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PATHWAYS

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Pathways

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Pathways, University of Saskatchewan Archaeology and Anthropology Graduate Student Journal is run by the UofS Department Archaeology and Archaeology Graduate Students' Association (ARCHAIA) and provides a medium by which to activate the conversations that we graduate students have within our classes to showcase the admirable work that is being done throughout our department. We also aim to provide opportunities for professional development to better prepare our graduates for futures in academia or in the professional realm. We promote original research, review articles, book reviews, high-reaching class papers, commentaries, plain writing summaries of theses, photo essays, and other multimedia submissions from graduate or senior undergraduate students. These works will focus on the four fields of anthropology and contribute to ongoing conversations of scholarship and collaboration. We welcome submissions from students studying at the University of Saskatchewan and beyond.

Produced by the University of Saskatchewan Archaeology and Anthropology Graduate Students' Association (ARCHAIA) and associated with the University of Saskatchewan Department of Archeology and Anthropology.

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Pathways Editorial Board

Letter From the Editors-in-Chief

Dear Readers and Contributors,

It is with great excitement that we introduce the second volume of Pathways, presented by ARCHAIA, the University of Saskatchewan Archaeology and Anthropology Graduate Students Association. Taking up the mantle from our esteemed predecessors, inaugural co-editors Rebecca Bourgeois and Rachel Simpson, we have spent the last year ensuring that Pathways remains a platform through which the works of archaeology and anthropology students are developed and shared. Because of the journal's focus on the human experience and given the reality of the continuing COVID-19 pandemic, this work, and the broader social science that it represents, is especially relevant. We are grateful for the enthusiastic effort and dedication of the editorial board and the contributing authors, as the difficulty of the tasks at hand was compounded by distance and the challenges of remote working that characterize these unprecedented times. Although the articles at the heart of this volume have been irrevocably altered by the pandemic experience, this issue retains the ethos of the journal and reflects the resiliency of Canada's archaeology and anthropology students.

Through this issue, we continue the work of the inaugural volume of this journal, making Pathways a space for excellent articles, crafted by an engaged student group who seek to share their work through the experience of the publishing process. This second issue highlights contributions from both undergraduate and graduate students from across Canada, with submissions from the University of Saskatchewan, the University of Alberta, and the University of Northern British Columbia. These fabulous pieces cover a range of subjects, including environmental anthropology, development anthropology, paleopathology, and zooarchaeology.

Though the labour of establishing this journal was undertaken by those who came before us, we remain grateful to the many people whose support has ensured the successful publication of this continued volume. To the U of S Department of Archaeology and Anthropology, and the ARCHAIA executive committee, we extend our warmest thanks for their enthusiasm and endless engagement with this project. Liv Marken and the team at the USURJ have been incredibly helpful and patient as we navigate new processes and experiences. The University of Alberta Libraries Journal Hosting and Publishing, especially Sonya Betz and Sarah Severson, have been integral to the existence of this journal and its online accessibility. And to our incredible team of reviewers, our copy editor Mckelvey Kelly, and our faculty advisors, Dr. Susanna Barnes, and Dr. Tatiana Nomokonova, we express our most sincere gratitude. With this volume, we bid farewell to Dr. Nomokonova and welcome professor Dr. Angela Lieverse to the Pathways team. Without these dedicated individuals, this volume and the journal would not exist, and we will be forever thankful for their hours of diligence, perseverance, and commitment.

We hope that this, the second volume of Pathways, continues to be a bright and welcoming oasis for students in academic landscapes relating to the human experience.

Sincerely,

Michelle Gowan and Jessica Jack
Co-Editors-in-Chief

Pathways
Volume 2 | 2021

RESEARCH ARTICLE

Assessing Impacts of the COVID-19 Pandemic on Anthropological Research Methods: An Undergraduate Research Project

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ABSTRACT
As the COVID-19 pandemic continues, there is a need to understand how the pandemic has influenced anthropological research. This paper presents the results of a research project examining these changes and the challenges anthropologists have faced in carrying out their research methods during the first eight months of the COVID-19 pandemic. At the University of Northern British Columbia in the Fall semester of 2020, undergraduate students led this project and conducted five virtual, semi-structured interviews with socio-cultural anthropologists across Canada, from a variety of career stages and with diverse research approaches. Interview participants described virtual research methods involving a heavy reliance on video conferencing and digitally available resources, benefits and challenges of remote and digital ethnography, changes to immersion and the spatial-temporal aspects of communication, and outcomes of adopting new technologies. The pandemic affected these anthropologists to varying degrees depending on the location of their field site and their career stage. Despite adaptations and challenges, interview participants also offered hopeful commentary on potential long-term changes in the discipline as the pandemic forces anthropologists to rethink the ways in which we conduct our work.

Keywords: anthropological research, fieldwork, virtual ethnography, remote methods, COVID-19, pandemic

INTRODUCTION

The ongoing pandemic of coronavirus 2 disease 2019 (COVID-19), caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), poses a challenge to socio-cultural anthropologists whose research methods often require international travel and prolonged in-person contact with research participants during ethnographic fieldwork. The COVID-19 pandemic has forced anthropologists to rethink their research methods in the short- and long-term due to travel restrictions and physical distancing measures. Digital ethnography and remote research methods have been practiced for years—if not decades (Coleman 2010; Boellstorff et al. 2012; Kozinets 2015; Pink, Horst, and Postill 2015). However, the pandemic has forced many anthropologists to adopt these approaches when they may not have done so otherwise, relying on different primary materials, methods, and experiencing interruptions to their typical fieldwork cycle—what has been described elsewhere as "patchwork ethnography" (Günel, Varma, and Watanabe 2020). This research addresses these

short-term methodological shifts and discusses how pandemic-related hurdles to conducting research may affect the methodological practice of the anthropological discipline.

The authors of this paper are upper-year undergraduate students who were enrolled in the University of Northern British Columbia's ANTH 300 – Qualitative Research Methods class in Fall 2020. We conducted this research study to gain first-hand experience practicing anthropological methods and to better understand the changes and challenges anthropologists have faced throughout the first eight months of the COVID-19 pandemic that were not yet reflected in the qualitative methods textbooks typically used for our course (e.g., LeCompte and Schensul 2010). Some of these challenges may stem from the mental and emotional trauma associated with COVID-19 and the lives lost during this pandemic; however, in this paper we will be focusing on the practical challenges and changes to anthropological methods that have arisen since March of 2020. The two driving questions of this research project are: How has the pandemic affected the research of, and methods used by, anthropologists? What novel methods are arising in anthropological research in response to the pandemic? We define anthropological research as a dialogue and encounter between texts, people, places, and things. Following anthropologist Anand Pandian, anthropological research is also a "method of experience" that includes reading, writing, teaching, and fieldwork (2019, 44). As such, while we focus on changes to fieldwork more specifically, our paper also touches on each of these themes.

To approach our research questions, we conducted five virtual, semi-structured interviews on Zoom with anthropologists across Canada. We chose to recruit anthropologists from all different levels of study and research. Ultimately, five anthropologists participated in the project: Angèle Smith, Lori Barkley, Samantha Moore, Tad McIlwraith, and a fifth interviewee who wished to remain anonymous. While the sample size is small, due to the time restrictions posed by our semester-bound research project, the five anthropologists interviewed represent diverse groups in the field. While all participants primarily conduct socio-cultural anthropological research, they conduct work across topics of Indigenous rights, community-based research, practicing anthropology, medical anthropology, and heritage studies, both within and outside academia. Smith and Moore conducted their previous research abroad, in Ireland and Kenya, respectively; the other three interviewees work in a Canadian context. Furthermore, they represent different career stages, including more junior scholars, applied researchers, graduate student supervisors, and senior scholars. During the interviews, we asked participants to compare research methods they used prior to and after March 2020. We focused on any potential adaptations, including changes from face-to-face interviews and participant observation to the use of virtual interviews, digital meetings, and localized research. Moreover, we explored with participants how new techniques and adaptations may be adopted into future methodological practice. The interviews were conducted and subsequently transcribed, coded deductively, and analyzed by our class, with instructor support – all virtually.

This paper presents the results of our class research project, following the major themes that emerged from interviews. First, we briefly discuss the methods used by our research participants before the onset of public health restrictions in March 2020. Second, we detail overall impacts to anthropological methods reported by our interview participants, including the adoption of remote methods, differing means of immersion, and financial, administrative, and practical changes to anthropological practices. Third, we outline several of key challenges and setbacks of

ethnographic research experienced by our anthropologist interviewees during the pandemic. Fourth, we discuss the potential outcomes of adopting new methods and technologies, including how interview participants felt they can both benefit and limit anthropological research. Fifth, we outline interview participants' thoughts regarding how the changes to anthropological research brought on by the COVID-19 pandemic may affect research practice in the long term. And finally, we conclude with a summary of our findings with recommendations for further research.

ANTHROPOLOGICAL METHODS BEFORE MARCH 2020

Anthropological research has largely been characterized by ethnographic fieldwork, which often requires the researcher to travel to locations far away from home to live and interact with the people or community they study (LeCompte and Schensul 2010). However, anthropologists have been theorizing that the lines between 'field' and 'home' are not so easily drawn, and the two intersect in a variety of ways for each anthropologist (Gupta and Ferguson 1997; Amit 2000; Günel, Varma, and Watanabe 2020). All of our participants described how essential fieldwork was to their research (Anonymous 2020, Barkley 2020, McIlwraith 2020, Moore 2020, Smith 2020) and most of them travelled to visit their respective study areas in Canada and abroad. However, one of our participants, Barkley, lives in the same community where she conducts her fieldwork (Barkley 2020). Each of our participants described using multiple research methods for gathering data, including participant observation, focus groups, one-on-one interviews, participant mapping, and writing fieldnotes and papers. All of our participants shared the importance of being in the field to gain a deep understanding of the day to day lives of the people they are working with (Anonymous 2020, Barkley 2020, McIlwraith 2020, Moore 2020, Smith 2020). The most commonly used method was participant observation, which McIlwraith describes as "deep hanging out" (McIlwraith 2020, 3). He shared with us his enthusiasm for just "being around" and that "sometimes you have to ask people questions and it is good to do that in informal and formal ways" (McIlwraith 2020, 3). For him, the most important aspect of his research was being in the community to collaborate on research design. However, Smith noted that anthropology is not entirely comprised of fieldwork and research, and that the writing process is another important, but often overlooked part of the discipline (Smith 2020, Pandian 2019).

Based on our interviews, we argue spending time within the community researchers are working with has proven to be the best way to learn about the daily lives and lived experiences of participants and sustain community collaboration. Interviews and focus groups are valuable when a researcher desires answers to specific questions. However, as stated by all of our participants, the time spent with a given community also helps in shaping the research.

CHANGES TO ANTHROPOLOGICAL METHODS DURING THE COVID-19 PANDEMIC

With the spread of COVID-19 forcing much of the world into various states of lockdown and isolation, many anthropologists have had to modify their existing methods in order to continue their research projects (Günel, Varma, and Watanabe 2020). As a result, our five participants reported a wide range of impacts to both their research process and the nature of the research they were conducting. While in general each participant had vastly different experiences from one another, some commonalities arose. Before the pandemic, all five relied on face-to-face methods which often necessitated international

travel (Anonymous 2020, Barkley 2020, McIlwraith 2020, Moore 2020, Smith 2020). There was agreement among researchers who lived outside their community of study that the most significant impact to research was the inability to travel to field sites or work with their research participants in-person. Of the five anthropologists interviewed, only four discussed the methods they used to continue their previous work during the pandemic. Of these, only Moore, as a graduate student in the early stages of her doctoral research, built her research methodology in response to the limitations posed by the pandemic. Barkley did not discuss how the pandemic had affected her research, in large part because her research was 'at home' in her community of residence and she could still continue by following local public health measures and forming a social 'bubble' on location (Barkley 2020). Meanwhile Smith, McIlwraith, Moore, and the anonymous anthropologist found their work heavily affected by the pandemic, despite their attempts to continue working and researching. For these anthropologists working in the academy at various universities, direct contact with those involved in their research, both participants and colleagues, had not been possible (Anonymous 2020, McIlwraith 2020, Moore 2020, Smith 2020).

The most common adaptation to the inability to interact with subjects in the field was through forms of online interviews, mostly using the video conferencing program Zoom (for a discussion of Skype interviews see, Deakin and Wakefield 2014; Seitz 2016). Four of our five participants reported that the COVID-19 pandemic had impacted their work, each expressing the feeling that online interviews were inferior to in-person interactions due to the loss of most non-verbal cues that an anthropologist may glean in a face-to-face scenario. Moore opined that online interviews were at worst a "band aid to get you data" and cannot properly be compared to more intensive in-person fieldwork (Moore 2020, 3). Similar sentiments were voiced by the other three anthropologists (Anonymous 2020, 4-5; Smith 2020, 8; McIlwraith 2020, 4). In contrast, McIlwraith noted that the positive side of online communication is its cost effectiveness due to lack of travel expenses. He also explained that the increasing normalization and use of video conferencing as a result of the pandemic has improved remote methods. For instance, video conferencing, he argues, is a superior means of communication to phone calls for gathering information, even if still not the same as being able to directly interact with members of a community because the interviewer can still read non-verbal cues associated with in-person interviews (McIlwraith 2020, 3-4).

Interview participants' preference for in-person interaction does not mean that they did not believe that online interviews should be removed from anthropological methods once the pandemic is over, with the anonymous participant noting that online interviews are another "tool" to add to anthropology's methodological toolbox (Anonymous 2020, 5). Indeed, some anthropologists even note how remote interviews may be better suited to certain research settings. Anthropologist Yarimar Bonilla, for instance, explains how phone interviews with survivors of disasters provided a more trauma-informed, practical approach for working with displaced individuals, and that interviewee comfort on the phone provided for richer narrative stories than in-person interviews (2020). Among our participants, Smith stated organizing online interactions with international colleagues and research participants was easier during the pandemic due to the increased interconnectivity (Smith 2020, 7). As a graduate supervisor, McIlwraith expressed appreciation for the ingenuity of many students in how they were able to enrich the data collected during digital interviews, such as through 'arts-based' methods where participants would interact as much with

drawings as with words (McIlwraith 2020, 1). The anonymous participant, however, also explained that despite its potential benefits, virtual data collection and interviews are not adaptable to all research designs. This anthropologist's methods relied on participant observation of a phenomenological nature, examining the non-verbal experiences in ritualist settings, and were ultimately unable to adjust to digital or remote methods of data collection (Anonymous 2020, 5). Working often in spaces of absolute silence, where non-verbal cues form the majority of field data, the virtual methodological toolkit currently available was not sufficient for this anthropologist's research. As such, they reported the most significant impacts resulting from distanced communication. While the other participants were forced to make use of virtual methods, and they may have expressed dissatisfaction at the inadequacies of the methods, our phenomenologically grounded researcher relayed being entirely unable to continue their research as a result (Anonymous 2020). However, participants overwhelmingly agreed that online interviews are an important part of anthropological research during this pandemic and may become a more commonly used method in the future.

Following the switch to virtual methods, interviewees most commonly reported disruptions to the research process due to the pandemic. The severity of disruptions caused by the pandemic was influenced dramatically by the stage in which the participant was in their research process when COVID-19 public health measures were first implemented. For those in the data collection stage whose fieldwork necessitated travel to the field-site, such activities have been indefinitely postponed at the time of writing. Even those anthropologists we interviewed who could receive exemptions from travel bans chose not to for the ethical risks of spreading COVID-19 to vulnerable participant populations (Anonymous 2020, Moore 2020). With international travel no longer a possibility, data collection is in limbo. Participants also reported that the costs of conducting research have increased significantly as a result of the COVID-19 pandemic. Specifically, the two-week quarantine period on either end of any non-local travel increases the funds and time required for travel significantly (Anonymous 2020). Moore also reported that funding agencies are unwilling to make allowances for new pandemic induced delays, reducing access to funding resources and opportunities (Moore 2020). Understandably, these delays in receiving official documentation from institutions poses a significant challenge for those researchers now experiencing increased research costs.

Despite the impacts of the pandemic on the stage of the project and research collection, it is not the only part of academic research. Smith emphasizes how she has found herself performing more of the writing portion of her work over the course of the pandemic, an aspect of the research that has been less affected by the pandemic than the research portion (Smith 2020). McIlwraith and Moore echoed similar sentiments of performing write-ups, data analysis, and grant proposals instead of the more in-person research methods that they found themselves unable to perform (McIlwraith 2020, Moore 2020).

Senior researchers and instructors reported a decrease in the time available to devote to research (Smith 2020). Smith, who also happened to be the department Chair at her university at the time, reported an almost exponential increase in the service work faculty were required to do. In fact, when asked, she reported that in addition to travel disruptions, "the time that COVID has taken away from my research is the most significant [change]" (Smith 2020, 5). With institutions also having to adapt to offering classes that comply with new COVID-19 related public health mandates, academics who fulfill an administrative role (sitting on boards and

councils), are being required to commit much more time to those tasks. Both senior and junior anthropology instructors also experienced increases in their workloads. For example, Barkley—who had recently left academia earlier than they had previously planned to avoid teaching during the pandemic—noted that their colleagues who were still teaching were struggling with the transition to online learning (Barkley 2020). This would appear to be another area of discrepancy in how this pandemic has impacted researchers at different career stages: those who did not already play an administrative or teaching role prior to this pandemic did not report that an increase in workload was an issue encountered.

That is not to say, however, that early career academics were not also uniquely impacted by pandemic changes. We were fortunate to have both a Ph.D. student, Moore (2020), and a graduate student supervisor, Mcllwraith (2020), as part of the project to provide insight into how those just starting in the discipline have found the experience. Both articulated that the effects of this pandemic on students appears to have been greater than on most fully accredited professionals. The reasoning for this appears to be due to the issue of establishment. Professionals who have been practicing anthropologists for a significant amount of time reported having already formed long-term relationships with the majority of the groups they work with (Anonymous 2020, Barkley 2020, McIlwraith 2020, Smith 2020). Yet graduate students are in the initial process of forging those relationships and are not so fortunate. Maintaining a preexisting relationship through trying times appears to be far easier, at least in respect to this pandemic, than establishing entirely new ones. As McIlwraith stated, "I think that the effects on students has probably in many ways [been] greater than [the] effects on faculty because faculty have long term relationships and, through our careers, we are able to maintain and anticipate an ongoing relationship with people into the future" (McIlwraith 2020, 2). For students and early career researchers, this is not the case.

