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ARCHAEOLOGY

Stable isotope evidence for the participation of commoners in Inka khipu production

Sabine Hyland^{1*}, Kit Lee^{2*}, Hannah Koon³, Sanna Laukkanen⁴, Luke Spindler³

This study presents previously unknown evidence about the social status of Inka-era khipu experts. A lack of physical evidence hinders our understanding of the specialists who made Inka khipus (knotted cords that served as writing). On the basis of primarily Spanish-language colonial chronicles, it is thought that khipus were created exclusively by male bureaucratic elites. We analyzed Inka khipu, KH0631, whose primary cord is composed of human hair. Historically, human hair on a khipu served as a “signature” to indicate the khipu’s creator. Recent advances in elemental analysis–isotope ratio mass spectrometry allowed us to undertake simultaneous carbon, nitrogen, and sulfur measurements from a single KH0631 hair sample, revealing that this individual consumed a diet characteristic of low-ranking commoners. This finding suggests that commoners participated in Inka khipu production.

INTRODUCTION

Despite recent advances in our understanding of Andean khipus (1), scholars know little about the specialists who created Inka khipus. With limited direct evidence concerning the lives of Inka khipu experts, our knowledge is based mainly on the chronicles of Spanish-language colonial observers. According to written sources, Inka khipus were made exclusively by elite, high-status male bureaucrats. This contrasts with the production of khipus in the 19th and 20th centuries, when low-status individuals, including hacienda laborers, peasant farmers, and female peasants, made khipus.

However, at least one colonial source suggested that Inka khipu production was more inclusive. It has been overlooked that an indigenous chronicler, Felipe Guaman Poma de Ayala, claimed that women made khipus in the Inka Empire. Physical evidence from the remains of khipu experts could reveal whether khipu production was limited to high-status male officials in the Inka state or whether khipus were also created by women and commoners. It is believed that khipu specialists were buried with the khipus they used in life. However, most Inka khipus from documented funerary contexts come from previously looted group tombs; hence, these can no longer be associated with the specific individuals with whom they were once interred.

We analyzed a Late Horizon khipu, KH0631, which has an “Inka-style” structure consisting of a horizontal primary cord from which hang pendants with knots indicating decimal numbers (Figs. 1 and 2) [the Open Khipu Repository (OKR), a prominent khipu database, has adopted a new khipu naming convention (2)]. Inka-style khipus generally have been associated with imperial Inka administration (3, 4). Post-Inka herding and produce khipus have simplified structures distinct from Inka-style khipus (5, 6). Mackey categorized post-Inka khipus as belonging to three types: (i) standard, (ii) a doubled cord with numerical zones, and (iii) a single cord with numerical zones. “Standard” post-Inka khipus are similar to Late Horizon Inka-style khipus, but many features, including the manner of signifying numerical values, differ considerably.

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In KH0631 (calibrated 1498 ± 26 CE; Fig. 3), the primary cord is composed of human hair, which we tested to determine the diet of the individual who contributed their hair to the khipu. Hair in the ancient Andes was a ritually powerful substance that represented the individual from whom it came. Historically, when human hair was incorporated into a khipu’s primary cord, it served as a “signature” to indicate the person who created the khipu. Recent advances in elemental analysis–isotope ratio mass spectrometry allowed us to undertake simultaneous carbon (C), nitrogen (N), and sulfur (S) measurements from a single KH0631 hair sample, revealing that this individual consumed a diet characteristic of low-ranking commoners, with little meat or C4 (maize). This evidence suggests that Inka commoners could be involved in creating Inka-style khipus.

RESULTS AND DISCUSSION

Inka khipu experts, or “khipukamayuqs,” have been viewed primarily as imperial male elites who played key roles in running the empire (4). Colonial-era authors emphasized the high-status food and benefits enjoyed by khipukamayuqs who “were given very good allotments of all sorts of sustenance for each month of the year” (7).

In Cuzco, high-status Inka boys and sons of local elites were taught to make khipus (8). Thus, each community in the empire supported at least two high-ranking khipu experts who kept the khipu accounts, which they provided to the central government. Along with population records, local khipukamayuqs trained in Cuzco kept track of the corvée labor performed by community members for the state. Colonial-era descriptions indicate that khipu specialists were bureaucrats who made their own khipus rather than scribes who recorded texts authored or dictated by others (8, 9). The term used to describe the Inka khipu maker, “khipu kamayuq,” is derived from the verb “kamay,” which refers to creation in the sense of energizing matter, a continuous act of creation that works upon an object as long as it exists (10, 11). In the Inka khipu tradition, there was no separation between “author” and “scribe”; both roles were combined into one.

