, a regular replacement of seed-tuber stock is required.

Tuber exchange across the landscape that provides diverse varieties (landraces) continues today, and is a common way to maintain yields, while combatting local diseases and bugs. Andean farmers trade seed potatoes throughout their region informally, as well as constantly moving their own seed-potato stock from field to field (Thiele 1999). This constant re-configuration of varieties is augmented by cross-pollination, occasionally producing plants that are allowed to go to seed. When a farmer recognizes new productive or flavourful varieties, they will collect the tubers for seed potatoes. New varieties also occur through mutation and cross-breeding with the wild tuber-bearing potato plants that grow throughout the Andes (Spooner *et al.* 2004). But the most active and impactful method for retaining diversity and robusticity is what is called the informal seed system, the seed-potato exchange (de Haan & Rodriguez 2016; Thiele 1999). This is done across the highlands through trade of seed potatoes between farmers via family relations and trading partners and at tuber markets.

A self-sufficient farmer's fields in the Andes can hold up to 80 different varieties (Brush *et al.* 1981). Over the years, traits that have been selected for, stored, planted and traded include flavour, texture, colour, shorter stolons, more tubers per plant, lower glycoalkaloid levels, cooking qualities, storage capacities and yield maintenance, as well as frost resistance, drought tolerance, blight resistance and insect repelling (Brush *et al.* 1981, 81–2). The newer, 'improved', commercial varieties are much more vulnerable to yield loss if they are continuously planted in one place, whereas the landraces can be grown for many more years in the same region while retaining yield and viability.

From this agronomic evidence, we learn that potato production has regularly to be infused with new seed tubers to maintain yields, thus encouraging the spread and diversity of varieties over time. Tuber exchange across the landscape was therefore critical for the early gatherers and the later propagators of potato, as the traded tubers moved into new conditions, maintaining robusticity by escaping from local nematodes and other predators.

These requirements, as well as the genetics, inform us that early foragers carried potatoes throughout the landscape, planting them in new locations as they went, but also maintained social exchange relations across broad areas. This fits with the early archaeological evidence we have, suggesting that groups moved up- and downslope seasonally in the highlands until about roughly 4000–5000 years ago, when they began to settle on the landscape. Once people settled more permanently and farmed more locally, seed-potato trade had to increase to retain yields.

With these data, we now realize that it was the northern Titicaca Basin inhabitants who dug up patches of the potato's progenitors, creating soil disturbance while selectively replanting certain tubers that encouraged the crop in ever-new locations, ultimately becoming this important domesticate. The farmer's actions throughout the highlands created new microenvironments in a wider variety of field types and microenvironments, which is the heart of niche construction's role in domestication (Zeder 2015). But what it is important to emphasize, if models are to be constructed, is the core place of social interactions that had to be enacted regularly.

*Solanum tuberosum* L. existed throughout the highlands for thousands of years before we can identify it in the archaeological record. This was the time when there was a shift from mainly gathering and hunting to increasing commitment to farming and herding, when people decided to dedicate more time to helping the plants grow in specific places. These cultivation activities seemed to occur at the same time as the shift from hunting to herding camelids, as selective culling produced more useful herds in different landscapes (Kuznar 1993; Moore 2016; Pearsall 1989; 2008). Since camelids are territorial, in a way, they domesticated the people to stay put to manage and grow with them, which in turn channelled the focus on the encouragement of local root-tuber cultivation. Cultivating potatoes at the same time as the camelid domestication was not surprising.

Camelids, root tubers and people interacted symbiotically across the highland landscape after the glaciers retreated, as camelid dung helped enrich the soil for potatoes and camelid hooves aided in aerating their subterranean growth. As in Deborah Pearsall's model for a *Chenopodium* and camelid co-domestication process that occurred in early corrals, so too could *Solanum tuberosum* varieties have prospered from growing where llamas were herded, with the enriched soils encouraging increased yields (Kuznar 1993; Pearsall 1989; 2008). As camelid herds were increasingly managed, the plants were as well.