The final component of anthropological practice that participants argued was impacted by the pandemic was academic conferences. While not an exclusive aspect of anthropology when compared to other disciplines, conferences are still a part of the discipline that shifted to adapt to the pandemic. Both McIlwraith and Moore noted how academic conferences had gone virtual rather than be in-person, and while Moore did not elaborate further, McIlwraith felt that this was actually a positive change (Moore 2020, 6; McIlwraith 2020, 2). He noted how that the digital medium combined with the increased online interconnectivity that resulted from the pandemic allowed conferences to display research and voices from those that typically would be unable to attend. McIlwraith ultimately felt that it would allow for a level of engagement and interconnectedness that would be beneficial to the discipline as a whole. McIlwraith also experienced an increased sense of interconnectedness with colleagues, explaining that he had more meetings recently than he ever had before (McIlwraith 2020, 2-3).

The anthropologists interviewed did their best to adapt to the different circumstances and unique challenges that were posed by the COVID-19 pandemic and their resulting inability to perform field research. All four of the anthropologists who discussed the methods they used during the pandemic displayed a preference for field research to online methods, but ultimately made the best they could out of their difficult situations using the methods available to them. However, there was a feeling that digital interaction and interconnectivity may become a permanent part of anthropological practice, even if it would not dethrone the importance of in-person fieldwork to the discipline.

KEY CHALLENGES AND SETBACKS

Now that we have demonstrated the overall impacts to anthropological research interview participants reported, we turn to a description of their key challenges and setbacks, both surmountable and insurmountable. Given the nature of the research many of our participants undertake working with marginalized and/or vulnerable peoples, a common challenge they reported was related to morality and ethics (see also Faubion 2009). Expressing the sentiments felt by most of those who agreed to partake in this study, Moore explained that "it's frustrating as an anthropologist to see the populations you're working with kind of struggling in that way. Which is always difficult, it is never easy, but COVID is exacerbating inequalities in ways that I think are challenging methodologically but challenging just as you know, a person who cares about the population you're working with" (Moore 2020, 5). Watching those you work with struggling to cope with the unequal impacts of this pandemic is understandably challenging. Similarly, those participants experiencing the hardships of COVID-19 are justifiably less able to commit to taking part in research. The researchers we interviewed referred to the decreased focus on research they had experienced among their own research participants several times (Moore 2020). The unique interpersonal relationship shared between the research subject(s) and the anthropologist(s), while offering the chance for incredible connections, also leaves participants susceptible to becoming far more emotionally attached than some of the less intimate sciences (Behar 1996).

Immersion in the 'field' was another aspect of anthropological research that was heavily impacted by the pandemic. Particularly for those who would normally examine lived experience, finding ways to gather the information needed to draw meaningful conclusions has been difficult. All of the participants interviewed mentioned in some form having resorted to non-traditional, yet reliable, sources of information to supplement their research. Publicly available documents such as blogs, newspapers, and Non-Governmental Organization (NGO) reports were just a few of those mentioned (Moore 2020). For example, Smith used sources such as newspapers, social media, and advocacy pages to retain a sense of what was happening in her study area, but recognized these sources were not a substitute for being able to visit the study area (Smith 2020, 5). Here, immersion in the field has shifted for many of our interview participants from being an embodied endeavour, to being solely a kind of digital or remote immersion of the mind. In both accounts, the 'field' may be entered by being in relation with research participants and colleagues, which is possible both in-person and digitally.

Closely related, the issue of prearranged informants choosing to withdraw participation with little or no warning was another challenge that was even experienced by our anonymous participant's researching team (Anonymous 2020). Individuals who might normally participate in research are also subject to the uncertainties and impacts of the pandemic such as managing their own and their families' mental and physical health alongside economic/financial uncertainties. Using technology to communicate can also be stressful for some, and it appears that it has not been uncommon for individuals to be unable or unwilling to adopt virtual methods. While the reported reasoning for this varied, be it that the group the researcher wished to study has an aversion to technology, did not have access, or simply never provided a rationale, there was an increase in the frequency of withdrawal of participation (Anonymous 2020).

The precarious nature of conducting research during a pandemic was also an issue impacting several of the anthropologists

interviewed (Moore 2020, Anonymous 2020). The current situation in many regions globally is highly volatile as new COVID-19 related developments are hard to predict with any degree of certainty beyond the immediate future. As such, planning a viable research design which adequately addresses an ever-evolving pandemic situation is extremely challenging. As the anonymous interviewee reported, even being able to put together a viable plan is not a guarantee of success (Anonymous 2020). Where, normally, a degree of flexibility is to be expected in ethnographic research and one could adapt to unexpected situations as they arose, since March 2020, even a small change in circumstances can derail an entire project. By applying measures to ensure the safety of participants, the anonymous interviewee negotiated access to do their ethnographic fieldwork onsite. A condition of this physical participation was that the anonymous researcher agreed to self-isolate in a cabin away from the main settlement for two-weeks before integrating into the population and beginning their research. While they happily accepted the more than reasonable terms, on the third day after coming out of isolation, they received news of a family emergency and promptly had to leave the site to return home. Having then dealt with the issue at home, they then faced a dilemma: should they return to the field site and spend another 14 days isolating, or call the project off and wait to reschedule until the pandemic eases? Ultimately, the time and monetary costs of having to spend another two-weeks isolating before beginning work were too great, and the project was postponed indefinitely (Anonymous 2020). While this is one experience among those interviewed for this project, the fragile and easily disrupted nature of researching on-site, was a challenge shared by many.

While the researchers interviewed were able to use methods such as digital interviews to circumvent their inability to perform in-person interviews or fieldwork, there were some problems that were too great and will remain as obstacles to research for the foreseeable future. Our anonymous anthropologist described their difficulties as follows: "[Fieldwork is] a big time commitment, and actually [a big] financial commitment" (Anonymous 2020, 3). In reference to a recently cancelled trip they stated, "I was supposed to go…on March 15th [laughing], which is sort of funny now. So, I obviously didn't go" (Anonymous 2020, 3). This financial commitment is a large burden on researchers and may prove to be insurmountable for many as the pandemic continues.

The concept of relationship is itself paramount to the anthropological process and being separated from the community in which one works in any means, be it physical or otherwise, prevents the anthropologist from conducting participatory methods. McIlwraith described the separation he felt as a community-based ethnographer, "I do feel a sense of detachment. I mean I live quite a long way away from the places that I work, and you know I have quite a number of friends in some of these places that I don't get to see as much or interact with as much." (McIlwraith 2020, 5). This sense of detachment and separation from community can tear at the heart of a community-based researcher and can produce a sense of homesickness for the field (LeCompte and Schensul 2010).

For our interview participants, separation often resulted in a cancellation or delay of existing research plans. Moore described her experiences as "being put on hold" (Moore 2020, 5), an experience shared by McIlwraith as he describes a community event which itself was "put off until at least next summer" (McIlwraith 2020, 4). Highlighting the expanded effects of separation from the region of one's work, McIlwraith stated that "the big setback, now that I think about it, is the cancelling of community events where we

were going to be mobilizing people around the things we identified during the research" (McIlwraith 2020, 3). With the typical rush of summer anthropological research being disrupted, McIlwraith added that "maybe one of the benefits unforeseen [of the pandemic and cancellation of events] is that communities get a break from people like me coming and trying to hang out" (McIlwraith 2020, 1). For better or worse, the pandemic has altered the extent and means by which anthropological researchers interact with the communities they research, and many of these changes will likely persist into the foreseeable future.

BENEFITS AND LIMITATIONS OF NEW METHODS AND TECHNOLOGIES

For most of our participants, moving and transitioning their research, methods and/or fieldwork online posed a difficult task (Anonymous 2020, McIlwraith 2020, Moore 2020, Smith 2020). Working online demanded the use of new technologies and practices with little advance notice. Many of our participants emphasized the importance of virtual ethnography during these times, as well as its benefits and shortcomings (Deakin and Wakefield 2014; Seitz 2016). Moore raised concerns about how conducting interviews in a virtual setting might affect the connection between a researcher and participant stating, "People get nervous on camera especially if they don't know you very well" (Moore 2020, 3). Yet she felt that a benefit of virtual methods was necessary in these times arguing it will allow anthropologists to "fine tune" and enhance methods she had used in her work pre-COVID-19 (Smith 2020, 7). For the anonymous participant whose work focused heavily on non-verbal interactions, virtual ethnography lacked the physical component required to get that same sense of "communal body" (Anonymous 2020, 4). Other electronic methods included the accessing of electronically published newspapers, reaching out to advocacy pages, and adapting non-virtual methods to an online space. While some of the participants expressed the possible difference between personally gathered data and virtually gathered data, they also discussed that there are ethnographic methods that are capable of being adapted to new technologies with some creativity and flexibility (Anonymous 2020, Smith 2020, McIlwraith 2020).

The pressures of the pandemic are encouraging more researchers to turn to virtual methods and for more research around virtual methodology to be done (Smith 2020). Most of our participants expressed an interest in how these virtual methods can be used in combination with other methodology, be it through adapting in-person methods to virtual environments, encouraging virtual collaboration between researchers, or an increase in hybrid conferences that mesh physical and virtual knowledge sharing. Moore stated that she thinks "there are a lot of benefits to virtual ethnography, it is something that is now gaining a lot of research around the methodology itself because of COVID" (Moore 2020, 3). McIlwraith similarly affirmed that "participating in interviews by phone or by Zoom is not entirely the end of the world, even if it wasn't what you set out to do" (McIlwraith 2020, 3). However, Moore was clear that she personally does not know if doing virtual ethnography would be an approach she would primarily adopt in the future (Moore 2020). She believes in the importance of in-person connections that are made between the researcher and their participants, and that virtual ethnography can be more challenging in terms of establishing rapport, especially if the participants are part of marginalized communities who may not have access to or comfort with technology and/or outsiders. In the context of her research, Moore stated that virtual methods are "kind of a band aid to get you data, but I don't know if the quality of the data is quite as good" (Moore 2020, 3). In response to these kinds of

arguments, Barkley expressed excitement at the potential of virtual ethnography's limitations encouraging more researchers to transition from conducting research internationally towards working locally among their own communities (Barkley 2020).

Smith noted that another advantage to conducting research virtually was that she was still able to connect with research colleagues who are located in different countries (Smith 2020). She added that this benefits her research as "it's much easier" to be able to connect with international research participants and colleagues to have a conversation reflecting on local topics of news in real time, as they happen, as opposed to when she is able to travel to see them in-person (Smith 2020, 5). Similarly, McIlwraith noted virtual communication platforms present new opportunities because a virtual platform "lends itself to a different kind of engagement...that just isn't possible if it's a face-to-face meeting" (McIlwraith 2020, 3). Research meetings and other events that focus on disseminating anthropological information have typically been generated by and for academics, yet McIlwraith noted the potential for engagement to become permanently more democratic and international by using digital technologies to better connect one another.

POTENTIAL LASTING EFFECTS OF THE COVID-19 VIRUS ON ANTHROPOLOGICAL RESEARCH

Across our five participants we also found a diverse collection of forward-looking research plans that respond to the pandemic in different ways. Although the thoughts of each participant were context-dependent, there were areas of general overlap in thoughts about the future adoption of virtual methods in anthropological practice. McIlwraith explained how the COVID-19 pandemic had provided a new opportunity to have virtual conferences and reach a wider audience (McIlwraith 2020). He highlighted that virtual calls and conferences were a part of the future as they allow for people from all over the world to join in, visit, and present. Being forced to go online has opened doors to new ways of learning and connection to other parts of the world, all while staying at home. For example, the University of Guelph's Masters students had to adjust quickly to the new travel restrictions. They either had to scrap their entire thesis idea or modify it to function within the new social distancing measures. As such, many student researchers conducted interviews over Zoom, which allowed them to form connections and conduct fieldwork without travelling. Virtual research methods give opportunities to reach audiences and connect with people they may not be able to otherwise, and this benefit may allow for more flexibility in anthropological methods in the future (McIlwraith 2020).

Similarly, Barkley alluded to how research methods she used during the pandemic will be adopted into her fieldwork in the long term, as it has introduced new ways to connect with others both near and far (Barkley 2020). She added that the pandemic may influence anthropologists towards working more from home and within one's home community more often, which can help shift away from the neo-colonial tendencies of going elsewhere to conduct research. She believes that the COVID-19 pandemic could function as a transitional period—a kind of "reckoning" (Todd 2018)—for anthropologists to shift away from their colonial roots of studying the Other, and instead localize their research to home communities (Barkley 2020).

Relatedly, Smith spoke of how the pandemic may cause changes to the way anthropologists show care towards themselves, their participants, and their peers. For example, anthropologists and those with whom they work may be more attentive to when someone needs a break and step away from the computer or when it is time for a walk (Smith 2020). Smith also noted that the pandemic will

influence future research questions because the pandemic has brought to light different social structures of communities, inequalities, and relationships. The pandemic highlights how people interact and deal with challenges, for example, which will help researchers identify new research questions and topics.

Anthropologists may experience a long-term shift in research-based relationships as a result of the pandemic. Among our five participants there were mixed feelings surrounding the shift towards remote and virtual research in the long term. Some agreed that the virtual methods represented the future of fieldwork as anthropologists can reach more people without previous temporal, financial, and spatial restrictions, while others felt the connections and relationships created through in-person fieldwork produced better data. Conducting ethnographic field work relies on creating and maintaining relationships with your research subjects, which can be done virtually or in-person—with differing results.

CONCLUSION

Anthropological methods traditionally emphasize in-person community interaction, and as such finds themselves in a difficult position as a result of the COVID-19 pandemic. Anthropologists interviewed for this project—Lori Barkley, Tad McIlwraith, Samantha Moore, Angele Smith, and an anonymous participant—all discussed how their particular research projects had been affected as a result of the pandemic. Due to the virulent nature of COVID-19, international travel and gathering were restricted across the world, posing a problem for a discipline whose research often consists of traveling across the world and gathering with community members for an extended amount of time. McIlwraith, Moore, and Smith were forced to adapt their research by adopting digital methods, in particular Zoom video interviews, to work around their physical distance from their research participants and communities. Meanwhile, Barkley was relatively unaffected by the pandemic as a result of her already performing research in her own community, while the anonymous interviewee found themself completely unable to conduct research in the current climate.

The interviewees all felt that digital interviews were inferior to more conventional, in-person fieldwork, and avoided changing their research to entirely focus on virtual methods in favour of accepting the prolonged time frames their projects would take. If the 'field' is defined as being in relation with the people, places, and things, the field may be entered remotely or in-person. As such, our research participants found other ways to remain in relation through digital media. Additionally, since not all aspects of anthropological research are reliant on fieldwork, such as grant applications, data analysis, and writing, these were all performed by interview participants when fieldwork was unavailable. Despite limitations of virtual interview methods, the interviewees did not believe that the discipline should entirely do away with digital interviews after the pandemic was over, perceiving these as yet another tool that anthropologists could use to perform research and gain data. The present issue posed by the pandemic, however, stems more from digital interviews being the only tool feasibly available for many. The digital paradigm emergent from the pandemic had other effects, such as changing how anthropological colleagues interact and how conferences occur. Participants also described the emancipatory potential of the pandemic on anthropological research, as it forces anthropologists to slow down and think through their methods more carefully—and potentially shift towards more decolonial practices (Günel et al 2020). These changes may remain as a part of anthropology past the end of this pandemic, and possibly even have beneficial impacts to the discipline as a whole going forward.

Beyond interviewing anthropologists, as we did in this study, there is also a need to understand how the pandemic is affecting participants of anthropological research, as evidenced by McIlwraith's comment about the lack of researchers in his field site this summer. This raises many questions such as: how does the pandemic affect anthropological research, not only from the perspectives of anthropologists, but from the points of view of our research collaborators, colleagues, and participants? These trends in changing anthropological practice will be worth watching and reflecting on as the pandemic continues. In all, the digital and remote paradigm adopted as a result of the pandemic by the researchers we interviewed will ultimately remain in place to some degree until in-person gatherings and international travel are relatively less restricted. Yet going forward, elements of this paradigm may remain as an integral aspect of anthropology.

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REVIEW ARTICLE

Entheseal Changes: Benefits, Limitations, and Applications in Bioarchaeology

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ABSTRACT
Reconstructing physical activities in ancient humans has long been pursued in bioarchaeology to understand our history and development. Entheseal changes (EC)—variations to muscle, tendon, and ligament attachment sites on bone—have been used in bioarchaeology since the 1980s to reconstruct activities in past populations such as changes in mobility, subsistence strategy, and gendered division of labour. EC research is based on bone functional adaptation, where bone responds to mechanical stress on entheses through bone formation or destruction in varying degrees of expression. However, the relationship between EC and activity is more complex than simple cause-and-effect, as it involves multiple confounding variables, which can affect EC morphology. This article addresses the use of EC research in bioarchaeology through two parts: Part 1 defines entheses and EC, including observational and quantitative methods developed in bioarchaeology to study EC. Part 2 will summarize the main known factors that influence EC beyond activity such as age, sex, and body size. The article concludes with a discussion of varying benefits and limitations to EC research in bioarchaeology including the use of archaeological samples, historical collections, and animal experimental models. Overall, EC research can be difficult to link with activity due to its multifactorial etiology, challenges of efficacy in developing methods, and limitations of working with human remains. However, recent studies are showing more positive results, demonstrating the usefulness of EC as a way to reconstruct activity.

Keywords: biomechanics, bone adaptation, bioarchaeology, entheseal changes, archaeology, activity reconstructions, methodology

INTRODUCTION

Activity reconstruction from human remains has long been a significant focus in paleoanthropology and bioarchaeology as a way to understand past populations. Skeletal markers can be observed and quantified to reveal clues about physical activities within a population such as occupation, gendered divisions of labour, subsistence strategies, and mobility (e.g., Eshed et al. 2004; Hawkey and Merbs 1995; Lieverse et al. 2013; Yonemoto 2016). However, the relationship between activity during life and the skeletal markers they leave behind are consequences of a multitude of external and internal factors that complicate our interpretation (Jurmain et al. 2012). Currently, there are three widely used activity indicators in skeletal analysis that can provide context for these avenues of inquiry: cross-sectional bone geometry (CSBG), osteoarthritis (OA), and entheseal changes (EC).