Some polities within the Inka Empire may have had their own khipu traditions, which continued after their incorporation into the Inka state (12, 13). While the khipus created by local elites to record produce and other tribute items are generally Inka-style, they



Fig. 1. Primary cord and pendants, KH0631 (cal 1498 ± 26 CE). Photo by Hyland, School of Divinity, University of St Andrews.



Fig. 2. The loose end of KH0631's primary cord from which the sample was taken. Photo by S.H., School of Divinity, University of St Andrews.

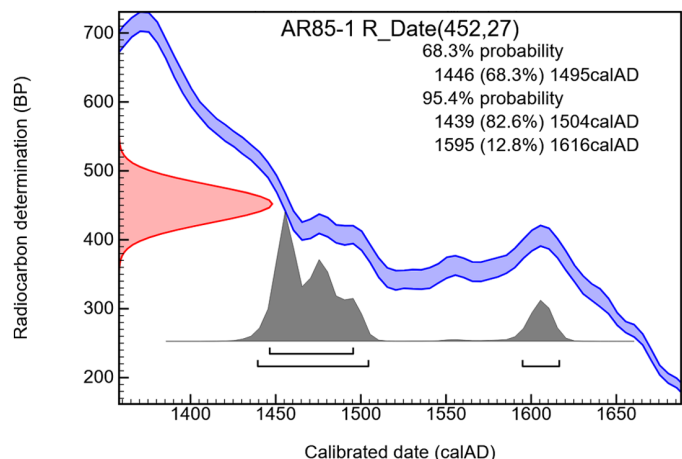


Fig. 3. Radiocarbon date for khipu KH0631. Radiocarbon date 452 ± 27 BP (red), part of the calibration curve (blue), and the calibrated probability density function (gray) calculated in OxCal. OxCal v4.4.4 (C. Bronk Ramsey; 2021); r5; atmospheric data from Ehleringer *et al.* (61).

occasionally exhibit slight variations from the imperial Inka standard. For example, Clindaniel (14) has demonstrated statistically that for the local Armatambo khipus, the significance of knot direction was the reverse of other Late Horizon Inka-style khipus. Local high-ranking khipukamayus continued to make khipus in the early colonial era (15–17). It has been thought that “khipu literacy was not widespread outside of those bureaucrats charged with keeping records”; commoners were not involved in Inka-style khipu production (4, 12). In the absence of other evidence, it has been believed that only elite, high-status male officials from the central government or local ethnic groups created the type of Inka-style khipus associated with imperial administration.

However, the indigenous chronicler, Guaman Poma de Ayala, stated that women also made khipu records, explaining that females over fifty “[kept] track of everything on their quipo” (18). Specifically, women created khipu records for the regional Inka aqllawasi—the house of the “chosen women.” Local aqllawasi housed females, called aqllas (“chosen ones”), were selected by Inka administrators to live in seclusion, performing duties that included weaving textiles (19). While most girls later returned to their home communities, others were sent as prestigious secondary wives to local elites or were designated for a life of service to various deities (20). A select few were offered as human sacrifices. The administration of an aqllawasi required khipus to track personnel, supplies, and goods. According to Guaman Poma, women created aqllawasi khipus.

Many museum khipus come from burials, but most khipus in museums lack provenance data (21). Recently found khipus from well-documented burial sites come from tombs containing multiple corpses, which were looted before excavation (9). Archeologists cannot associate specific khipus found in these group tombs with individuals. There exist only two Late Horizon burials where Inka-style khipus were associated with individual corpses: Grave K in Soniche and Burial 19 in Armatambo.

In Grave K, the individual interred with khipus had grave goods from distant parts of the empire, in contrast to the locally made objects in Soniche's other burials. Initially, this person was described as an elite male khipukamayus, “a man who had prestige... a civil servant in the Inca administration” (22). Subsequent analysis revealed that the Soniche khipu specialist was a young woman in her early 20s (23), corroborating Guaman Poma's assertion that women made khipus. Her individual burial (other burials at Soniche are group tombs) and foreign grave goods imply that she may have been an aqlla sent to a local coastal leader.