I therefore suggest that the potato participated in the highland pre-domestication cultivation trajectory along with camelids and chenopods.

Except for the genetic evidence, identifying the onset of farming and spread of the domesticated potato is essentially an archaeological issue. At this point, we can only 'see' produced tubers when we have dated archaeological field evidence, when we encounter identified domesticated animals or other domesticates like *Chenopodium*, or increased densities of parenchymous and potato starch grains. Visiting what archaeological data there is, we can say that wild potatoes were being collected and consumed by the earliest residents of South America. Wild *Solanum maglia* Schltdl. tubers were found on a use surface near a hearth at the Monte Verde site dating to 13,000 BP, located in a marshy wetland that would have yielded wild tubers available year-round (Dillehay 1989; Ugent *et al.* 1987). Several wild potato specimens also have been identified at Tres Ventanas cave in western mid-range Peruvian mountains by 5000 BC (7000 BP: Engel 1970; D. Pearsall pers. comm., 2000). Macrobotanical potato evidence at Huaynuná, on the well-preserved north-central Peruvian coast in the Casma valley, dates to between 2200 and 1200 BC (Ugent *et al.* 1982). These examples illustrate that *Solanum* tubers can be found and identified in the archaeological record. In this small Initial period (Late Archaic) ceremonial centre, potatoes were accompanied by sweet potatoes, manioc and *Canna*, suggesting a full range of tuber agriculture by that phase on the coast and therefore surely in the highlands as well (Ugent *et al.* 1981; 1984; 1986). This scant evidence exists in part due to the excavation and sampling strategies that have been applied in the Andean region, plus the difficulty in identifying tuber fragments, rather than the actual distribution of the *Solanum* tubers in archaeological sites across the Andes. The increasing study and identification of starch will help greatly (Perry *et al.* 2007). Starch grains tell of tuber grinding in northwestern Argentina at 2500 BC (4500 BP) identified by Babot (2006; Babot *et al.* 2014). Duncan and Pearsall have also found more tuber evidence just south of Huaynuná in the Chillón Valley at another Initial period site, Buena Vista, where a range of agricultural products have been identified by their starch grains, identifying *Solanum*, arrowroot and manioc that date to 2200 BC (Duncan *et al.* 2009). Rumold (2010) has identified diagnostic modifications to potato-starch grains, indicative of tuber freeze-drying and/or grinding, at the Titicaca Basin site of Jiskairumoko that dates to between 2000 and 1000 BC, further supporting a commitment to tuber consumption through processing and probable crop production by this point in the heartland of

potato domestication (Rumold & Aldenderfer 2016, 13674). This early evidence will continue to grow as archaeologists increasingly add more rigorous techniques to their excavation, collection and identification methodologies.

Turning to the models that might explain this history, first is the optimal foraging/diet breadth model, which suggests that it is all about collecting the highest-yielding plants first, adding less-productive foodstuffs as population grows (Gremillion *et al.* 2011; Hastorf 1993). Given the ubiquitous but low density of geophytes across the Andes for gatherers, underground storage organs would be added late in this food uptake model, linked to declining availability of other resources. I do not believe this model fits the Andean history of indigenous plant use, especially not tubers. We have evidence that a range of wild plants, tubers, fruits, nuts and animals were collected and consumed early on, at least by 7000 BC in the central Andes (Rossen *et al.* 1996) and much earlier in Chile at Monte Verde. No one plant or even plant form became dominant throughout the early plant use on the coast, as all food plants had to be brought in and then cultivated, providing a clear example of adopting the domestic package. This is where we have the best preservation and therefore the best history of plant use through time, but all were carried in as domesticates, primarily from the Amazon basin, as no real *in situ* domestication occurred on the coast (Hastorf 1999). The highlands are a different matter.