This article uses EC as the primary indicator of activity for analysis. Given the current

state of human EC research, this topic will be discussed based upon two main questions:

1. How have EC been used in archaeological research as a method for reconstructing activity?

2. What factors influence EC etiology and what are the benefits and limitations of EC research?

Each question will be addressed in two corresponding parts. Part one analyses the definition and current understanding of entheses and their two anatomical types, fibrous (FE) and fibrocartilaginous (FCE). This part describes EC and explains how they are understood in terms of bone biomechanics and includes a summary of the main EC literature and methods developed since the 1980s. The second part discusses the etiology of EC and how the effects of age, sex, body size, and other systemic factors influence entheseal morphology. Part two then examines the benefits and limitations of EC research and demonstrates how EC have been used to reconstruct past activity.

CONTEXT

The link between skeletal morphology and activity in bioarchaeology is based upon the widely accepted concept of bone functional adaptation (Ruff, Holt, and Trinkaus 2006). This concept may be best known through Wolff's Law as "form follows function", meaning that cortical and trabecular bone architecture will remodel and adapt to best disperse mechanical loading forces (Benjamin et al. 2006; Ruff, Holt, and Trinkaus 2006; Wolff 1986). Simply put, bone functional adaptation reflects the microdamage to bone and connective tissue caused by mechanical overloading, which stimulates the production of osteoblasts (bone-producing cells) and osteoclasts (bone-destructing cells) (Benjamin et al. 2006; Ruff, Holt, and Trinkaus 2006). This cell activity alters the architecture and morphological appearance of bone tissue as our skeletons continue through stages of growth, maintenance, and destruction over time (Benjamin et al. 2006; Ruff, Holt, and Trinkaus 2006). The variation and expression of these accumulated morphological changes can then be analysed in different ways to infer past physical activities, of which CSBG, OA and EC are the most popular indicators in bioarchaeology (Jurmain et al. 2012). Since these indicators are often used together to increase the accuracy of interpretations of skeletal morphology, it is important to briefly define their current role in bioarchaeological research.

CSBG analyzes changes to cortical bone structure and geometry on long bone diaphyses (bone shafts) in response to bending, twisting and compression from biomechanical loading (Becker 2020; Ruff, Holt and Trinkaus 2006). The shape and geometry of long bones can indicate general levels of activity in individuals or compare populations to reveal chronological changes in subsistence strategy such as hunter-gatherers to sedentary agriculturalists (Becker 2020). For example, the shape and volume of cortical bone on the lower limbs of a mobile forager would expect to be markedly different from a sedentary farmer when comparing bone cross sections due to the nature of bone adaptation to mechanical loading (Ruff, Holt, and Trinkaus 2006). However, researchers must also consider the impact of non-mechanical factors on CSBG such as hormones, diet, genetics, or age that can influence bone structure (Becker 2020; Jurmain et al. 2012).

OA is a chronic and degenerative condition of synovial joints characterized by a combination of inflammatory bone responses to hyaline cartilage breakdown (Lieverse et al. 2016; McGonagle, Hermann, and Tan 2015). Skeletally, OA can present as either marginal hypertrophic changes (osteophytes) or as pitting, porosity, or erosion on joint surfaces (Domett et al. 2017). It is ubiquitous in modern and ancient populations and is multifactorial in etiology, where physical activity, age, sex,

genetics, and skeletal trauma experienced during life—such as fractures or infections—are all risk factors (Domett et al. 2017). Bioarchaeologists can use OA to describe general levels of physical activity in ancient populations when accompanied by archaeological evidence, strong statistical methods, and population-level comparisons (Becker 2020; Dommett et al. 2017; Jurmain et al. 2012).

Entheseal changes (EC) are the morphological alterations to *entheses*—muscle, tendon, and ligament attachment sites on bone—that occur as an adaptative response to biomechanical stress (Villotte et al. 2010). EC are also known in bioarchaeology as musculoskeletal stress markers (MSM) (Hawkey and Merbs 1995), markers of occupational stress (Kennedy 1983; İşcan and Kennedy 1989), evidence for occupation (Kelley and Angel 1987), activity-induced pathology (Merbs 1983), activity-induced stress markers (Hawkey and Street 1992) and, in clinical literature, as enthesophytes, enthesopathies, and enthesiopathies (Benjamin et al 2002, 2006; Jurmain et al. 2012). The recent shift of terminology to 'entheseal changes' was intended to avoid the assumption that occupation, activity, or pathological changes are the sole contributors to EC, which are now known to have a multifactorial etiology (Villotte et al. 2010).

PART 1: ETHNESEAL RESEARCH IN BIOARCHAEOLOGY

Entheses

As stated earlier, entheses are sites on bone to which muscles, tendons, and ligaments attach (Benjamin et al. 2002, 931). Each enthesis is different in size and shape, and their soft tissue attachments vary depending on their location on the skeleton (Benjamin et al. 2002, 2006). Tendons attach muscles to bone and facilitate movement, such as the Achilles tendon connecting the calf muscles to the calcaneus (heel), whereas ligaments connect bone to bone and provide joint stability, such as the anterior cruciate ligament (ACL) connecting the femur to the tibia and stabilizing the knee (Benjamin et al. 2002). When skeletal muscles contract to create movement, mechanical strain is transferred to the affected tendon or ligament. Here, mechanical stress is dissipated away from the hard-soft tissue boundary on the enthesis and distributed more evenly across the soft tissue structures, creating a stronger resistant force (Benjamin et al. 2002, 2006). The transfer of strain is essential for minimizing the risk of tearing and avulsion fractures in which the tendon or ligament is completely torn away from the enthesis because of mechanical overloading (Benjamin et al. 2002; Ruff, Holt, and Trinkaus 2006). Moreover, entheses tend to overlap with one another, and fasciae connect different muscles, which further solidify the bond between soft and hard tissue (Benjamin et al. 2006). Entheses are also part of an "organ complex," where anatomical structures surrounding the enthesis such as bursae and fat pads also assist in dissipating mechanical stress by reducing shock and friction on joints and are thus also affected by the same factors that influence entheseal morphology (Benjamin and McGonagle 2009).

Types of entheses: Fibrous (FE) and fibrocartilaginous (FCE)

Entheses are divided into two forms, fibrous entheses (FE) and fibrocartilaginous entheses (FCE) (Benjamin, Evans, and Copp 1986; Benjamin et al. 2002). FE develop through intramembranous ossification and are found closer to the diaphyses of long bones (Benjamin et al. 2002, 2006). FE have no cartilaginous tissue and are associated with large and powerful muscles in the body like the quadriceps and adductor muscles attaching to the *linea aspera* of the femur or the deltoid muscles of the shoulder (Benjamin et al. 2002). Thus, these entheses typically cover a larger surface area than FCE (Benjamin et al. 2002). FE are further subdivided into two types, peri-

osteal and bony. The former denotes attachment indirectly onto bone via the periosteum––a layer of vascular connective tissue covering bone. The latter indicates direct attachment onto bone *without* involvement of the periosteum (Benjamin et al. 2002, 2006; Benjamin and McGonagle 2009).

Histologically, FE are bound by dense fibrous connective tissue and do not contain fibrocartilage, unlike FCE. In addition, extrinsic fibers (EF), previously named Sharpey's fibers due to their close anatomical similarity to those in the periodontal ligament of teeth, are a dense mat of collagen fibers that are responsible for anchoring tendons to the periosteum and directly onto the bone (Turcotte et al. 2020). EF are in the deepest aspects of the cortical layer where other fibers attach (Benjamin et al., 2002). These fibers are well known in some FE but not in FCE and are not found on entheses with little or no cortical bone (Benjamin et al. 2002). There is no definitive 'normal' or unchanged appearance of FE, but medical literature characterizes it by a smooth cortical surface (Villotte et al. 2016; Benjamin et al. 2002, 2006).

FCE are typically found on the epiphyses (ends of long bones) and closer to joint surfaces, attaching directly to the bone without any periosteal involvement. FCE also have four histological layers, from superficial to deep dense fibrous connective tissue (i.e., the tendon), uncalcified fibrocartilage, calcified fibrocartilage, and bone (Benjamin, Evans, and Copp 1986; Benjamin et al. 2002). The boundary between uncalcified and calcified fibrocartilage is called the tidemark, observed as the bony surface remaining after all soft tissue has been removed (Benjamin et al. 2002). On dry bone, a 'normal' or unchanged FCE presents as "smooth, well-circumscribed and devoid of vascular foramina" (Benjamin et al. 2002, 939) and has more visible boundaries than FE, which is why most new studies tend to focus on FCE only (Henderson et al. 2016, 2013; Villotte et al. 2016, 2010).

A new EC scoring method, dubbed the Coimbra method, also delineated FCE into two distinct zones (Henderson et al. 2013, 2016). Zone 1 is the small area on the outer portion of the enthesis that reflects the most oblique angle of tendon attachment, and Zone 2 is essentially the rest of the entheseal area (Henderson et al. 2016, 2013). Henderson's team argue that these zones are important to delineate because compressive and/or shear strain on a tendon—particularly at its most oblique angle—changes the molecular composition of bone's extracellular matrix. As such, Zone 1 normally forms a greater amount of fibrocartilage than Zone 2 as an adaptational response to mechanical loading, thus altering the appearance of attachment sites (Benjamin et al. 2006; Henderson et al. 2013, 2016).

Entheseal Changes (EC)

EC are non-pathological morphological changes that reflect bone formation or bone destruction through mechanical strain and other factors including age, sex, body size, and genetic variables (Henderson et al. 2016; Jurmain et al. 2012)). Bone *formation* is observed as osteophytic (bone-producing) cellular activity creating robusticity and rugosity (roughness) on cortical bone often characterized by bony crests, ridges, or enthesophytes (Foster, Buckley, and Tayles 2014; Hawkey and Merbs 1995). Bone *destruction* appears as various forms of osteolytic (bone-reducing) erosions, cavitations, macroporosities, and microporosities in bone (Henderson et al. 2013, 2016).

In terms of bone functional adaptation, the main idea in EC research is that increased muscle use through physical activities increases strain on human tendons or ligaments and causes microscopic damage and tears to connective tissue. This damage increases blood flow to the attachment site, in turn, encouraging bone cell activity that alters the shape, size, and appearance of the enthesis (Jurmain et al. 2012).

Based on this understanding, entheses that show more morphological changes are attributed to greater amounts of physical activity. This allows researchers to discern patterns of activity in archaeological contexts (Jurmain et al. 2012). The frequency, duration, and extent of loading also contribute to the varying expressions of EC in addition to the type and anatomical location of the enthesis on the skeleton (Ruff, Holt, and Trinkaus 2006). It should also be noted that the appearance of a "normal" FE and FCE¬—that is, the absence of EC—does not imply that the individual did not participate in activities, as EC etiology is multifactorial. Thus, the absence or presence of morphological changes and their overall degrees of expression do not necessarily reflect the intensity or duration of activity during life (Dewey 2018).

Pathological changes to entheses are often caused by overuse injuries. Overuse injuries can be anything from "jumpers' knee" on the patella to "tennis elbow" in the humeral epicondyle in athletes, or can reflect inflammatory, metabolic, traumatic, or degenerative conditions such as spondyloarthropathies, OA, and diffuse idiopathic skeletal hyperostosis (DISH) (Dewey 2018; Jurmain et al. 2012). These changes, called *enthesopathies* in clinical literature, are an abnormal osteolytic or osteophytic response to the above conditions, and are not considered EC in its most recent definition (Jurmain & Villotte, 2010; Villotte & Knüsel, 2013). However, multiple scoring methods (see Hawkey and Merbs 1995; Mariotti, Facchini, and Belcastro 2004; Villotte et al. 2010) incorporate enthesopathies and other pathological lesions into their scoring methods through aggregate scores that consider normal and pathological changes either together or separately. The incorporation of pathological changes on entheses are still important to consider as they are intrinsic to the enthesis organ and thus affected by the same biomechanical forces. However, the exclusion of pathological changes in recent terminology was intended to avoid implicit associations between EC and pathological origins (Jurmain and Villotte 2010; Villotte and Knüsel 2013).

Methods for EC Analysis: Observational Scoring Systems

Research on EC in the 1980s and 1990s introduced various nonmetric and visual scoring methods of entheses using skeletal remains from archaeological sites (e.g., studying effects of occupational stress in Kelley and Angel 1987). Diane Hawkey and Charles Merbs (1995) were the first scholars to introduce the first well-known standardized scoring method in bioarchaeology intended for repeated use. This method considered three EC features each scored on a three-point ordinal scale on FE and FCE alike: stress lesions, ossification exostoses (enthesopathies), and robusticity markers (Hawkey and Merbs 1995). This method was the first to use a ranked scoring structure and standardize morphological expressions, which allowed other researchers to comparatively identify common links between EC expression and activity. However, many scholars have criticized this method for failing to incorporate clinical entheseal research, being overly simplistic, and having poor intraobserver and interobserver repeatability (e.g., Davis et al. 2013). Some authors recommend modifying this method in future studies by combining all three features' scores (on a scale of zero to six) to indicate total muscle use, allowing the results to be less sensitive to anomalies, instead focusing on broad activity levels rather than individual muscle use (Molnar 2006; Weiss 2007).

Another popular nonmetric methodology similar to Hawkey and Merbs (1995), created by Valentina Mariotti, Fiorenzo Facchini, and Maria Giovanna Belcastro (2004; 2007), also applies to both FE and FCE. This method analyzes robusticity and two different categories of enthesopathies: osteolytic lesions and osteophytic lesions. In addition, reference

photographs of each score from one (minimal expression) to three (strongest expression) on each recorded enthesis are provided (Mariotti, Facchini, and Belcastro 2004, 2007). Notably, this scoring method was tested using a historically identified skeletal collection of 19th and 20th century Europeans, whereas Hawkey and Merbs (1995) applied their scoring method to archeological Inuit remains[1]. 'Historically identified' refers to individuals or populations (in this case, curated skeletal collections) that have accompanying documentation of their age-at-death, date of birth, sex, occupation, and any other information detailing their life histories useful for testing EC methods. However, the use of historically identified skeletal collections does not render this method infallible, since Mariotti and colleagues' work has also been criticized for failing to include clinical entheseal research and for their high intraobserver and interobserver variability for scoring robusticity (Jurmain et al. 2012; Villotte and Knüsel 2013). Additionally, these collections are useful in that they provide more accurate data on age and sex than in archaeological remains. However, future scholars must consider and consult the modern descendants of these remains when necessary, particularly when contributing to ethical Indigenous research and reciprocal Indigenous-non-Indigenous relationships over exploitative, colonial interpretations of Indigenous remains.

Sébastien Villotte and colleagues (2007, 2010) developed a visual scoring method that incorporated medical literature on entheses. The focus of the scoring method was the distinct anatomy and histology of FE versus FCE. As stated previously, FCE and FE are different in their histology and location, reflecting different molecular responses to biomechanical strain and thus their manifestation of EC. For example, fibrocartilaginous tissue is present only on FCE and increases as an adaptation to compression and/or shearing forces in the deeper part of an enthesis (i.e., closer towards the center of the attachment) compared to its more superficial parts, thus resulting in different entheseal morphology (Benjamin et al. 2002; 2006). Indeed, their tests on a historically identified collection showed a positive correlation between activity and changes to FCE. However, they found no link between activity and FE, thus reinforcing the suggestion that FE and FCE show EC differently and should be scored separately (Villotte et al. 2010).

A newer standardized method in EC research, dubbed the Coimbra method (Henderson et al. 2013, 2016), was developed exclusively for FCE. Two previous scoring methods developed by Mariotti, Facchini, and Belcastro (2004, 2007) and by Villotte and colleagues (2010) served as the basis for this new protocol. The method considers six categories of entheseal morphological variation: textural change, bone formation, erosion, fine porosity, macroporosity, and cavitations. Further, this method also divides the enthesis into two zones, Zone 1and Zone 2, where Zone 1 is the thin margin along the border of an enthesis that represents the most oblique angle of attachment for the tendon or ligament, and Zone 2 is the rest of the entheseal surface (Henderson et al. 2013, 2016). This method incorporates medical literature and considers the effects of age, sex, and body size in their scoring methods, which has allowed for higher observer repeatability and shows potential as a reliable method for future EC research (Henderson et al. 2013, 2016).

[1] According to Hawkey and Merbs, the Inuit remains used in this study were recovered between 1967 and 1969 during the "Northwest Hudson Bay Thule Project" (1995). Their justification for utilizing these skeletal remains was their good preservation and "cultural and genetic isolation", which allowed the authors to connect their results to specialized activities associated with this population. However, this article fails to include any mention of ethical concerns or consultation with Indigenous communities leaving many questions surrounding the effects of research based on bone collections held in colonial institutions, like museums and archives, on modern Indigenous peoples as well as reconciliation and repatriation efforts.

Methods for EC Analysis: Quantifying Entheseal Dimensions Using 3D Surface Models and 2D Topography

Although nonmetric scoring systems based on visual analysis served as the basis for most early research on EC, there are some drawbacks to these methods. The first limitation is the influence of human subjectivity affecting observer bias, and the second is the low statistical power of ranked scoring systems (typically zero to three), which reduces observer error but also negatively impacts the detection of statistical patterns linking EC and activity (Havelková and Villotte 2007; Nolte and Wilczak 2013). Given the increased availability and lowered costs of computers and laser scanning technology at the turn of the twenty-first century, EC methodologies that use quantitative computational data like two-dimensional (2D) topographical analysis and three-dimensional (3D) models of entheses, have become more popular. These methods are beneficial in that they have high repeatability and precision compared to observational scores and counter the drawbacks of low statistical power in nonmetric systems, opening new avenues of precise data analysis for EC research. Quantitative analysis has also proven useful in experimental studies that use animal models as human proxies (Rabey et al. 2015; Wallace et al. 2017; Zumwalt 2006), where 3D laser scanning and topographical analysis of entheseal structures are employed to identify any links between EC and activity.

The first application of digital technology for EC utilized entheseal measurements to study their linear profiles via 2D topographical analysis and optometric scanners to quantify the size and surface roughness of FE and FCE on human remains (Pany-Kucera, Viola, and Teschler-Nicola 2009; Wilczak 1998). Monica Nolte and Cynthia Wilczak's subsequent study in 2013 investigated the effects of biological variables (age, sex, body size, and secular changes) and quantified FCE of the upper limb using Next Engine 3D scans on skeletal collections. Efthymia Nikita and colleagues (2019) introduced another approach that considered the shape of the *supraspinatus*, *infraspinatus*, and *subscapularis* entheses on the humerus (muscles that attach on the shoulder blade and connect to the upper arm) by adopting a 3D microscopic method. Though these works failed to find strong links between EC and activity, they draw attention to the importance of considering impacts of biological variables (e.g., age, sex, and body size) and how different quantification methods can be beneficial to EC research (Nikita et al. 2019; Nolte and Wilczak 2013).