At the Ychsma site of Armatambo, a khipu was excavated in the hand of an adult interred in the elite burial site of Huaca San Pedro (24). The Ychsma khipu expert's high-status burial in an elite cemetery supports the hypothesis that local elites made khipus. While the evidence from Soniche and Armatambo reveals that women and non-Inka elites created khipus, neither khipu expert was a commoner.

Herring has described how in Inka cosmology, human hair bore the essence of the individual: “Bodily matter stood in indexical relation to the [individual] himself: [the person's]... hair retained his identity even when physically separated from his body” (25). A child's first haircutting was a major Inka rite of passage (18). The hair removed in this ritual was given as an offering to the huaca or “kept in the house as a sacred object” (26). For important ceremonies, the Inka emperor sacrificed his own hair (18). His hair clippings were saved during his lifetime; after death, they were fashioned into a life-size simulacrum revered as the emperor himself (27). The

Inka children offered as human sacrifices on Mount Llullaillaco were accompanied by bags containing their own hair (28).

Pereyra (29) reported human hair in the cords of a khipu whose current whereabouts are unknown. An Inka khipu (#1967-29-340) in the Krannert Art Museum (University of Illinois, Urbana-Champaign), whose most probable radiocarbon date is between 1447 and 1511 CE (Fig. 4), has a braid of human hair attached to the primary cord (we were unable to sample the hair for isotopic analysis). The OKR does not include systematic data about primary cords, so it is unknown how frequently human hair appears on khipu primary cords.

Historically, when human hair was tied onto khipus, the hair served as the signature of the person from whom the hair was removed. In the Peruvian village of Jucul, human hair attached to the primary cord of a colonial khipu indicates the individuals who made each section of the khipu. In the 20th century, herders in highland Peru attached their hair to khipus “like a signature,” signifying their responsibility for the information on the cords (30). Personal objects tied to or otherwise incorporated into the primary cord represent the khipu creator or author. For example, on a 16th-century khipu from the village of Collata, strips of a leader’s insignia scarf tied to the primary cord symbolize the man who authored the khipu, imbuing the khipu with his authority (31, 32). In contrast, when khipus contained information about multiple individuals, each person’s data was signified by a band of pendants of the same color (14, 33) or by including hair from multiple individuals in the pendants. The human hair that comprised KH0631’s primary cord likely represented

the person who made the khipu, marking the khipu with this individual’s authority and essence.

Isotopic analysis of C, N, and S in human hair has been used to determine the diet of ancient Andeans (34, 35). The diet of high-status versus low-status groups in the Inka state differed in the relative quantity of resources. Elites consumed more meat and maize-based dishes, while commoners consumed proportionally more tubers and greens (26).

To determine the diet of the person who made KH0631, we analyzed the human hair in the primary cord. KH0631 was brought to Munich, Germany, by the early 20th century, but its provenance within the Andes is unknown. We removed a sample of human hair from the loose end of KH0631’s primary cord for C, N, and S isotope testing. Camelid fiber samples from this khipu had been accelerator mass spectrometer (AMS) radiocarbon dated to the Late Horizon (cal 1498 ± 26 CE). The primary cord is constructed of a section of human hair at least 104 cm long, folded in half, and twisted (Fig. 1). Assuming hair growth at 1 cm/month (32), the hair represents more than 8 years. Because the scalp was doubled over, the loose end includes hair cut nearest the scalp and hair from the end of the tresses (Fig. 2). Thus, the sample represents two periods of the individual’s life separated by 8+ years.

The values of our analysis can be seen in Tables 1 and 2. Isotope δ measurements reported below are relative to the following standards: Vienna Standard Mean Ocean Water for oxygen and hydrogen isotope delta ($\delta^{18}\text{O}$ and $\delta^2\text{H}$) values, Vienna Canyon Diablo Troilite for sulfur isotope delta ($\delta^{34}\text{S}$) values, Vienna Pee Dee belemnite for carbon isotope delta ($\delta^{13}\text{C}$) values, and atmospheric nitrogen for nitrogen isotope delta ($\delta^{15}\text{N}$) values. The isotope delta values are reported in per mil (‰).