Niche construction theory, which stresses multi-directional engagement between the environment, the plants and the people, with each part affecting the others over the long-term, focuses our attention on the inhabitants and their interactions with the plants, their capacities to react, as well as the landscapes that these plants resided in (Fuller *et al.* 2014; Laland & Sterelny 2006; Langlie *et al.* 2014; Smith 2015). This dynamic strategy focuses on people's protracted engagement with plant species before, during and after clear domestic or farming evidence exists, tracking changes in the productive capacities of the land, as well as plant and cultural changes. This model fits better with what I am outlining for potato domestication: the long-lived, on-going human–potato interaction across the South American highlands and the commitment to steady social interaction and exchange, which escalated when people began settling across the upland valleys and mountainsides. Mainly, however, the niche-construction model allows for early and long-term engagement with the Andean tuber and root crops (ARTCs: de Haan & Juarez 2010). Even if these wild tubers were not hugely productive per plant 8000 years ago, they existed throughout the year

in the ground: they provided a stable year-round food source and therefore were part of the foraging package of the highlands. Clearly after many years of selection the range of tubers and roots increased their yields and eventually became a real focus of agricultural production. The archaeological record supports this second model in terms of human–tuber engagement.

These tuberous plants tell an intriguing tale: they speak of plants making themselves attractively visible to food seekers above ground, so that foragers could return to their patches, encouraging and allowing them to prosper. We can see this not only by the tubers found at Monte Verde, but also due to their spread across the region, as food seekers carried them across the landscape and helped the plants prosper in new places, lower down the valleys and eventually along to the west coast. We can therefore propose an early, dynamic engagement and expansion of the more edible, tuber-producing *Solanum* species with the coming of people into South America: as people followed the animals to rich microzones of lake and river shores, these plants dispersed and evolved. This was a directed, agentive engagement, encouraging both the plants and the people to adjust to the many environments.

## Conclusions

Since the first peopling of the Andean regions where plants produced starch-rich tubers, people have been digging tubers up and modifying local environments to make them more amenable to yet more tuber growth. Through digging and disturbance, geophytes were encouraged to produce and thrive. I propose that this process of tuber domestication has been a long, dynamic, social process, as it continues today in the Andes, where new varieties are still being created and exchange is still a vibrant and essential part of potato sustainability.

Change in the plant during the domestication process was probably well under way by 6000 BC (7750 BP), with cultivation across most of the region by 2000 BC. In many ways potatoes still have control of themselves and are not fully domesticated. Tubers self-start if they are in soil, as they grow out of their own storage tissues in an unending process of renewal. Yet potatoes have changed and expanded over time through active propagation strategies, expanded field-niche construction and tuber exchange across the Andes, increasing the production of more tubers in more places, and allowed different textures, flavours, colours and climatic characteristics to develop and be maintained against field vermin. The actions that participated in this domestication process include field development and niche expansion.

Clonal potatoes and other Andean tubers also promote cooperative interactions between farming families, encouraging regular extra-community social interactions to keep the yields steady. The evidence we have today suggests that potatoes, along with camelids, participated in the highland pre-domestication cultivation trajectory, forming a synergy between plants, animals and people.

This geophyte production requires unique forms of social interaction, providing an unusual example of human agency operating within the domestication syndrome of the potato. The domestic potato and its domestication process therefore reflect the past state of mind of those who engaged with these tuberous plants; they had to maintain social relations with their neighbours and farther residents to maintain their crop. This archaeobotanical example displays the human agency in the evolution of the potato, through the power of exchange that created the diverse and genetically robust domestic potato we see and eat today as a staple food source throughout the Andean region, which has now spread around the world, to feed people in many different climates and cuisines.

## Note

1. The potato that came to Europe is the common potato throughout Eurasia, the *S. tuberosum* Chilotanum group, today only propagated in western Chile. The Andigenum group is the more diverse and more common group throughout the Andean region, the origin of most of today's landraces.

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