Other researchers have considered the relative size of entheses to identify EC and activity patterns including the series of publications by Karakostis and colleagues, particularly Karakostis and Lorenzo (2016). This research by Karakostis and colleagues explore the development of hand entheses by introducing a 3D recording method for entheseal area (Karakostis et al. 2017). When testing this method, they quantified entheseal surface area in a skeletal collection and identified patterns in individuals of similar activity levels (e.g., individuals with high manual labor occupations versus low manual labor) (Karakostis et al. 2017). After criticisms of low interobserver and intraobserver repeatability in this method, Karakostis and colleagues (2018) introduced a new method analyzing the *shape* of entheses using 3D landmark-based geometric morphometrics and multivariate statistics. Recent publications in EC research encourage the use of multivariate analysis to control for confounding variables affecting EC etiology (e.g., Millela et al. 2015). Statistical protocols that consider multiple contributing variables in EC morphology allow researchers to better identify links between EC and activity, countering the obscuring effects of age, sex, and body size on EC scores to an extent (Milella et al. 2015).

Considering this, Fotios Alexandros Karakostis and colleagues (2018) developed a new 3D approach found to be highly repeatable and addressed the limitations of previous studies using topographical analysis because previous methods could not measure the variation in the shape of multiple landmarks on an enthesis simultaneously. Morphometric geometric analysis thus seems effective when applied to historical skeletal collections and archaeological remains (Karakostis et al. 2018). Karakostis and colleagues (2021) subsequently published a case study identifying a specific pattern of EC on the hand in an approximately 8,500 cal. BP individual from the Peruvian Andes. EC on the thumb and fingers were associated with precision gripping, suggesting that this method is sensitive enough to identify precise muscle activities in past individuals and shows potential for future EC research (Karakostis et al. 2021).

PART 2: EC ETIOLOGY, BENEFITS, AND LIMITATIONS

EC and Age

It was noted in early EC research that entheses typically showed more pronounced morphological changes in older individuals, and this trend has proven consistent in more recent studies testing EC scoring methods on skeletal collections (Henderson et al. 2016; Mariotti, Facchini, and Belcastro 2004; Milella et al. 2012; Molnar 2006; Niinimäki 2011; Villotte et al. 2010). The high correlation between increased age and pronounced morphological expression is also relatively consistent in studies testing the efficacy of multiple different visual scoring methods on the same skeletal collection. For example, a study by Efrossyni Michopoulou, Efthymia Nikita, and Efstratios Valakos (2015) used the Athens Collection to test methods developed by Hawkey and Merbs (1995), Mariotti, Facchini, and Belcastro (2004), and Villotte and colleagues (2010). A subsequent test of the Coimbra method using the same testing parameters found age to be a less significant causative factor when compared to previous scoring methods (Michopoulou, Nikita, and Henderson 2017). The authors attributed their results to the method's greater efficacy rather than suggesting that age was a lesser causative factor.

These observations suggest that age obscures distinctions between EC and activity. For example, Niinimäki (2011) found that score differences between populations of heavy and light manual labourers were consistently higher in heavy manual labourers, but scores were equal between labour groups after the age of 50. This raises many questions between the connections between age, EC, and activity such as does this mean that these individuals transitioned to lighter manual work as their bodies aged? Or does it mean that the effects of age-associated degeneration obscure the impacts of physical activity? Michopoulou, Nikita, and Henderson (2017) attributed this to the 'leveling off' process, whereby EC increase with age until around 40 to 50 years when physical activity typically decreases, and their bodies are biologically limited to respond to mechanical stress.

The observed prominence of age as a confounding variable of EC may be due to a few factors: the reduction of osteoblastic activity as a by-product of aging, the resorption of bone because of muscle underuse, and/or the accumulation of stress on bone in old age from years of wear and tear, overuse, and isolated events of physical trauma (Henderson et al. 2016; Michopoulou, Nikita, and Valakos 2015; Michopoulou, Nikita, and Henderson 2017; Niinimäki 2011; Villotte and Knüsel 2014). In addition, the relative association between EC and age seems to vary among different populations, suggesting that age effects on EC may be related to physical activity in and of itself (Yonemoto 2016). Charlotte Henderson and colleagues (2016) point out that age effects on the skeleton have numerous components that

are still poorly understood. Given the multifactorial impacts of age on the human musculoskeletal system, for instance, it is difficult to determine these factors without additional multivariate analysis to control for other confounding variables such as body size, sex, and other historical data (e.g., indicating occupation, environment, population genetics, and any other influential factors). Nonetheless, research shows that age seems to have a statistically significant impact on EC morphological expression (Henderson et al. 2016; Mariotti, Facchini, and Belcastro 2004; Milella et al. 2012; Molnar 2006; Niinimäki 2011; Villotte et al. 2010; Weiss 2003, 2004, 2007).

EC and Body Size

In addition to age, body size has been noted as a statistically significant contributor to EC morphological variation (Foster, Buckley, and Tayles 2014; Weiss 2003, 2004, 2007; Wilczak 1998; Zumwalt 2006). Considering bone functional adaptation and gravitational effects on muscle size, larger bodies require larger muscles to meet the basic demands of movement and stability, which by extension affects their morphological expression on entheses (Foster, Buckley, and Tayles 2014; Ruff, Holt, and Trinkaus 2006; Villotte et al. 2010; Weiss, Corona, and Schultz 2012). This relationship has been identified in studies using skeletal measurements as proxies for body size (Niinimäki 2011; Weiss 2003; 2015) and studies testing entheseal surface areas where body size was found to be the most significant variable correlating with entheseal area (Nikita 2019; Nolte and Wilczak 2013;). Further, body size has been found to affect lower limbs more than upper limbs, being attributed to higher load-bearing requirements of the legs in enabling bipedal locomotion and body support (Ruff, Holt, and Trinkaus 2006; Weiss 2003, 2015; Weiss, Corona, and Schultz 2012). Body size also affects entheseal types differently, as studies show that FE correlate with body size more than FCE because FE attach to larger muscles and over a broader area of diaphyseal bone (Villotte et al. 2010; Weiss 2015).

Interestingly, using skeletal measurements to calculate body *mass* rather than body *size* (the difference being the use of different skeletal measurements and calculations, see Ruff et al. 2012) has also shown different correlations to EC. Michopoulou and colleagues (2015, 2017) noted that body size had a less significant correlation to EC scores in their study when using upper limb measurements to determine body mass. This contradicts earlier findings that used skeletal measurements to determine body size (e.g., Weiss 2003; 2004; 2007; 2015; Niinimäki 2011; Weiss, Corona, and Schultz. 2012). However, Michopoulou, Nikita, and Henderson state that

> "…it must be stressed that earlier studies had used specific bone dimensions as a proxy for body size, rather than body mass…[i]t is possible that although body mass is a better overall measure of body size, the dimensions of the bone elements on which the ECs have been recorded approximate body size more directly concerning the ECs under study" (2017, 415).

This implies that measurements for body mass as a proxy for body size is a more accurate indicator, and that stronger correlations between body size and EC expression found in earlier studies may be partially explained by the researcher's choice of bone dimensions as proxies for body size. Therefore, the impact of body size and the measurements used to calculate body size versus body mass show different correlations to EC, which requires further study.

In general, body size has a stronger correlation with lower limb than upper limb EC and affect FE more than FCE, probably due to their anatomical differences in muscle demands in

resisting gravitational and biomechanical forces (Foster, Buckley, and Tayles 2014). However, the measurements used to calculate body mass as proxies for body size show differing correlations to EC scores than previous findings; thus more research is required to fully understand the impact of body size on EC (Michopoulou, Nikita, and Valakos 2015; Michopoulou, Nikita, and Henderson 2017). In addition, the entanglement of body size as an innate characteristic of sexual dimorphism complicates the distinction between these two factors, as will be described further.

EC and Sex

Most EC studies have found that males typically show greater EC expression than females. This observation has prompted scholars to suggest that these sex differences are largely a result of sexual dimorphism in body size (Niinimäki 2011; Weiss 2003, 2004, 2007, 2015; Weiss, Corona, and Schultz. 2012). However, Weiss (2015) points out that the correlation with size disappears when controlling for sex or considering male and female scores differently in both the upper and lower limbs, implying that hormonal sex differences may be more responsible for these observations than body size (Weiss 2004, 2007, 2015; Weiss, Corona, and Schultz 2012). Indeed, males should be expected to have larger entheses than females since males have higher ratios of muscle mass to body size due to testosterone levels experienced during and after adolescence (Foster, Buckley, and Tayles 2014). Thus, although muscle size correlates with entheseal size, this relationship should not imply causation and may not fully account for innate traits of sexual dimorphism. Additionally, the different measurements of body size versus body mass as proxies must be considered to avoid introducing further error.

In early publications, differing EC scores by sex were attributed to males engaging in higher activity levels than females due to gendered division of labor rather than innate sexual differences (e.g. al-Oumaoui, Jiménez-Brobeil, and du Souich 2004; Hawkey and Merbs 1995). Likewise, cases with reverse sex differences—females showing higher EC scores than males—were also assumed to result from higher activity levels in gendered tasks. For example, Eshed and colleagues (2004) attributed high EC scores in the upper limb of Natufian females to gathering and grinding activities, and Hawkey and Merbs (1995) attributed higher *trapezius* scores in female Inuit to their role in *umiak* rowing. These interpretations have been criticized for their oversimplification of EC scores being attributed to gender-structured activities instead of biological sex. However, more contemporary studies confirm that sex differences in EC scores can be partially attributed to these social factors, particularly in the upper limb, where the impact of body size is reduced (Mazza 2019; Weiss 2015).

Overall, authors still disagree as to whether sex or body size is the most influential factor for EC. Given the interconnected nature of body size with innate hormonal characteristics of sexual dimorphism, some authors argue that body size need not be controlled for at all, citing the connection between sexual dimorphism and body size (Villotte et al. 2010; Weiss 2003). However, sex impacts the expression of EC, particularly in the upper limb(s), where body size has less influence, indicating that body size and sex should not be considered equal in their influence on EC morphology (Weiss, Corona, and Schultz. 2012; Weiss, 2015).

EC and Other Genetic Factors

Although age, sex, body size, and activity are the primary influencers of EC expression, other genetic factors can explain some of the observed variation in EC morphology (Jurmain et al., 2012). Considering muscle tissue, Foster, Buckley, and Tayles (2014) note that the amount of muscle fiber determines a muscle's mass and shape, and by extension,

impacts the morphology of an enthesis. They explain that muscle size increase via physical activity causes hypertrophy in muscle fibers rather than increasing fiber numbers themselves. Instead, muscle fiber number is genetically determined, implying "a genetically imposed limitation to muscular development based on the numbers of fibers available to respond to stress" (Foster, Buckley, and Tayles 2014, 524). In addition, genetic variation also influences average muscle size in males and females, suggesting that population genetics has an impact on the expression of EC through its influence on muscle morphology (Foster, Buckley, and Tayles 2014). Moreover, Benjamin and colleagues (2006) note a genetic influence on the presence of enthesophytes on the skeleton, where some individuals are "bone formers" and more prone to osteogenesis in reaction to mechanical stress than others (Rogers et al. 1997). This suggests that some populations may show higher EC scores than others despite similar levels of activity. These examples do not encompass all possible impacts of genetics on EC, but serve as a reminder that the multifactorial etiology of EC depends on many variables other than age, sex, and body size, and that these should also be considered.

Other Benefits and Limitations of EC Research

As stated earlier, EC have been used to study archaeological human remains to provide valuable information about past activities and behaviours of ancient peoples. This can include social relationships such as division of labour among age, gender, and other social categories, and changes in occupation, mobility, and/or physical activity over the life course. Yonemoto (2016), for instance, compared the EC of Japanese males from four historical sites known for different occupations from the fifteenth, seventeenth and nineteenth centuries: fisherman, salt producers, samurai, and townspeople, respectively. She found that significant EC differences were found between individuals of different classes and occupations, and each population showed variations among age categories as well, particularly between young adults (aged 20 to 40 years) and old adults (aged 60 plus years) (Yonemoto 2016).

EC in the lower limbs among the samurai group shows little change across age categories. This was attributed to the formalized and consistent behaviours of samurai etiquette throughout their lives. In contrast, the wide variability of EC among the townspeople reflects their different occupations that required various levels of physical labor (Yonemoto 2016). Differing EC in the fishermen's knee and ankle joints according to age category reflects historical documentation describing how younger men would be responsible for tasks with high manual labor (such as loading and unloading nets onto boats), while older men would take less physically intensive roles such as sea navigation. Similarly, younger age categories of salt producers showed slightly lower levels of EC than older adults, though the *profile* of EC remained similar. This suggests specific entheses exhibiting greater changes were consistent between age classes, signifying differing age roles of the same occupation (Yonemoto 2016).

In another example, Lieverse and colleagues (2013) examined lower limb EC of three spatiotemporal populations of foragers occupying the Cis-Baikal region of Siberia over approximately 4,000 years. Their study found that the femora of one population—the Kitoi mortuary complex dated approximately 8,000 to 6,000 years ago—showed higher femoral loading and knee degeneration in males than other populations (Lieverse et al. 2013). This indicates increased mobility across steep and uneven terrains while bearing heavy loads (Lieverse et al. 2007, 2011; Macintosh 2011). These communities were large, likely resulting in rapid resource depletion and the need to travel more extensively (Weber and Bettinger 2010; Lieverse et al. 2013). In

contrast, the Isakovo, Serovo, and Glazkovo mortuary complexes from the Late Neolithic-Early Bronze Age showed lower EC scores (Lieverse et al. 2013). These groups had lower population density and higher spatial distribution than the Kitoi, meaning they did not require extensive travel to acquire resources (Lieverse et al. 2013; Losey, Nomokonova, and Goriunova 2008). This interpretation is also supported by OA and CBSG studies in the same region (Lieverse et al. 2016; Lieverse 2010; Lieverse et al. 2011; Stock et al. 2010). Therefore, when accompanied by supporting environmental and historical data, archaeologists can infer physical activities of past populations.

Although these studies demonstrate the usefulness of EC in reconstructing activity in past populations, there is a limitation to using EC methods on archaeological remains, which may impact interpretive accuracy: archaeological human remains are not typically accompanied by extensive documentation listing the occupation, sex, and age-at-death of each individual. For studies wishing to test the efficacy of EC methodologies and their ability to identify links between EC and activity, authors refer to the use of historically identified skeletal collections.

Testing scoring methods on skeletal collections with documented life histories is beneficial for EC research for several reasons. First, it allows the comparison of scores between categories of occupations with low and high levels of physical activity (i.e., a tailor or clerk compared to a stonemason or builder), as well as other factors influencing EC such as age, sex, and body size that can help identify links between EC and activity (Alves Cardoso and Henderson 2013). An EC scoring method can also be tested on multiple collections, and multiple scoring methods can be tested on a single collection, allowing identification and refinement of observer error as well as comparisons of the efficacy of scoring methods (Michopoulou, Nikita, and Henderson 2017; Michopoulou, Nikita, and Valakos 2015). Second, historical collections are typically larger ($n \geq 100$) than archaeological samples (Henderson and Nikita 2015). Charlotte Henderson (2013) published a meta-analysis showing the median number of individuals used in previous archaeological studies for EC research to be around 15 to 44 individuals. Having larger sample sizes is important because it considers a larger variety of morphological variability and reduces bias of limited demographic profiles (Henderson and Nikita 2015). Finally, using historical collections in EC research reduces the effects of confounding variables such as age, sex, and body size, which can be controlled to a greater degree of accuracy than with archaeological remains.

A notable limitation to using identified skeletal collections is that they cannot accurately reflect similar EC patterns of past populations based on chronological differences in activity levels and social or economic structure. For example, EC from a documented collection of skeletons from a 19th-century agricultural population would not accurately compare to the EC of ancient hunter-gatherer populations in terms of physical activity and mobility. Since EC are multifactorial, differences in age, sex, and body size between populations would undoubtedly affect EC morphology differently, as would other factors such as diet and population genetics (Alves Cardoso and Henderson 2013; Foster, Buckley, and Tayles 2014).

Another limitation is that the reliability of historic demographic information varies from collection. Some skeletal collections lack documentation on age and sex, so these variables must be estimated using skeletal measurements of individual specimens (Alves Cardoso and Henderson 2013; Henderson and Nikita 2016). Even in collections with well-documented life histories, historical data are not infallible and must be regarded with caution. In particular, the documentation of activities is

highly variable. Many collections are largely focused on males and only list known occupations at the time of the individual's death, failing to specify other physical activities, clinical histories, socioeconomic status, or hobbies during their life histories which have an unknown effect on the morphology of EC (Alves Cardoso and Henderson 2013).

Francisca Alves Cardoso and Henderson (2013) demonstrated this limitation by analyzing two Portuguese skeletal collections, 211 male skeletons from the Coimbra collection and 107 male skeletons from the Lisbon Luis Lopes collection. They applied three different methods of categorizing occupation as used in previous scoring methods developed by João Roque (1988), Alves Cardoso and Henderson (2010), and Sébastien Villotte and colleagues (2010). These categories split occupation by ranked levels of presumed physical activity (such as non-manual, light manual, and heavy manual), or type of occupation (for instance, 'government and services,' 'unskilled workers,' 'skilled workers/artisans,' 'farmers/servants', and 'commerce/transport) and found that EC scores varied considerably. Occupations like stonemason, weaver, and photographer were grouped in the same category using Roque's (1988, cited in Alves Cardoso and Henderson 2013) method (skilled workers/artisans), but when using the method by Villotte and colleagues (2010), stonemasons would move to manual or heavy manual, weavers to light manual or manual, and photographers to non-manual (Alves Cardoso and Henderson 2013, 194). In terms of finding statistical links between these activity categories and EC, the sole significant factor in almost all cases was age (Alves Cardoso and Henderson 2013). In addition, occupational categories were considered differently depending on the language of origin. In Portuguese, the word *lavrador/agricultor* (farmer), for example, could refer to tenant farmers, landless day laborers, dependant poor, or wealthy landowners. As for disparities of sex, the authors point out that female skeletal remains have far less comprehensive documentation in the Coimbra collection, where many occupations were listed as *domésticas* (housewife/housekeeper). This research draws into question the inherent subjectivity of classifying occupation and the interpretations of previous studies using EC methods on historical collections (Alves Cardoso and Henderson 2013).