Carbon ($\delta^{13}\text{C}$) and nitrogen ($\delta^{15}\text{N}$) isotope analyses are commonly used to reconstruct the protein contribution to the diet (36, 37). Nitrogen isotopes track nitrogen pathways within the local ecosystem, reflect the trophic level of the consumer, and detect whether the diet is composed of primarily terrestrial or aquatic resources (37, 38).

Carbon isotopes track carbon pathways through plants into the food chain, reflecting the contribution of C3 or C4 vegetation within the diet, and can also be used as a means of differentiating between terrestrial and marine food chains (39–42). For an overview of the principles behind dietary reconstruction using stable isotopes and reviews of previous research within this field, see (38, 43, 44).

The $\delta^{13}\text{C}$ and $\delta^{15}\text{N}$ isotope ratios for the hair sample are -20.9‰ (± 0.2 ; $n = 4$) and 6.2‰ (± 0.8 ; $n = 4$), respectively, indicating a terrestrial-based diet composed of largely C3 plants (such as trees, shrubs, legumes, temperate grasses, and foods such as quinoa) with little herbivorous terrestrial animal protein (38, 45). Without a contemporaneous faunal baseline to compare the data against, it is

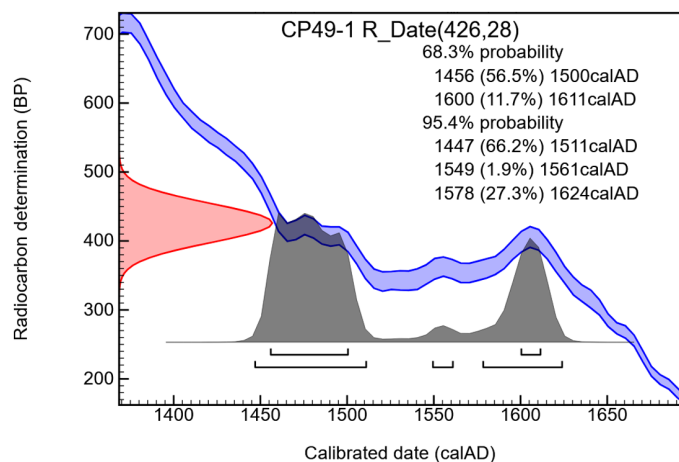


Fig. 4. Radiocarbon date for khipu KAM 67-29-340. Radiocarbon date 426 ± 28 BP (red), part of calibration curve (blue), and the calibrated probability function (gray) calculated in OxCal. OxCal v4.4.4 (C. Bronk Ramsey; 2021); $r:5$; atmospheric data from Ehleringer *et al.* (61).

Table 1. Combined carbon, nitrogen, sulfur isotope analyses. Amt, amount.

Sample ID	Wt.	$\delta^{15}\text{N}\text{‰}$ measured	$\delta^{13}\text{C}\text{‰}$ measured	$\delta^{34}\text{S}\text{‰}$ measured	$\delta^{15}\text{N}\text{‰}$ corrected	$\delta^{13}\text{C}\text{‰}$ corrected	$\delta^{34}\text{S}\text{‰}$ corrected	Amt% N	Amt% C	Amt% S	C/N	C/S	N/S
6591a	0.966	6.69	-19.40	4.03	6.82	-20.70	5.88	12.15	37.96	3.19	3.64	31.76	8.72
6591b	0.694	5.31	-19.41	4.41	5.35	-21.00	6.34	13.13	37.59	3.22	3.34	31.12	9.31
6591a	0.963	6.36	-19.97	4.41	6.66	-21.08	7.10	12.59	39.22	3.83	3.63	27.28	7.51
6591b	0.950	5.64	-19.65	4.84	5.96	-21.14	6.59	12.64	38.63	3.93	3.57	26.22	7.35

Table 2. Oxygen and hydrogen isotope analyses. Amt, amount.

Sample ID	$\delta^{18}\text{O}\text{‰}$ measured	$\delta^2\text{H}\text{‰}$ measured	$\delta^{18}\text{O}\text{‰}$ corrected	$\delta^2\text{H}\text{‰}$ corrected	Amt% O	Amt% H
6591a	13.32	−104.21	11.89	−82.97	24.30	4.91
6591b	13.79	−107.55	12.44	−86.99	23.34	5.06

difficult to assess precisely the extent of animal protein in the diet but the low nitrogen isotope values suggest that the diet was largely plant based.