Using Experimental Animal Models

A major limitation to EC research is our lack of insight into the direct relationship between muscle use and entheseal morphology. This problem can be addressed through experimental studies where the duration, intensity, and repetition of muscle use can be controlled and its effect on entheseal structure can be assessed. To date, three experimental studies using animal models have been performed to test the relationship between EC and activity, of which the first was performed by Ann Zumwalt (2006). Her model exercised ten sheep on treadmills (60 min/day for 15 min intervals) for 900 total hours while wearing weighted packs. Six 3D laser scanned entheses on the forelimb and hindlimbs showed that, although muscle size significantly increased as a result of activity, there was no difference in entheseal hypertrophy or surface complexity for either group. She concluded that her experiment could not find a link between EC and activity, citing instead the impact of body size on EC morphology (Zumwalt 2006).

Another study by Karyn Rabey and colleagues (2015) used a juvenile mouse model to perform different physical activities such as climbing and wheel running and assessed changes to bone growth, muscle fiber architecture, and entheseal morphology on the humerus. The climbing and running groups were observed over 78 days, with climbers traveling an average distance of 140 meters per night and the wheel runners ran around 1900

meters per night (Rabey et al., 2015). Comparing these factors among the sedentary, climbing, and wheel-running groups after digital processing, mice in the climbing group had larger muscle mass and shorter fiber length than the other two groups (Rabey et al., 2015). The wheel runners had the smallest muscle mass and the longest fiber length. In addition, cross-sections of diaphyseal bone revealed cortical bone growth in both exercise groups (after fusion of the humeral growth plate) was larger than the sedentary group (Rabey et al., 2015). However, like Zumwalt's (2006) results, Rabey and colleagues (2015) failed to find any difference in entheseal morphology across all three groups despite the changes to muscle mass, fiber length, and cortical bone structure, concluding that there was no observed link between EC and activity.

The third experimental study performed by Ian Wallace and colleagues (2017) examined the lateral epicondyles on the femora of ten female Eastern wild turkeys. The experimental group ran on a declined treadmill for 30 min per day, four days a week, for ten weeks. After laser scanning the femora and producing 3D models, the dimensions of the entheseal surface was quantified using topographical analysis (Wallace et al. 2017). Although changes in limb bone structure were apparent¬¬—exercised turkeys had a 21% increase in trabecular volume—there were no observed changes to entheseal morphology. The authors also concluded that their experiment found no link between EC and activity (Wallace et al. 2017).

The results of these experiments may seem disappointing, but there are some limitations to these studies that may explain this lack of connection compared to studies using observational data on human remains. First, the use of animal models as proxies cannot directly predict or reflect the same response to biomechanical stress in humans because bone functional adaptation is different in every species (Ruff, Holt, and Trinkaus 2006). Second, the experimental parameters are limited in their ability to test the type, duration, and intensity of physical activity required to cause EC, and, thus, cannot accurately reflect the activities of past human populations. It is doubtful that the average hunter-gatherer or agricultural community limited their exercise to less than an hour per day, and the moderate activity level the animal models were subjected to do not accurately reflect the high physical requirements of surviving in past living conditions. Finally, the methods of data analysis in these studies may be inappropriate for observing changes to entheseal morphology. Some digital technology used for 3D scanning and topographic analysis are considered outdated or may have been improved since the times of publication, introducing the possibility that outdated methods were too imprecise to detect microscopic changes to entheses (Karakostis et al. 2018).

Despite the lack of observed links with entheseal morphology to activity in these studies, valuable information can be gained from the observed changes to soft muscle tissue and bone in these experiments. Analyzing the differences in muscle fiber length and volume between climbing and wheel-running mice offers insight into what types of activity (endurance versus strength training) cause changes to these tissues (Rabey et al. 2015). These experiments also encourage potential longer-term studies that more accurately model the types of activities characterizing past human populations. For example, a study by Karakostis and colleagues (2019) look at the same turkey femora from the experiment performed by Wallace and colleagues (2017) and re-analyzed the femoral lateral epicondyles using a novel quantification approach of 3D principal component analysis (PCA) and multivariate statistical analysis. Surprisingly, this analysis method *was* able to detect different entheseal morphological patterns between control and experimental groups, demonstrating that future analytical techniques may be

employed to identify links between EC and activity in studies that previously failed to document these associations (Karakostis et al. 2019).

CONCLUSION

Since the 1980s, EC have been used in bioarchaeology to describe the physical activity and mechanical stress in past populations, though this direct relationship remains unclear. Entheses are now understood to present in two distinct types, where FCE are better understood in terms of morphology and etiology than are FE. Entheses, in general, vary in size, shape, and density depending on their location in the body. Though the manifestation of enthesopathies have been included in most early visual scoring methods, contemporary EC research normally does not include these pathological lesions. In addition, EC are multifactorial and highly dependent on an individual's age at death, body size, sex, and other genetic factors. These confounding variables may affect EC morphology more than do activity, occupation, and mechanical stress.

Despite this, archaeological studies using EC have shown some convincing relationships between muscle attachments and activity when accompanied by contextual data. However, archaeological sites normally have small sample sizes, which is not the best for testing the efficacy of EC. Instead, methods are tested on historically identified skeletal collections, but there are inherent biases in the composition of these collections and limitations regarding collection documentation and occupational terminology.

Experimental studies using animal models such as sheep, mice, and turkeys to test the relationship between EC and activity have revealed valuable insights into the changes of muscle and tendon tissues, despite the lack of connection to entheseal morphology. Encouragingly, a recent 3D approach using PCA and other multivariate statistics has identified morphological changes to entheses in one animal study where the analytical methods in the original publication did not, demonstrating potential for future research on experimental studies using animal models. Overall, as EC research continues to incorporate clinical literature, refine visual and quantification methods, and employ appropriate statistical analysis on skeletal remains in humans, this field will undoubtedly reveal more avenues of application for EC as a way to reconstruct activity.

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REVIEW ARTICLE

A Case for Lice: Using Lice from Archaeological Sites as Proxy Data to Further Understand Human Behaviour

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ABSTRACT
Hair, body, and pubic lice plagued past populations just as much as they do today. These types of lice require a human host to survive, and they thrive in contact-rich and sedentary groups. Lice, especially head lice, are difficult to get rid of without constant attention, which makes them suitable as proxy data for studying human behaviours of the past. By studying lice in the archaeological record, archaeologists can further understand the human experience. For instance, lice, eggs, and delousing combs have been found with human remains in the archaeological record and have been collected, cleaned, and studied, to better understand the lives of past humans. Additionally, body lice can spread diseases and can indicate stressors people endured during life and prior to death, such as overcrowding and illness. Lice studies have also been used to evaluate human cultural behaviours, how people interacted with others, how people lived with lice (if and where delousing activities took place), and how people dealt with ongoing infestations in the past. This article serves to provide a comprehensive overview of the archaeological analysis of lice, the important insights that lice can bring to current understanding of the past, the importance of proper collection, cleaning, and studying of lice, and the ways in which lice in the archaeological record have informed archaeologists about the past.

Keywords: lice, proxy data, lice remedies, delousing combs, nits, pediculus

INTRODUCTION

Head, body, and pubic lice are ectoparasites that survive by drinking the blood of humans and by residing within human hair or on clothing (Amanzougaghene et al. 2016). Archaeologically, lice are sometimes found in graves with human remains (Arriaza et al. 2013b, 2014; Mumcuoglu 2008a, 2008b; Naddaf 2018), in hearths (Forbes, Dussault, and Bain 2013), in textiles (Mumcuoglu et al. 2003; Araujo et al. 2000; Amanzougaghene et al. 2016; Marcondes and Linardi 2017), and in shelters people used (Amanzougaghene et al. 2016, Mumcuoglu et al. 2003; Mumcuoglu 2008a, 2008b; Mumcuoglu and Gunneweg 2012). Previous research demonstrates that studying lice in the archaeological record adds significant interpretive value when lice are present and preserved alongside human remains to understand living conditions and mortuary practices of past human populations, and to provide insights into how cultures may have viewed these parasites.

This review article provides a comprehensive overview of the archaeological analysis of lice and the important insights that lice can bring to our understanding of the past. First, I provide information about eggs (also known as nits), lice, and delousing combs found with human remains. I will then discuss how lice are

collected, cleaned, and studied in the archaeological discipline. Next, I explain how studying lice can reveal aspects of the lives of past humans. This paper concludes with examinations of lice in a variety of archaeological sites to demonstrate that lice are a valuable form of proxy data that should be examined when they are present.

LICE: A BACKGROUND

There are approximately 530 types of known lice species of which only P. humanus capitus (head lice), P. humanus (body lice), and P. pubis (pubic lice) plague humans (Marcondes and Linardi 2017; Naddaf 2018). Head, body, and pubic lice live in human hair, in clothing, and in the genital regions respectively (Araujo et al. 2000). Lice are obligate hematophagy ectoparasites, meaning they must drink the blood of a host to survive (Arriaza et al. 2013a; Mumcuoglu 2008a) and cannot survive for more than twenty-four to forty-eight hours without a host (Naddaf 2018; Nutanson, Steen, and Schwartz 2007). Lice can live in an anoxic environment for up to 12 hours (Candy et al. 2018) and can also be submerged in water for up to 36 hours by closing their spiracles and slowing their metabolism (Arriaza et al. 2013b; Candy et al. 2018). Human lice are small (approximately 800 micrometers in length), wingless, and cannot jump, thus requiring the use of specialized claws on each of their six legs to maneuver between strands of hair (Mumcuoglu and Hadas 2011; Naddaf 2018; Nutanson, Steen, and Schwartz 2007). They can vary slightly in colour from brown, to grey, to white, and can even appear translucent (Boutellis, Abi-Rached, and Raoult 2014). There is also clear sexual dimorphism between females and males (Arriaza et al. 2013a; Nunez et al. 2017).

Lice have three life stages: the nit (egg) stage (Figure 1), the nymph stage, and the adult stage (Figure 2) (Arriaza et al. 2013a). Nits embryonate within five to ten days then mature through three nymphal stages over a six to nine day period before becoming adults (Arriaza et al. 2013a). A female head louse will begin to lay nits a day after mating and will lay approximately five nits every twenty-four hours (Arriaza et al. 2013a). This reproductive cycle enables a potential yield of up to 140 nits in the female head louse's lifespan (Arriaza et al. 2013a; Gill and Owsley 1985). In contrast, a female body louse has the potential to lay up to three hundred nits in her lifetime (Nutanson, Steen, and Schwartz 2007).

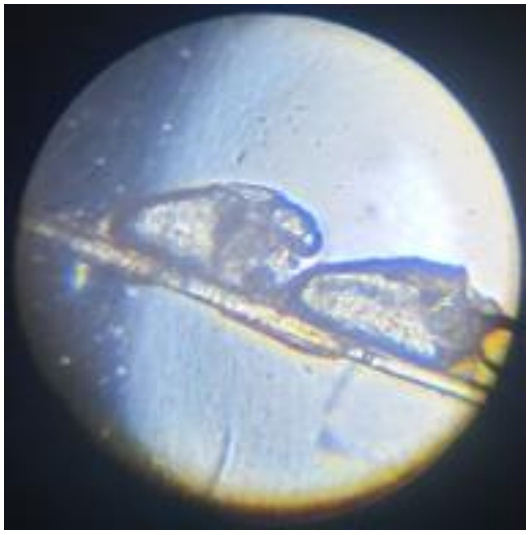

FIGURE 1—*Two nits attached to single hair shaft under a microscope. Photo taken by author.*

FIGURE 2 —*Adult louse under microscope. Photo taken by author.*

The nits of head lice are secured to the hair between 0.5 cm and 0.75 cm from the scalp (Gill and Owsley 1985) depending on environmental temperature (Arriaza et al. 2013a). In warm weather, female lice will lay multiple eggs on a single hair while in colder weather, they will lay their eggs closer to the scalp and only one egg per strand of hair (Arriaza et al. 2013a). The nits are secured by a keratinous substrate called cementum (Arriaza et al. 2013a) (Figure 3). Unlike head lice, body lice lay their nits within the seams and fibers of clothing (Araujo et al. 2000; Marcondes and Linardi 2017). After a head louse has hatched, both the cementum and the nit remain attached to the hair strand (Arriaza et al. 2013b). All forms of human lice must consume blood within 24 hours of hatching to survive (Arriaza et al. 2013a; Nutanson, Steen, and Schwartz 2007).

F*IGURE* 3— Cementum attaching egg to hair shaft under a microscope. Photo taken by author.

Lice must feed five times a day and are adapted to pierce the skin and drink the blood of the host (Boutellis, Abi-Rached, and Raoult 2014; Nutanson, Steen, and Schwartz 2007). When lice bite, they inject the skin with biologically active proteins including an anticoagulant and an anaesthetic, which causes intense itching in 14% to 36% of the host population (Boutellis, Abi-Rached, and Raoult 2014; Meister and Ochsendorf 2016). A head lice rash—a condition characterized by swollen lymph nodes located in the neck region and hair that is encrusted and stuck together—may also occur from scratching and this rash may lead to secondary infections such as Staphylococcus aureus (Meister and Ochsendorf 2016). Aside from itching and the potential infections scratching can cause, body lice are the only type of human lice that transmit life-threatening diseases such as epidemic typhus, relapsing fever, trench fever, and plague caused by Yersinia pestis (Amanzougaghene et al. 2016; Argenbright 2008; Boutellis, Abi-Rached, and Raoult 2014; Marcondes and Linardi 2017; Naddaf 2018).

LICE IN HUMAN POPULATIONS: MECHANISMS OF TRANSMISSION AND IMPLICATIONS OF INFESTATIONS

Lice are unable to fly or jump. The only way they can transfer hosts is via shared head coverings, other items of clothing, or by transferring to the scalp of individuals in close proximity by maneuvering between strands of hair (Arriaza et al. 2013b; Boutellis, Abi-Rached, and Raoult 2014; Mumcuoglu and Hadas 2011; Naddaf 2018; Nutanson, Steen, and Schwartz 2007). Therefore, hosts with long loose hair may be more prone to a lice infestation (Arriaza et al. 2013a, 2013b, 2014). Lice thrive in large, highly aggregated human populations that are contact-rich, sedentary, and are comprised of extended social networks that allow lice to maneuver freely between hosts (Arriaza et al. 2013b). Thus, hosts living under these conditions create the opportunity for high rates of transmissions and infestations (Arriaza et al. 2013a, 2013b, 2014).

The process of removing head lice has been seen as a social action worldwide as lice are mainly removed via picking them out of hair (Arriaza et al. 2013b, 2014; Gill and

Owsley 1985). Physically removing nits and lice was the only way to control an infestation especially prior to the advent of delousing combs in the western hemisphere at least 2400 years B.P. and in the eastern hemisphere between 13,950 to 11,950 years B.P. (Arriaza et al. 2014; Mumcuoglu et al. 2003). However, removing lice is a time consuming and laborious task that tends to require help from others. Being unable to remove nits daily could result in out-of-control infestations (Gill and Owsley 1985).

Head lice are widely seen today as endemic across the world and do not discriminate between cleanliness and socioeconomic status (Forbes, Dussault, and Bain 2013), nor are they geographically distinct or confined to one specific region (Nunez et al. 2017). That being said, body lice are often associated with high stress and poor hygiene that comes from overcrowding, war, poverty, or homelessness (Boutellis, Abi-Rached, and Raoult 2014; Marcondes and Linardi 2017; Naddaf 2018; Nutanson, Steen, and Schwartz 2007), while pubic lice are often transferred through sexual contact (Kenward 1999). Body lice live in the armpit, groin, waistline, and collar area of the host's clothing (Argenbright 2008; Naddaf 2018; Nutanson, Steen, and Schwartz 2007).

The health repercussions of lice extend beyond the organisms themselves. As was mentioned previously, body lice are possible vectors for epidemic typhus, relapsing fever, trench fever, and plague (Yersinia pestis) (Amanzougaghene et al. 2016; Argenbright 2008; Boutellis, Abi-Rached, and Raoult 2014; Marcondes and Linardi 2017; Naddaf 2018). Body lice created an epidemic typhus outbreak which posed a significant problem in both World Wars and in the Soviet Union in 1918 to 1922 during the civil war, due to infected people and body lice traveling by rail (Argenbright 2008; Marcondes and Linardi 2017). Understanding body lice transmission and the stressors they cause may give bioarchaeologists a more in depth understanding of the stressors people endured during life and prior to death, such as overcrowding and illness.

LICE IN THE ARCHAEOLOGICAL RECORD: PRESERVATION AND ANALYTICAL METHODS

Preservation

Lice have been found in archaeological sites worldwide, though they are incredibly small and only preserve in areas with optimal conditions (Forbes, Dussault, and Bain 2013). To survive in the archaeological record, lice require preservation conditions such as waterlogged, arid, anoxic, or frozen environments (Forbes, Dussault, and Bain 2013). When present in the archaeological record, lice are found attached to strands of hair, beside human remains (having fallen off or detached from the hair before the death of the louse), and in the tines of teeth on delousing combs found within graves (Arriaza et al. 2013b, 2014; Mumcuoglu 2008b). Lice have also been found in hearths, the entrances of homes (Forbes, Dussault, and Bain 2013), and in coprolites (Arriaza et al. 2012; Mumcuoglu 2008a).

Even if present, there is a high chance that lice could be lost during the excavation process of a site, when human remains are transferred from the site (Arriaza et al. 2013b), or when stored or transferred from museum collections (Arriaza et al. 2013a). There is also the possibility that many archaeologists do not look for lice during excavations. In sum, there is an inherent bias in the nature of the archaeological record itself and the processes of archaeological excavation and curation that may collectively curtail the preservation and study of archaeological lice remains.

Methods for Counting and Analysing Lice Preservation

When studying lice, there are a variety of tests that can be performed. At the macroscopic level, archaeologists can observe and count the number of lice and nits present on

scalps of human remains to infer the potential severity of an infestation (Arriaza et al. 2013b). As nits are approximately eight hundred micrometers (μm) in length, scanning electron microscopy (SEM) can be used to identify morphological details of mummified nits and embryos (Arriaza et al. 2013b). SEM can highlight the fragility of nits and head lice while demonstrating the strength of the cementum even after thousands of years (Arriaza et al. 2013b). As cementum withstands nit picking, grooming, and washing, archaeologists could use SEM to re-evaluate mummies that were deemed nit free (Arriaza et al. 2013b). Mummies that are lice free will not have cementum present on the hair shaft; however, the cementum will be present if nits were removed (Arriaza et al. 2013b). By evaluating the presence of cementum, archaeologists may be able to infer whether populations were able to get rid of infestations or if populations simply removed all lice and nits prior to burial (Arriaza et al. 2013b). This creates the ability to study how effective different social groups were at controlling infestations and the risks that those living in poverty may have faced (Arriaza et al. 2013b).

The cleanliness of the head affects counting and the collection of lice as there is often sediment intermingled in the hair (Arriaza et al. 2012). The counting of head lice is done by physically counting all the lice and nits that appear in a 2 cm by 2 cm area on the head of a deceased individual (Arriaza et al. 2013b, Reinhard and Buikstra 2003). This is done by taking a 2 cm by 2 cm cardboard cut out and placing the cut out 1 cm from the scalp, usually around the temporal or parietal regions (Arriaza et al. 2013b; Reinhard and Buikstra 2003). The lice and eggs that are present within this square are counted and estimates for the whole head are based on these counts (Arriaza et al. 2013b; Reinhard and Buikstra 2003). Multiple counts are necessary because sediment present in the count may be miscounted as lice, or lice may be missed in the initial count, which often causes collection and counting to be a painstaking task (Arriaza et al. 2012). Lice can be cleaned by rinsing them in distilled water twice for up to fifteen minutes (Amanzougaghene et al. 2016). Cleaning and rehydrating the lice may be required before performing any nuclear DNA, or mitochondrial DNA tests (Amanzougaghene et al. 2016). SEM testing can be performed on lice with uncoated, non-rehydrated samples of both lice and eggs (Arriaza et al. 2013a).

ARCHAEOLOGICAL INTERPRETATIONS FROM LICE

Although there are many problems in finding, collecting, cleaning, and testing lice, they are still worth studying when found. Unhatched nits can provide archaeologists with an estimate for a potential infection (Arriaza et al. 2013b) as can the sex of lice, since females help predict future infestations (Arriaza et al. 2012). Lice can also be used to evaluate human cultural behaviours. Understanding lice transmission and the relationship between lice and human behaviours is useful in assisting archaeologists in understanding how a past society may have interacted with others, how close people lived together, and how clean or sedentary a group was (see also, Gill and Owsley 1985; Arriaza et al. 2013a, 2013b, 2014; Forbes, Dussault, and Bain 2013). Through studying lice, we may be able to develop a broader picture of how a past society was constructed or determine a particular season that a site was inhabited. We may also develop a better understanding of how people dealt with ongoing infestations in the past.

Interpreting Living Conditions

People have developed a multitude of ways to deal with lice including preventative measures as well as treatment methods. These methods vary depending on the time, the place, and the culture in question. Not all people saw lice as a nuisance and not all people actively sought to dispose of the infestations (Arriaza et

al. 2013b). However, other populations have picked the lice out of the hair (Arriaza et al. 2013b, 2014; Gill and Owsley 1985), used herbal remedies (Mumcuoglu and Hadas 2011), and developed delousing combs (Arriaza et al. 2014; Mumcuoglu 2008b; Mumcuoglu and Gunneweg 2012; Mumcuoglu and Hadas 2011) to eradicate infestations. Some populations have also disposed of lice by eating them and by throwing them into hearths or entranceways (Forbes, Dussault, and Bain 2013). The following sub-sections highlight several of these diverse cultural approaches of coping with and treating lice infestations as discovered archaeologically.

Case Study: The Chinchorro

The Chinchorro population, who occupied northern Chile and Southern Peru from 11,950 B.P. to 3450 B.P., had long hair, lived close together, and did not remove lice from their hair, which resulted in a high prevalence of head lice (Arriaza et al. 2013b). Although they did not remove lice, children may have had lice removed from their heads as they do have lower rates of head lice (Arriaza et al. 2013b). However, since the prevalence of lice infestations were so high and there is no evidence for delousing combs, this population may have even seen head lice as normal and not as an infestation (Arriaza et al. 2013b). As mummifying technology progressed, wigs began to be made from human hair and took the place of the deceased's natural hair (Arriaza et al. 2013b). Arriaza et al. (2013b) note that even young children had these elaborate wigs, suggesting that wigs were made from the hair of others and not just the hair of the deceased as young children would not have enough hair to create wigs of this length out of their own hair. When mortuary wigs were being utilized, there appears to be a decrease in nits and lice population, yet cementum was still present. The presence of cementum without nits and lice suggests that the nits and lice were being removed after death due to a desire to not have them in the afterlife (Arriaza et al. 2013b). Lice are useful archaeologically as they can help archaeologists infer how people would have viewed lice and how these views may change over time.

Case Study: The Chiribaya People

The Chiribaya people lived between 950 and 700 B.P. along the coast of what is now Peru and Chile (Reinhard and Buikstra 2003). In the 1990s, mummies found at the archaeological sites of El Yaral, Algodonal, and Chiribaya Alta were examined for the presence of head lice (Reinhard and Buikstra 2003; Reinhard and Camacho 2019). It was determined that Chiribaya Alta was an administrative center along the coast that overlooked arable farmlands, while El Yaral was further inland and at a higher elevation (Reinhard and Camacho 2019). Mummies found at Algodonal were mostly immigrants and farmers who were economically poor and were considered a relatively destitute subpopulation (Reinhard and Camacho 2019).

Through studying head lice on the mummies found at these three sites, Reinhard and Buikstra (2003) were able to show that lice prevalence rate was 18% at El Yaral, 36% at Chiribaya Alta, and 71% at Algodonal. Algodonal had the highest rate of infestation. These infestations may have been increased due to the poorer economic status that resulted in overcrowding and a lack of hygienic practices while Chiribaya Alta only experienced a moderate infestation rate due to overcrowding (Reinhard and Buikstra 2003). Delousing combs were found within graves at Chiribaya Alta showing that this group had the technology to remove head lice, which may be why prevalence was lower at this site compared to Algodonal (Reinhard and Buikstra 2003). El Yaral experienced the lowest infestation rates as the population was not as dense as the population at Chiribaya Alta (Reinhard and Buikstra 2003).

Evaluating the head lice infestation at Chiribaya Alta showed that head lice prevalence varied according to age and sex, with children having the least amount of infestation and men having the highest (Reinhard and Buikstra 2003; Reinhard and Camacho 2019). Reinhard and Buikstra (2003) suggest that the reason children had less head lice may have been due to their lack of involvement in social settings such as schools or childcare settings unlike that of modern-day children. Men at Chiribaya Alta used head coverings and had long hair that was styled into elaborate hairstyles (Reinhard and Buikstra 2003; Reinhard and Camacho 2019). These hair styles resulted in a lack of nit picking for several days, which led to men having higher infestations than the women who wore their hair in simple braids (Arriaza et al. 2014; Reinhard and Buikstra 2003; Reinhard and Camacho 2019). Archaeologists can also infer how this prevalence varied both between and within groups, and why the prevalence may have varied.

Case Study: The Pitchfork Mummy

The Pitchfork Mummy was one of two bodies excavated at the Pitchfork Rock Shelter in northwestern Wyoming (Gill and Owsley 1985). The skull of one of these mummies was missing and the second mummy had no preserved hair strands from the frontal, parietal, or temporal regions although they did have hair present from the occipital region (Gill and Owsley 1985). It should be noted that when a host has long hair, the frontal region of the skull is not a preferred spot for lice to lay their eggs rather, lice will lay their eggs in the temporal region and the nape of the neck (Gill and Owsley 1985). Even with parts of the skull missing, this second mummy had a high prevalence of head lice located in the hair strands from the occipital region (Gill and Owsley 1985). The high prevalence of head lice was used to infer that the second mummy may have experienced social unrest and long-term isolation prior to death and may have been a warrior or had renegade status (Gill and Owsley 1985). The Pitchfork Mummy had nits ranging from 0.5 cm to 9 cm from the scalp with as many as four to eight nits present on some individual hair strands (Gill and Owsley 1985). As hair grows an average of 0.3 mm a day and a female louse typically lays eggs between 0.5 cm and 0.75 cm from the scalp, we can infer that the Pitchfork Mummy had lice for a period of around three hundred days leading up to his death (Gill and Owsley 1985).

The removal of lice is a social activity, usually performed by close kin (Arriaza et al. 2014), as it is incredibly difficult to remove lice effectively from one's own head. When lice are not regularly removed from one's head, the infestation can worsen as mentioned above with both the Chinchorro and the Chiribaya cultures. However, for those who did not have the means to remove lice from their own heads, they too experienced a worsened infestation as seen in the Pitchfork Mummy. If an individual with lice is removed from their social group, they will inevitably see an increase in head lice population (Gill and Owsley 1985). Archaeologists can examine lice infestations to better understand the importance of social groups in treating lice infestations and how long someone may have been away from their social group (Gill and Owsley 1985).

Remedies

There are a variety of remedies past populations have developed to deal with lice. Herbal remedies developed around the world have helped to reduce infestations. Remedies for disposing of lice include using soda scum and bryony (a climbing flowering plant that produces fruit), oil and vinegar, viper broth, acre seeds, Delphinium, quicksilver, oil of roses, cresol powder, naphthalene, sulfur, mercury powder, and even kerosene (Mumcuoglu and Hadas 2011).

Delousing combs are the oldest remedial therapy, having been used in the western

hemisphere at least 2400 years B.P. and in the eastern hemisphere between 13,950 to 11,950 years B.P. (Arriaza et al. 2014; Mumcuoglu et al. 2003). These combs are one of the best remedial therapies for getting rid of head lice and are still in use (Arriaza et al. 2014). Although delousing combs vary slightly in shape and style, they are effective tools for removing all stages of head lice (Figure 4) (Mumcuoglu 2008b). The basic style varies between single-sided delousing combs (Figure 5) and double-sided delousing combs (Mumcuoglu 2008b; Mumcuoglu and Gunneweg 2012). These combs are easy to grip and there is an extra labour cost associated with making dense combs suggesting that they were deliberately made for delousing (Arriaza et al. 2014). The tightly bound tines would have only been good for delousing and not for simply brushing hair (Arriaza et al. 2014). SEM examinations also ruled out the use of these combs for secondary functions such as that of textile manufacturing (Arriaza et al. 2014).

FIGURE 4—Modern-day delousing comb with eggs and nits in teeth. Photo taken by author.

FIGURE 5—*A modern day, single-sided delousing comb. Photo taken by author.*

Double-sided delousing combs had teeth with larger spaces on one side for detangling hair and tightly packed tines on the other side that were effective for lice removal (Arriaza et al. 2014; Mumcuoglu 2008b; Mumcuoglu and Gunneweg 2012). As high numbers of lice on the tines of tightly packed delousing combs indicated, these were effective delousing instruments that are still used today (Mumcuoglu 2008b). Overall, wood is considered to be the most popular material used to make delousing combs (Arriaza et al. 2014; Mumcuoglu 2008b; Mumcuoglu and Hadas 2011), yet delousing combs were also made of bone, ivory (Arriaza et al. 2014; Mumcuoglu 2008b), and precious metals such as silver, which were rare yet used by Indian aristocracy (Mumcuoglu 2008b). In the eastern hemisphere, delousing combs have been found in royal tombs dating to Pharaonic Egypt (Mumcuoglu 2008b; Mumcuoglu and Gunneweg 2012; Mumcuoglu and Hadas 2011), in Masada dating to the first revolt (1884 to 1876 B.P.) (Mumcuoglu et al. 2003; Mumcuoglu and Gunneweg 2012), and in caves such as the Christmas Cave in the Delta

of Wadi Kedron near the Old City of Jerusalem 2100 to 1900 years B.P. (Mumcuoglu 2010). In the western hemisphere, delousing combs have been found in ancient burials along coastal and inland Chilean sites (Arriaza et al. 2014). These combs were used in life as well as included as grave goods (Arriaza et al. 2014).

Delousing combs are the oldest remedial therapy, are found worldwide and are effective tools for removing head lice (Arriaza et al. 2014: Mumcuoglu 2008b; Mumcuoglu et al. 2003). These combs were a cultural response to an endemic and persistent problem. Delousing combs were usually locally made from raw materials native to the area and were manufactured for lice control independent of secondary uses (Arriaza et al. 2014). By studying lice remedies, archaeologists can further understand what treatments were used to treat lice and how effective these treatments were. This understanding adds another layer of complexity to our understanding of the people we study.

Disposal

Picking lice out of hair is one way of removing head lice, but once they are removed, they need to be discarded. People have crushed them between teeth (Gill and Owsley 1985), eaten them, as evidenced in coprolites (Gill and Owsley 1985; Mumcuoglu 2008a), or tossed them in hearths and in entrance ways (Forbes, Dussault, and Bain 2013). Taxation was also a way of remedying head lice (Arriaza et al. 2014). The elite class of the Incans, during the Late Horizon Period (474 to 407 B.P.) encouraged the poorer populations to pay their taxes with live head lice as a way of keeping the lice population down, while also getting people to provide something that they had produced (Arriaza et al. 2014). By studying how lice was disposed of, archaeologists can make inferences on how people removed lice, used lice, and, in turn, how different cultures may have viewed infestations.

CONCLUSION

Lice have been the companions of humans throughout the ages, surviving in human hair and clothing (Araujo et al. 2000). The close proximity of lice to humans and the impact of lice on their hosts make them valuable proxy data when they are found. By studying lice, researchers have the potential to add a layer of complexity to the people and societies that they study including class, social interactions, their hygienic customs, and even funeral practices. Lice can inform archaeological interpretations by providing insight into the lives of nomadic people (Arriaza et al. 2013b), or if people lived under crowded or high stress conditions (Boutellis, Abi-Rached, and Raoult 2014; Marcondes and Linardi 2017; Naddaf 2018; Nutanson, Steen, and Schwartz 2007), and may also tell archaeologists about the grooming practices of people in the past (Arriaza et al. 2013b, 2014; Reinhard and Buikstra 2003; Reinhard and Camacho 2019). Humans have developed numerous ways of living with and exterminating lice such as picking nits and lice from the hair (Arriaza et al. 2013b, 2014; Gill and Owsley 1985), using a plethora of remedies such as oil and vinegar, viper broth, or sulfur to kill or prevent infestations (Mumcuoglu and Hadas 2011), and have also developed technologies such as delousing combs to combat infestations more effectively (Arriaza et al. 2014; Mumcuoglu 2008b; Mumcuoglu and Gunneweg 2012; Mumcuoglu and Hadas 2011).

Managing lice is a highly social activity, which has been viewed and treated differently throughout time and around the world (Arriaza et al. 2013b, 2014; Gill and Owsley 1985). As a result of different societies dealing with lice and the various records and artifacts uncovered, archaeologists have been able to better understand how people would have interacted within their environments, some stressors they

would have faced, and how people would have responded to the creatures that still plague us today. Lice are a valuable form of proxy data and careful attention should be made when excavating human remains to look for lice so they can be examined to help further understand the people and societies that we study.

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REVIEW ARTICLE

How Bizarre, How Bizarre, How Bees Are: Domus and Umwelt in the Multispecies Entanglements of Humans and Honeybees

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ABSTRACT
Relationships between humans and honeybees are complex because they are deeply entangled. These entanglements take on many forms, such as those present in the honeybees' self-centered worlds—*umwelt*—as well as the intersections in their mutually constituted lived world, or their domus. As honeybees are involved in pollinating up to 85 percent of the world's agricultural crops, understanding these entanglements is a vital component of environmental anthropology. To highlight these interconnected relationships as they apply to commercial beekeepers, this paper explores the case study of an Australian almond farmer named Mark deCaux who has incorporated beekeeping into his agricultural practices to ensure his crops are adequately pollinated. Since adopting beekeeping, his crops have grown his apiary to a commercial-sized practice. Through the lens of his experiences, the concepts of umwelt and domus emphasize the intricate negotiations between humans and honeybees that constitute their mutually entangled relationships.

Keywords: environmental anthropology, umwelt, domus, multispecies entanglements, honeybees, sociality, agriculture

FLYING BY: INTRODUCTION

"We've got some bees under a dog. Under a dog and next to a chair! That's different," says Mark deCaux, an Australian apiarist also known to his YouTube followers as the Bush Bee Man (deCaux 2020d). Mark is "rescuing" a hive of bees that have made their home in someone's backyard pond pump, a common occurrence on his channel that is full of the interactions between humans and honeybees as he has deeply entangled himself with *Apis mellifera*, the Western or European Honeybee. It was to these same entanglements which bee-focused author Sue Hubbell was referring when she said, "I like pulling on a baggy bee suit, forgetting myself and getting as close to the bees' lives as they will let me, remembering in the process that there is more to life than the merely human" (1988, 7). Her process of remembering and Mark's observations of the human elements of the bees' chosen hiding spot highlights the complex relationships we humans have with our honeybee compatriots. Both Sue and Mark approach these entanglements between humans and honeybees in their daily work, pointing to the plethora of relationships that form and reify the connections between us and these industrious insects.

Both human and bee lives are deeply interconnected for many reasons, the least of which is that pollinators like bees are involved in 85% of the world's commercial crop production and

some crops like almonds are entirely dependent on bee pollination (Klein et al. 2007; American Beekeeping Federation n.d.). To explore these entanglements, I turn to the concepts of *domus* and *umwelt* to dig into the myriad ways in which both honeybees and humans construct and reify the intertwined relationships that they have shared for tens of thousands of years (Abou-Shaara 2020). In recent times, these relationships have grown and transformed under the influence of industrial farming (Bartlett et al. 2019). To gain a deeper understanding of the current impacts of these multispecies entanglements between humans and honeybees, I explore the case study of Mark, The Bush Bee Man, who has taken up beekeeping to pollinate his crops and has since grown his apiary to a commercial-sized practice (deCaux n.d.). In doing so, I will use the concepts of domus and umwelt to highlight the multispecies entanglements between humans and honeybees in the context of modern Western agriculture and commercial beekeeping practices.

BUILDING THE HIVE: DEFINITIONS

To examine the entanglements between humans and honeybees, I must define my terms. The first central concept of this paper is umwelt. Umwelt is a German word used by Jakob van Uexküll to describe the mix of perception and action that creates an animal's "self-centered world", made of their perceptor and effector worlds (Uexküll 1992, 320). Others have used the term to refer to the "intimate worlds" of animals (Bubenik 2007), their "meaningful environments" (Koutroufinis 2016), or their "environmental carriers of significance" (Van Dyck 2012). To understand how this term is useful, I borrow from Clint Westman and colleagues who explain that, because moose have very different connections between "mind, body, and environment", their umwelten, the plural of umwelt, radically differs from ours and results in the moose inhabiting very different worlds than we do, even if they are within a shared domus (2020, 11). Extending this concept to honeybees, their umwelten are likely to be even more different than ours. This is because bees are not mammals but insects that are colonial organisms; they can fly, and they are very small in comparison to us, so the scale of their environments are quite different than ours. Understanding the umwelten of honeybees without the participant observation of walking among their hives and attempting to observe both the effector and perceptual worlds of bees in person is difficult, so its application in a research paper is limited. Including the case study of Mark and his apiary videos is my attempt to address that shortcoming. Regardless of that limitation, I will endeavour to explore the applications of umwelt to honeybees in a theoretical and academic but removed way, perhaps recalling the armchair anthropologist forebears whose early contributions helped form this discipline.