Sulfur ($\delta^{34}\text{S}$) isotopes can discriminate between marine and terrestrial diets and track changes in diet where foodstuffs of varying $\delta^{34}\text{S}$ content were sourced from different background geologies (41). Because there is only weak fractionation between diet and body protein, sulfur can be considered as a type of geolocation indicator. The $\delta^{34}\text{S}$ value for the hair sample was 6.9 (± 0.6 ; $n = 4$); this does not suggest a marine contribution to the diet, and this is also consistent with the nitrogen isotope value.

The hair was run twice, each in duplicate. While the carbon values are consistent between runs and duplicates, the nitrogen and sulfur are more variable and beyond analytical error ($<0.2\text{‰}$). Because the sample contained hair from two periods in the individual's life, separated by 8+ years, we anticipated that there would be two distinct values for nitrogen. This variation appears to represent seasonal changes in dietary resources, specifically meat consumption.

We also tested O and H isotopes to determine geolocation. Our results indicate that the individual lived between 2600 and 2800 m [(46); also see Supplementary Text]. In other words, the individual lived in the highlands, relatively far from the Pacific Ocean. This finding correlates with the low level of marine resources in the diet. Our results also suggest that the individual lived in southern Peru or northern Chile. However, without better data on local water values, this finding remains tentative (see Supplementary Text).

C and N isotope results indicate that the individual whose hair comprised the primary cord in Khipu KH0631 ate a plant-based diet consisting primarily of tubers and greens with little consumption of meat or high-status C4 plants such as maize. S isotope analysis shows little marine contribution to the diet, indicating that the individual likely lived in the highlands. In the Andes, this diet is a characteristic of low-status commoners, unlike the diet of high-status elites who consumed considerably more meat and maize. It may have been possible, if unlikely, for a powerful Inka or local khipukamayuy to avoid eating meat, perhaps due to periodic famines or various ritual observances. However, it is difficult to imagine a scenario where an official khipukamayuy could have refrained from consuming large amounts of maize in the form of beer. Obligatory drinking of maize beer formed a central feature of Inka ceremonies of governance in which high-ranking khipukamayuyqs participated (47–50). Given the symbolic importance of hair in the Andes, and the frequent use of hair on the primary cord to indicate the khipukamayuy, our results indicate that the creator of KH0631 was likely a non-elite commoner. Because KH0631's creator appears to have been a commoner rather than an Inka or local government official, KH0631 does not necessarily express the needs of state administration despite its Inka-style structure. Isotopic analysis of human hair on KH0631 indicates that commoners participated in Late Horizon Inka-style khipu production.

This finding has implications for the nature of khipu literacy during the Late Horizon. The remains of a female khipu specialist in Grave K in the Soniche coastal cemetery suggest that women made khipus, as the Andean chronicler Guaman Poma asserted. Our isotopic evidence indicates that, contrary to previous assumptions, commoners in the Inka Empire apparently created Inka-style khipus as well. Although KH0631 is only one khipu, there do exist circumstances when, as Houston (51) has noted, “a fresh text may substantially” alter the narrative of early script usage. The new isotopic evidence from KH0631 suggests that khipu literacy in the Inka Empire may have been more inclusive and widespread than hitherto thought.

MATERIALS AND METHODS

All ethnographic research with human subjects was approved by the St Andrews University Teaching and Research Ethics Committee (UTREC). The ethics approval reference no. is SA11397. Informed consent was obtained from the informant—a 70-year-old man—who supplied the information cited in the article. We explained to him verbally how we would use his information and that he could refuse to answer any of our questions at any point or retract any information he provided to us. Because he was unable to read or write, we communicated verbally with him.

Materials: We removed a sample of human hair from the loose end of KH0631's primary cord. As indicated in the provenance section, fiber samples from this khipu had been AMS radiocarbon dated to the Late Horizon (cal 1498 \pm 26 CE). The primary cord is constructed of a section of human hair at least 104 cm long, folded in half, and twisted (Figs. 1 and 2). Assuming hair growth at 1 cm/month (26), the hair represents more than 8 years. Because the hair was doubled over, the loose end includes hair cut nearest to the scalp and hair from the end of the tresses. Thus, the sample represents two periods of the individual's life separated by 8+ years. White hair indicates that the individual probably was elderly.