The other major concept central to this paper is that of domus. Here I borrow from Marianne Lien and John Law, who define domus as "a fragile assemblage of animate beings and inanimate things that loosely holds together and mutually constitutes the conditions of existence of its component parts" (2016, 16). David Anderson and his colleagues summarize this approach to domus as "a synonym for the assemblage where human-animal relationships are housed and performed" (2017, 400). They go on to elaborate that a useful ecological approach to domus "might focus on how the attention of many different species, and the artefacts of that attention, come to work together in a particular setting", which they call "a co-specific domus" (Anderson et al. 2017, 401). Within these three theoretical explanations of domus are the useful ingredients for applying this concept to the entanglements between honeybees and humans.

Research and media attention in the last decade has highlighted the fragility of the

human-honeybee domus because of neonicotinoid insecticides and colony collapse disorder (Suryanarayanan and Kleinman 2013; Thomson et al. 2013; Vanengelsdorp et al. 2017; Ellis 2019). Animals, humans, and non-living aspects of their surroundings like rocks and wind are all implicated in these entanglements, recognizing the complexity of these relationships that extends beyond anthropocentric considerations of humans as masters, of bees as mindless drones in service of humans needs, and of things as tools suited only to manipulation by intelligent humans (Boddice 2011; Giraud 2019; Rülke et al. 2020). Finally, Anderson and colleagues' "co-specific domus" highlights the role of attention, calling to mind the observer effect in physics that dictates that observation, or "the artefacts of attention", paid to something results in changes to that thing (Dirac 1987, 3). As I will illustrate in this paper, the concept of domus paired with umwelt is a useful tool for examining the entangled relationships between humans and honeybees.

A VOICE FOR THE BEES: CASE STUDY

To understand the relationships between Mark and the bees, it is important to contextualize his environment. Mark hails from Australia's Riverland, a region of South Australia. Originally occupied by Australian Aboriginal groups since time immemorial (Westell et al. 2020; Flinders University 2020), European settlers colonized the area in the late nineteenth century (Murray-Darling Basin Authority 2010). The area has a warm, Mediterranean-style climate that has contributed to the current primary industry of wine production, almond growth, and the farming of stone fruit (Renmark Paringa Council n.d.; South Australian Centre for Economic Studies 2012). Changing the zone's water flows through irrigation was the key to the economic success of the region, without which large-scale fruit and nut farming would be impossible (Department of Primary Industries and Regions 2017). Water is also vital to keeping the pollinating bees that many of these industries rely on alive and happy (Casey 2018), so irrigation is also key to any Riverland apiarist. The mild winters with an average temperature of 16.2°C make keeping bees easier than in more temperate climates but the scorching summers, with an average of 32.5°C yet often reaching into the 40s (Destination Riverland 2021), present unique challenges for both humans and bees alike. Yet, bees are a major aspect of the Riverland economy with more than 2,000 beekeepers and 68,000 hives in South Australia contributing more than $101 million in both bees themselves and in bee by-products yearly (Department of Primary Industries and Regions 2020). The environment in which Mark and his bees are making their livings bears the mark of human development and design, making it an attractive area in which to consider the entanglements between humans and these insects.

Mark fits these common themes of the Riverland very well. He is a large-scale almond farmer who experimented with beekeeping to pollinate his crops and uploaded videos about his bee adventures to his YouTube channel because, as he argues, "the bees need a voice" (deCaux 2019a). His operation has grown from a few bee boxes to hundreds of hives accompanied by an increasing variety of processing equipment for cleaning, maintaining, sorting, and storing the bees and their valuable by-products of honey and wax. He has an earthy sense of humour and, when on camera, is always chunnering to himself about the chaos of his life with the bees. While Mark's videos are intended to spread information to viewers about how beekeeping works and how they can tend to their own hives, the sheer breadth of his videos (to date, 273 videos in 4 years) give viewers a chance to analyze the relationship he demonstrates with his bees and the worlds in which they both live. As a result, I have chosen him as a representative case study for this paper because his life in

these YouTube episodes contains many important elements for understanding the concepts of umwelt and domus. This methodology is limited, as there is much curation between Mark's actual field experiences with the bees and the final videos that are released for the public to view, removing contextual information and other potentially important aspects of his beekeeping. The videos I review for this paper are but a fraction of his actual life with the bees and are thus no substitute for direct participant observation. As such, I do not imagine that Mark's intention was to showcase the entanglements between humans and honeybees, but as he often says, "Well, good golly gosh, let's give it a try," (deCaux 2017).

EXPLORING INNER WORLDS: UMWELT

At first, it seems tricky to apply the concept of umwelt to honeybees. The life-span of the majority of *Apis mellifera* bees is quite short in comparison to human lives – a few weeks to a few months for workers, up to a year for drones, and up to five years for queens. The individual honeybee perceptor worlds, an important component of umwelt, could be described in many sensory mediums. These include, but are not limited to: the feelings of air currents; the genetically programmed language of pheromones; the sensations of rising and falling temperatures; the tastes of nectar, of pollen, and of the regurgitation of fellow bees; and the rhythms of performance and sleep that dictate the patterns of their lives (Chittka 2017). Umwelt could also include the bright, loud, smoky intrusion of the beekeepers as they inspect the hive and address any issues they perceive. Individual honeybees perceive a vast array of information, all of which are useful for the purposes of survival and productivity that can be seen in the example of bees pollinating Mark's almond crops. The perceptor worlds of individual honeybees, and, therefore, their umwelten, are complex indeed.

Moving away from individual bees, the concept of umwelt changes in application to the collective organism that is the hive. *Apis mellifera* are eusocial, meaning that colonies are created by a single egg-laying female bee, the queen, with the worker and drone bees hatching from eggs laid by the queen (University of Florida n.d.). Many of the activities that are central to the lives of honeybees could be seen as resulting from the hive as a whole rather than the activities of individuals. One aspect of the umwelt of bees is what Mark calls their "song". Mark is often sent to relocate nests of bees that have been built in places inconvenient for humans, such as backyards, utilities boxes, and neglected cars (deCaux 2020e). Capturing the queen is a necessary part of such relocation efforts because, without her, the bees will try to return to the place from which they were moved where the queen remains. In order to tell if the queen has been captured among the other thousands of bees, Mark listens to the "song" they make, or the tone of the hum made through the concert of thousands of flapping wings and vibrating bodies. This song, the product of the collective hive, changes when the queen is among the other bees (Michelsen et al. 1986; Boucher and Schneider 2009). It is a part of both their perceptor and effector worlds, as the bees perceive their queen is among them through scent, sound, or touch and react by changing their activities to reflect her presence among them. By sharing this information with each other, the worker bees that make up the majority of the hive can act in concert to protect the queen and ensure the continued survival of the hive as a whole (Bencsik et al. 2011; Slone et al. 2012). Thus, honeybee umwelt is both individually constituted, such as the focus on the queen bee, and made of the group or hive, who act in response to the presence of the queen.

As I have mentioned, perception is one of the key ingredients in a creature's umwelt (Uexküll 1992) and in humans, the experience of perception is modulated by a person's

cultural orientation (Kawahara et al. 2017). Though direct comparisons between humans and non-humans are not always possible (Smart 2014), the similarities between humans and other animals make the exploration of non-human cultures an important aspect of understanding the relationships between humans and honeybees (Smart and Smart 2017; Hartigan 2014). One aspect of honeybee culture visible in the experiences of Mark is the phenomenon of social learning (Hartigan 2014, 13). Honeybees engage in social learning based on their self-centered worlds of nectar and pollen collection, warning others of danger, and supporting their hive mates in the maintenance and growth of the hive. One example of this is honeybees transmitting information to each other through forms of physical communication that humans call "dancing" (Raffles 2010, 175). Different types of dances communicate different messages, and these messages can cause not only individual bees, but sometimes a whole hive, to change their behaviours (Raffles 2010, 179). Honeybee dancing is an example of umwelt because it demonstrates the connection between what the bees perceive, i.e., food, danger, or humans, and their effects, such as the physical movements necessary to transmit their perceptions to other bees. The self-centered world of honeybees contains a culture of communication and learning.

The learning that leads to honeybee communication in Mark's hives, like their singing and their dancing, includes him in ways that are both peripheral and central to the bees' umwelten. While honeybees are concerned with the collection of both pollen and nectar to feed their hive, Mark is sometimes the one supplying those food sources when they are not available from his almond trees or the surrounding vegetation (deCaux 2020b; 2021). When the bees are learning and transmitting information about where these food sources are, Mark must take care to ensure that the food he provides matches the bees' umwelt by putting them in places that the bees can find, ensuring they fall within the limitations of the bees' perceptor worlds.

Another aspect of the bees' perceptor world is their reaction to risk. When the bees perceive danger, they transmit this to each other by butting their heads against other bees and by patterns of vibration (Srinivasan 2010). Often times, this danger is Mark opening the hive to do routine maintenance (deCaux 2019d), meaning he is a part of both perceptor and effector worlds of the bees and is a constituent part of their umwelten. These interactions between Mark and the bees is also an example of the co-created domus, as both groups work with and around each other in their daily activities. This means that, though the concepts of domus and umwelt are separate, in reality they work together to influence and co-create each other.

Comparing the honeybee umwelt to how honeybee lives are perceived by humans reveals further entanglements between the two species. Donna Haraway notes that in many aspects of Western writing and thinking, animals "are not allowed personal pronouns such as *who*, but must be designated by *that*, *which*, or *it*" (2008, 206). Whether or not we discuss non-humans as being a "who" or an "it" often turns on whether we see them as a "means to the purposes of the [human] other", which is often the case for domesticated animals (Haraway 2008, 206). The other option is whether the animals "can be somebody, ends not means", which Haraway suggests is only available for wild animals (2008, 207). In this context, I argue that honeybees in a commercial setting occupy an uncomfortable middle ground, that 'betwixt and between' liminality that is so often of anthropological interest. This liminality is a result of the differences between the bee population's umwelt and human perceptions about the purposes of bees. For the bees, their umwelt is likely to be bees reacting to bee stimuli and making decisions for the good of themselves and their hive. Humans see bees

differently, such as their roles as pollinators, producers of honey and wax, or as potential nuisances or sources of physical harm. It may therefore be easy to assume that humans see bees as an "it", but the reality, as is often the case in anthropology, is more complex.

It is undeniable that, for agriculturalists like Mark, the honeybees serve as a means to an end. That is the reason he began his beekeeping – to pollinate crops (deCaux 2019e; 2019b) and, now that his beekeeping has reached a commercial scale, to sell the bee by-products of honey and wax (deCaux 2020a). Were it not for this productive outcome, he may see bees in much the same way as do many of his neighbors in the Riverland, who often call him to extricate nests of bees from inconvenient locations. If he did not perform these removals, the bees would likely be destroyed by pest removal services or killed by those who made the call, reduced to an "it" of tiny bodies littering the ground. In some views, using bees to pollinate large-scale crops already renders bees an "it" in the Marxist sense, used for their labour to produce profit. This objectification is especially poignant when combined with the other "biophysical barriers" inherent to industrial-scale farming, such as soil erosion, the demand for irrigation, and the increased risks of infectious disease, that serve human capitalist needs at the expense of other organisms (Ellis et al. 2020, 439). Thus, the honeybee umwelten and domus is not only shaped by the perceptions of Mark and his beekeeping practices but are also co-created by the economic need for Mark to support himself and his family, by the environmental stresses created by the large-scale farms so predominant in the Riverland, and, by extension, the entire edifice of capitalism that drives human demand and consumption for these products. For people who do not come into regular contact with farmed bees or the pollination in which farmed and wild bees engage in, the lack of bees in their own umwelt may contribute to this association of bees as an "it". Without that close contact and intimate understanding of the inner lives of bees, it may be easy for the average human on the street to objectify these tiny, often unobtrusive creatures (Nimmo 2015). In their role as pollinators, bees are transformed into Haraway's "it", changing their umwelt by placing them in the service of human farming activities and, ultimately, the cycle of profit inherent to capitalism.

Yet Mark does not see the bees as an "it", as his close interactions with them have led to a complex, anthropomorphized relationship with the honeybees that includes the numerous complexities of his impacts on the honeybee umwelten. He genders the bees, referring to them as "the girls", "ladies", or "chicky-babes" with great regularity (deCaux 2020c). While it is true that most honeybees are females, the cultural implications of gender hint at the complex relationships between utility and autonomy in Mark's approach to the bees. These complex relationships carry further into Mark's perceptions of the bees; even though they produce for Mark by pollinating his trees, he sees the bees as autonomous beings that are definitely not within his control. Mark sees "the girls", as he calls them, as independent animals full of agency and personality in many of his videos. They may swarm, which involves the queen leaving with some or all of her bee children and find a preferable place to live (deCaux 2019c). They have their own personalities or dispositions, often defined by how much they tolerate the presence of humans. If they react with hostility to Mark's intrusion into their hives, he often refers to them as "toey", meaning "nervous, anxious, or worried" (Merriam-Webster 2021). If they are calm when Mark is working with the hive, they are "chilled out" and "cool", ascribing a group personality to the hive as a whole (deCaux 2020c). Of course, these attributions of personality cannot be separated from the fact that Mark is making these judgments based on how easy it is for his human self to intrude on the

bee's homes and disturb their contents for the purposes of continued commercial success. This distinction of animals as either a means or an end is not a clear binary when it comes to honeybees but falls on a spectrum of intermingled closeness and productivity. This spectrum is partially the result of the differences between honeybee and human umwelten, creating this push and pull of utility and agency present in the relationships between Mark and the bees. The difference between how bees are situated in the lives of the farmers who use them for pollination and how humans anthropomorphize bees demonstrates the complexity of entangled multispecies relationships.

CREATING OUTER WORLDS: DOMUS

To further understand the relationships between humans and honeybees, it is worth investigating what constitutes the honeybee domus. At the most fundamental level, the domus of an individual honeybee begins with the cell made from wax, where bees begin their lives as eggs, developing into larvae after a three day gestation period (Crane 1999, 20). These cells are the foundation of the domus because each cell is affixed to hundreds of other similar hexagonal cells in what is called a "comb". There are different types of combs that have multiple uses: brood comb is where eggs are laid and new bees are reared; honey comb is where concentrated nectar is stored, dehydrated, and aged into sweet honey; combs that hold pollen; and some combs are left strategically empty to act as insulation for the hive. In a commercial beekeeping operation like Mark's, the building and maintenance of comb is managed by the use of vertical frames that are hung within a hollow box, known as the Langstroth hive (Crane 1999, 422). Already the intersection between humans and honeybees in the creation of their shared domus is evident – Mark provides the frames, protected by a home of wooden boxes, in which honeybees are encouraged to build their comb and thus their home. In nest rescue operations, this relationship is even more direct as Mark will cut out existing pieces of comb and affix them to empty frames using rubber bands. The bees will gradually attach the comb to the frame with more wax and then will chew through the rubber bands and remove them from the hive, leaving them just outside the hive entrance (deCaux 2020). The small, jumbled pile of rubber strands is a visual representation of the multispecies entanglement at work in the co-creation of honeybee domus.

The hive boxes represent another intense intersection between honeybees and humans in the creation of their domus. The protective wooden outer shell of a Langstroth hive closely replicates the preferred nesting sites of *Apis mellifera* and other types of honey bees, who prefer the safety of nesting in a cavity (Crane 1999, 21). The frames contained within that protective shell also mimic the natural tendency of some honeybee species to make their combs in vertical sheets. Yet they also differ from wild hives, as these frames have been modified for human purposes. Wild comb is affixed to its nesting site, while the Langstroth frames can be easily removed from their box for inspection, handling, or processing. The entrances to wild hives are hidden and numerous while those of the boxes are purpose-built for ease of human handling. In these ways, the construction of commercial hives represents the intersection between domus and umwelt for the bees.

The process of removing frames from the hives is disruptive, even if only for the short term. Examining this intersection raises several questions about the activities of bees, such as, how do the bees make sense of the temporary disappearance of whole parts of their hive? How do they handle the removal of the hive lid and the sudden flooding of light and air movement into their carefully tended spaces? Does the relative regularity of these

activities in a commercial beekeeping operation make these changes easier for the bees to deal with, or is it a fresh disruption each time? These are, of course, incredibly difficult questions to answer, though hearing the "voice" of the bees is an important aspect of postmodernist multispecies ethnography (Smart and Smart 2017, 54). The bees themselves make their voices heard very easily. Aside from the singing I mentioned earlier, the bees are regularly audible throughout Mark's videos; the contented hum of a happy hive, the frantic buzzing of a hive about to swarm, the intentional fanning of bees at the entrance of a hive on a hot day while they work to cool their sistren within, or the angry hiss of bees perceiving danger (Wehmann et al. 2015). Their voices are therefore present in the creation of their shared domus with humans.

Mark also partially answers these questions through his personal interpretation of how the bees react to his presence. He often speaks to the bees and sometimes speaks for them, adopting a different voice to represent the bees' contribution to this back-and-forth dialogue he holds with himself. In these conversations he will refer to the beekeepers as "polar bears". This is Mark's term for the white-clad apiarists whose physical size and power are so much greater than that of any individual bee that he imagines the experience to be as terrifying to them as would be a human encountering a wild bear in the Arctic circle (deCaux 2018). Thus, the "voices" that are entangled in the comingled and co-created domus are shared by Mark and the bees in his hives, as Mark brings these voices to life through his own vocal cords and the bees make themselves heard by humans in the course of their daily activities. Though we cannot know for sure how honeybees perceive humans and their activities within bee lives, exploring how humans think honeybees may perceive us highlights the intersection of umwelt and domus present within the lives of bees.