Preservation: Hair is composed of α -keratin, a structural protein that is resistant to degradation in the burial environment (diagenesis) (52, 53) and thus has been studied from archeological sites to investigate diet and migration in past populations (34, 53–55). The preservation of the archeological hair samples at the elemental level was assessed by quantifying their atomic C/N ratios and the C, N, and S content by weight %. The atomic C/N ratios average 3.5 \pm 0.1, which falls within the range proposed for modern hair (2.9 to 3.8) (56). The content by weight of carbon averages 38.4% \pm 0.8, and nitrogen averages 12.6% \pm 0.5. These values are similar to those measured in other well-preserved archeological human hair, e.g., (57).

The sulfur content for the hair sample averages 3.4 \pm 0.5, which is comparable to those reported by Díaz-Zorita Bonilla *et al.* (54) (2.7 to 4.3%) for human scalp hair. On the basis of these parameters, it appears that the hair keratin sample analyzed in this study did not

undergo significant diagenetic alteration and can provide reliable bulk stable isotope results.

Provenance and radiocarbon date: Khipu KH0631, made from camelid fibers and human hair, was brought to Munich by the early 20th century. It is unknown whether it was among the archeological items, which were acquired by Princess Therese von Bayern during her 1898 fieldtrip to South America and deposited in Munich (58). There is no available data about where it was collected in the Andes. KH0631 is currently held by the University of St Andrews.

In 2023, a sample was removed from KH0631 for AMS radiocarbon dating by Measurlabs in Helsinki, Finland. The textile sample was determined using a single-stage accelerator mass spectrometer (SSAMS, NEC, USA) (Automated Graphitization Equipment AGE-3, IonPlus AG). The sample was pretreated using Soxhlet extraction and acid-base-acid protocol. Reference materials were IAEA C3, NIST-OXII, and IAEA C9. The test was performed by an ISO/IEC 17025–accredited external service provider.

The khipu KH0631 fiber sample radiocarbon age is cal 1498 ± 27 (see Fig. 3). The calibration curve indicates an 82.6% probability that the sample is in the time range between cal 1439 and 1504 CE, with a 68.3% probability that it is between cal 1446 and 1495 CE.

The sample for radiocarbon dating was taken from the end of a camelid fiber pendant. While textile fibers are a poor choice for reutilization because of their fragility, animal fiber cordage is particularly ill suited to reuse. Because of the tendency to felt—that is, for the fibers to interlace and become permanently entangled—animal fiber cordage becomes unusable for knotting and plying if subjected to repeated friction. In tests comparing the feltability of sheep wool, goat cashmere, and alpaca (59) and rabbit, goat cashmere, and alpaca (60), alpaca was found to give the highest feltability in all cases. In other words, it is likely that the khipu was created relatively close in time to when the camelid was sheared. Had the camelid cords been reused over decades or even centuries, they would have felted because of repeated friction and agitation.

In 2024, a sample was removed from the Krannert Art Museum's khipu 67-29-340 for AMS radiocarbon dating by Measurlabs in Helsinki, Finland. The textile sample was determined using an SSAMS (NEC, USA) (Automated Graphitization Equipment AGE-3, IonPlus AG). The sample was pretreated using Soxhlet extraction and acid-base-acid protocol. Reference materials were IAEA C3, NIST-OXII, and IAEA C9. The test was performed by an ISO/IEC 17025–accredited external service provider.

The khipu KAM 67-29-340 cotton fiber sample radiocarbon age is cal 1524 ± 28 . The calibration curve indicates that there is a 95.4% probability in the range between cal 1447 and 1624 CE, with the highest relative likelihood in the year range between cal 1447 and 1511 CE.

Methods, pretreatment: Hair sample was placed in a scintillation vial with a cleaning solution (2:1 methanol:chloroform) in a fume cupboard and left overnight. The sample was then sonicated in a closed vial for 3×10 -min cycles, with the cleaning solution changed between each cycle. The same process was then repeated using deionized water before the sample was freeze dried for 24 hours.

Supplementary Materials

This PDF file includes:

Supplementary Text
References

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