Within Mark's polar bear comparison lies an unspoken power dynamic because he represents humans as towering beasts capable of devouring anything (including the bees) in their path. This dynamic can be questioned because beekeepers choose to wear their bee-repelling suits, as those suits are proof that the stings of bees are at best a serious annoyance and at worst a fatal threat to the wellbeing of individual humans (Visscher 1996). This is part of the human domus, as Western approaches to the stinging honey providers we call bees "trigger our vulnerability: we want to repel and contain them. They are fascinating, but elusive, and for many of us, they are frightening" (Moore and Kosut 2013, 85). Many tools in the apiarist's toolkit embody the notion of "repelling" bees and work to create a specific kind of honeybee domus that protects this human vulnerability. Mark's videos regularly feature his bellows-type smoker (Hobbs and Roddy 1990), used to inject smoke into the hive in an effort to calm the bees (Moore and Kosut 2013, 70). Smokers ensure that the bees do not get too "toey" and start to attack the beekeepers. The head-to-toe suits worn by Western beekeepers like Mark are designed to prevent any ingress by small individual bees looking to protect their hive from these huge intruders. Hive tools, thin metal sticks with hooks on the end, are helpful in prying apart hive frames that have been attached to the box by wax but are also useful for keeping gloved hands out of the hive and away from potential stings. Though Mark does not come across as frightened of the bees in his videos, his actions do align with "repelling and containing" the threat of the bees. Despite the massive size and perceived power imbalances between humans and bees, humans and their relative fragility result in the creation of a specific type of domus regarding domesticated honeybees.

Fragility is an interesting concept to apply here as the relative size and strength of humans compared to any single bee renders the bee and their physical abode of the hive inherently

fragile. The combs, made of wax and honey, are soft and malleable, easily destroyed by the comparative strength of human hands and other intruders. The bodies of bees are an inevitable casualty of handling a beehive, as individual bees are often damaged or killed among the throng of bodies that the invasive human often stirs up, though this is generally accidental. Regardless of intent, beekeepers bring death to individual bees in their quest for order and pollination. Whether this death is of great consequence to the bees is an interesting question as it might be the survival of the swarm itself, and not of individual bodies, that is at stake for the bees. Indeed, the only single bee that the beekeeper takes great pains to avoid damaging is the queen. Though she is larger than her daughters and sons, she is still fragile in comparison to the huge, white-clad humans who disturb her nest. Thus, Lien and Law's definition of the domus as "fragile" plays out in the power relationships between humans and honeybees (2016, 16).

Speaking more broadly, the commercial relationship humans impose on the bees that results in their particular domus is also fragile. Changes to the environment through anthropogenic climate change (Flores et al. 2019), human-spread pathogens such as American Foul Brood and Acute bee paralysis virus (ABPV) (Poppinga and Genersch 2012; Glenny et al. 2017), and perhaps most famously, from the use of pesticides like neonicotinoids (Woodcock et al. 2017), have recently highlighted the fragility of the commercial beekeeping domus. Globally, the vitally important pollinators that have kept commercial crops viable and productive are in widespread decline, and both wild and domesticated honeybees have been deeply affected (Jaffé et al. 2010). As a result of these human effects on the global domus of bees, the umbrella term of "colony collapse disorder", used to explain the sudden decline of managed honeybee populations, is a concern for every commercial apiarist (Williams et al. 2010). Though bees have agency and will happily live out their lives without interference from humans, the aforementioned changes mean that bees worldwide, whether wild or managed, are influenced by the activities of humans and, thus, humans have a place in the honeybee domus.

INSIDE THE HIVE: CONCLUSION

Though the concepts of umwelt and domus are separate, my investigation of the multispecies entanglements that have humans and honeybees at their centre demonstrates that both domus and umwelt are always intimately connected. The complex processes of perception and effect that shape the "self-centered worlds" of umwelten influence the ways that the domus is created, and the creation of the domus shapes the way that creatures experience their umwelten. In other words, the relationship between humans and bees is highly complicated. Humans like Mark rely on the bees for their livelihood and thus support the bees with resources like food and water, but they also constrain them and kill them. Bees produce for humans by pollinating crops and making honey and wax, but they also attack them and work to their own ends which is sometimes frustrating or harmful for humans. In addition, both Mark and the bees are at the mercy of larger systems, like capitalism, that drive their engagements with one another in the specific perceptor and effector worlds that constitute their umwelten and the assemblage of relationships that comprise their domus.

Understanding the complexities contained within and arising from this intersection of domus and umwelt provides necessary insight into how and why we might change our part in these relationships. The sharp increase in the use of pesticides and other substances that are harmful to honeybees threatens their health and productivity, which could and has led to collapses throughout the natural systems in which *Apis mellifera* plays a vital role (Cilia 2019). Comprehending the inner worlds of

bees and how they connect to the outer worlds with which we are familiar could allow humans to reimagine the ways we employ bees in our industrial farming, potentially leading to higher rates of biodiversity and lowering the environmental damage caused by these farming processes (Cuthbertson and Brown 2009; Cayuela, Ruiz-Arriaga, and Ozers 2011). Investigations of honeybee domus and umwelt could even support the use of non-honeybee pollinators in farming practices by understanding when other pollinating species may be a better fit for the environment or crop (Christmann and Aw-Hassan 2012). By embracing the complex entanglements in which humans and honeybees are situated, we humans are better positioned to work with the bees at their own level and could therefore improve the quality of both their lives and ours. Ultimately, though I wish I was writing for both honeybees and humans to read, I conclude by returning to Sue Hubbell's words as our entangled relationships with honeybees should remind us "that there is more to life than the merely human" (1988, 7).

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REVIEW ARTICLE

The Reintroduction of the Horse to the Northern Great Plains and its Influence on Blackfoot Lifeways

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ABSTRACT
The presence of horses in archaeological sites across North America is often noted in research as an indicator of European contact. Fewer studies, however, have considered how Indigenous peoples incorporated horses as an intrinsic aspect of their lives. Research that considers Indigenous peoples' relationships with horses typically focuses on Southern Plains groups and does not feature Northern Plains communities as a central aspect. Looking specifically at one Northern Great Plains Indigenous people, this paper analyzes how Blackfoot lifeways were altered as a result of the protohistoric (seventeenth to eighteenth century) reintroduction of the horse. Blackfoot lives were transformed as their relationship with the land evolved, economic systems reformed, and trade, religion, and war became centered around the horse. Almost all Blackfoot people would have felt the effects of the horse's introduction, however not necessarily equally as these changes caused a shift in hierarchy. These impacts and changes on lifeways are evidenced by European historical accounts, Indigenous oral histories, and the archaeological record. Examining the relationship that the Blackfoot formed with horses demonstrates the significant influence that animals can have over people's lives. Horses' introduction to Blackfoot peoples proved to cause significant changes in the ways many conducted their lives, such as through the establishment of nomadic pastoralism and trade routes centered around the horse. This paper additionally calls for further research into the continued relationship between the Blackfoot peoples and the horse.

Keywords: Plain's horses, protohistoric period, Blackfoot, archaeology, zooarchaeology

INTRODUCTION

The most widely accepted theory regarding the horse population in North America is that horses were prevalent during the Ice Age and went extinct sometime at the end of the Pleistocene (Barrón-Ortiz et al. 2017). It is theorized that roughly 11,000 years later, North America was reintroduced to the horse (Equus ferus) by Spaniards who settled in what is now New Mexico (Hall 2020). This same hypothesis goes on to stipulate that towards the end of the seventeenth-century, Spanish horse herds were captured and utilized by Pueblo and Apache warriors (Hall 2020). Subsequent trade and capture then allowed horses to spread and multiply throughout Indigenous communities in the Southwest and beyond (Hall 2020). However, there are contradicting claims regarding the history of the horse in North America. Indigenous scholars such as Collin (2017) have posited genetic and traditional knowledge that supports an unbroken relationship between North America's most ancient horse breeds and Indigenous peoples. While the reintroduction of horses by Spanish settlers is currently the most accepted

theory in academic literature, the premise that horses were 'gifted' to Indigenous peoples by Europeans plays into a colonial narrative. This narrative consequently tends to minimize the unique horse cultures that many Indigenous groups have maintained for time immemorial (Collin 2017).

Bearing these connotations, this paper will consider the current and widely accepted theory of mid-eighteenth-century adoption of horses in the northernmost portions of the Great Plains, while recognizing that this version of history may change in the coming years (Hall 2020; Bastien and Kremer 2004). Focusing specifically on the Blackfoot, I argue that the adoption of horses altered lifeways of the Northern Great Plains by modifying individuals' relationships with the land, by improving socioeconomic conditions, and by facilitating a hierarchical society. While there are many more changes that horses brought to Blackfoot life (see Hämäläinen 2003; Landals 2004; Zedeño, Ballenger, and Murray 2014), the effects that I discuss represent the most fundamental and drastic ways that Blackfoot lifeways were altered with the introduction of horses. Despite the history of the horse's relationship with Indigenous peoples being well studied within the southern regions of the Great Plains, less is known about the horse's impact on the Northern Great Plains (Bethke 2017; 2020b; Ewers 1955). Examining the relationship that the Blackfoot formed with horses demonstrates the significant influence that animals can have over people's daily activities and lives more broadly. Through the study of the Blackfoot's experiences with horses, it is apparent that these animals were seen as extremely valuable and had a substantial impact on many lifeways.[1]

MODES OF UNDERSTANDING THE HORSE'S INFLUENCE

The Northern Great Plains includes a vast ecoregion that ranges east to west from the 100th meridian to the plains east of the Rockies, and north to south from southern Alberta and Saskatchewan to northern Wyoming and Nebraska (Barker and Whitman 1988). The horse is suggested to have reached the Northern Plains via Indigenous groups such as the Comanche, Shoshone, and Flatheads (Hall 2020). Through trade and seizure, archaeologists argue that sometime in the 1720s, horses were introduced to the traditional territory of the Blackfoot (Hall 2020). Taking place well before the Europeans were established on the Northern Plains, these horses would have roamed in what is present-day southern Alberta, western Saskatchewan, and northern Montana (Hall 2020; Bethke 2020b). By approximately 1725, the Blackfoot had developed a word for the horse: ponokaomitaa—which translates into 'elk dog' (Baldwin 1994; Bastien and Kremer 2004).

Prior to the introduction of horses, the Blackfoot utilized dogs to aid them in various activities. Since time immemorial, dogs were used to pull travoises (a frame made up of two wooden poles used to tow heavy loads) with as much as 35-kilogram loads (Bastien and Kremer 2004). However, the newly introduced horse proved to be a significant improvement over the dogs that the Blackfoot had relied upon for transportation and other services before the 1700s, because horses could travel four times further than dogs and pull larger travoises for twice as long (Baldwin 1994; Landals 2004). Despite this replacement, it is important to note that dogs were not completely disregarded with the introduction of the horse. Dogs continued to be used alongside horses, as dogs were viewed as companions and useful for lighter work (Bethke

[1] It is important to recognize my positionality in this context as a non-Indigenous settler. While I have endeavored to shift away from a Eurocentric interpretation and portrayal in this work, Blackfoot peoples themselves will always be those best suited to speak to their relationship with horses.

2020a). While the Blackfoot had survived on the Northern Great Plains for generations with only domesticated dogs, they perfected the mastery of the horse in a matter of decades. In 1754, British explorer Anthony Henday (fl. 1750–62) noted the expert horsemanship that Blackfoot adolescents displayed while he found his horse difficult to control (Hall 2020; Graham 2008). Although there are conflicting perspectives regarding the rapid adoption of the horse by the Blackfoot versus a continuous primordial relationship, there is no denying that the horse had a substantial impact on Blackfoot lifeways (Collin 2017; Bethke 2020b).

The influence of horses on Blackfoot peoples' lives is inferred from several modes of evidence, including historical accounts, oral histories, and archaeological findings (Bethke 2017; Hovens 2009; Landals 2004). It is imperative to note, however, that there are limitations to each of these forms of knowledge. Knowledge of Blackfoot interactions with horses frequently stems from the accounts of European fur traders and surveyors, many of whom lived with and relied upon the Blackfoot for survival (Bethke 2017; Hovens 2009). Indeed, the Blackfoot may be one of the most studied and well-known North American groups to Europeans due to their documented relationship with European fur traders (Hovens 2009). However, most Europeans arrived on the Northern Great Plains decades after horses were already incorporated into the Blackfoot culture, leaving many questions about precontact horse life in Blackfoot communities (Bethke 2017). While still valuable, these accounts are influenced by Eurocentric interpretations and must be viewed with scrutiny. Alternatively, the Blackfoot's oral histories are rich and can enhance academic knowledge of the horse's history on the Plains and fill in the gaps of colonial sources (Bethke 2020a). For instance, nineteenth-century lessons surrounding horses are still known today, such as Blackfoot Chief Buffalo Back Fat's advice to not have one's entire financial assets invested in horses (Hämäläinen 2003). While oral histories are well known by many Indigenous peoples, they are not widely available within academia and future scholars will be required to make a concerted effort to seek out these verbal accounts if communities are willing.

The impact of horses on Indigenous lifeways is further supported by archaeological evidence. However, due to the loss of many sites in the last two centuries and some standard post-mortem practices of leaving horses' bodies exposed to the elements after death, there are few archaeological remains of horses across the Northern Plains (Bethke 2017; Ewers 1955). European-contact archaeological sites are often identified from the presence of horse bones but are severely under-represented on the Northern Plains. Indeed, one estimate posits late pre-contact sites on the Northern Plains at a 20:1 ratio to contact sites (Landals 2004). While the lack of archaeological sites from the contact period may be due to the aforementioned preservation and taphonomic issues, there are other factors at play. It can also be argued that the limited number of contact period archaeological sites is implicated by an altered relationship between the Blackfoot and the land that resulted from the introduction of the horse (Landals 2004). The next section will investigate these effects.

PASTORALISM, ANIMAL HUSBANDRY, AND MOBILITY: AN ALTERED RELATIONSHIP WITH THE LANDSCAPE

The introduction of horses changed how the Blackfoot used the land. Bethke (2020b), for instance, argues that the introduction of horses to Blackfoot people caused a shift from little to no management over domesticated seasonal pack animals (excluding dogs who can survive on much of the same diet as humans), towards nomadic pastoralism. With the horse, the Blackfoot people no longer had to rely as heavily on specific locations for

hunting. This reliance can be considered by examining the methods of bison jumps and drivelines. Although the Blackfoot people had successfully used these methods to manipulate the bison's actions and ecology for generations without the horse, communities were required to live near localities that allowed for the creation of bison jumps and drivelines (Oetelaar 2014; Bethke 2017). Additionally, as dogs cannot travel as great of distances, or carry as large of loads as horses, there was insufficient means to transport bison meat over expansive stretches of land, thus requiring the Blackfoot to live near hunting sites seasonally (Hall 2020; Bethke 2017).

Rather than bring the bison to the people, the introduction of horses allowed hunters to move to the bison and to transport bison meat more freely (Bethke 2017). Using horses, hunters could pursue bison independently, or communally employ a surround method of hunting, which allowed for a high return in mass kills that could then be moved back to camp to process (Oetelaar 2014; Zedeño, Ballenger, and Murray 2014). The Castle Forks (excavated 1993) and Flicka (excavated 2006) kill-sites of southern Alberta potentially provide evidence for the use of horses in hunting and the movement of both unborn bison calves and "meat bundles" — multiple disarticulated skeletal elements of bison— by horses back to camps (Peck 2010, 429). The utilization of horses to transport fetal bison and meat bundles from these sites is hypothesized for several reasons. The Castle Forks site contains the humerus of a fetal bison, and both sites suggest a style of meat processing where large pieces of bison were butchered at one time, thus implying that transportation was of little concern, likely because of the horse (Peck 2010). This hypothesis is additionally supported as both the Castle Forks and Flicka sites can be placed within the contact period since they contain protohistoric material, such as metals (Peck 2010; Landals 1993). Furthermore, within the Flicka site, the remains of a horse that appears to have died accidentally were uncovered, thus confirming the presence of horses and indicating their likely utilization (Peck 2010; Vivian, Dow, and Blakey 2019).

With limited archaeological data, the frequency of movement cannot be accurately tested; however, hunting methods altered by the introduction of the horse likely allowed for increased mobility (Bethke 2017; Bethke 2020a). An increased mobility hypothesis augments the likelihood that groups no longer stayed in one location for as long as they had in the pre-contact era (Bethke 2017; Landals 2004). Evidence of this (or lack-there-of) likely fits into the archaeological record with few documented protohistoric sites on the Northern Plains. Instances of such sites include Alberta sites DgOv–2, DgOv, and DgP1–1 (see Pyszczyk 1997, 60 for further examples). Because pre-contact sites were generally occupied for multiple generations and thus left behind copious material culture, they are more archaeologically visible than shorter-lived contact period sites. As an example of this, the pre-contact archaeological site of Ross in Alberta has nine clear cultural occupation layers. In contrast, contact sites in general have brief occupation periods, and their artifact density is lower than pre-contact sites, thus rendering them less archaeologically visible (Landals 2004).

Within the traditional Blackfoot territory, archaeological databases indicate that there are 240 contact sites compared to 1,077 pre-contact sites (Bethke 2017). While these site ratios suggest that the Blackfoot may have had greater mobility due to the horse, there are several factors to consider. The pre-contact period lasted upwards of ten thousand years while the contact period of archaeological interest lasted for only a few hundred years (Landals 2004). These differential durations are likely due to declines in Blackfoot populations resulting during the contact era from colonial impacts, such as disease and famine, and there remains a bias in archaeologists'

desire to discover pre-contact sites (Bethke 2017; Landals 2004).

Despite these potentially confounding factors, there is little doubt that the Blackfoot would have been forced to increase the movement of camps due to the grazing habits of horses. As grazers, horses could not stay in one area for too long without depleting their resources (Hämäläinen 2003). Furthermore, horses require more water than dogs (Bethke 2017). While the proximity to potable water had always been of concern, with the addition of horses, camps now continuously had to be near adequate sources of water (Bethke 2017; Hämäläinen 2003). Additionally, it appears that the horse influenced the tendency to live near wooded areas, as bark would have provided additional food for horses (Bethke 2017; Ewers 1955). Cottonwood, specifically, is known to have been used as additional feed when deep snow in the winter prevented horses from reaching grass (Ewers 1955). On average, contact archaeological sites are in closer proximity to both water and wooded areas, thus supporting the idea that horses influenced camp locations (Bethke 2017) (see Tables 1 and 2).

Distance (km)	Precontact Sites (%)	Contact Sites (%)
0.5	42	81
1	18	12
2	14	7
5	9	0
10	6	0
20	11	0
Minimum Distance	0.0016	0.0007
Maximum Distance	19.4	1.9
Mean Distance	1.6	0.3

Table 1–*The distance of camps to water bodies decreased following European contact. (Source: data reproduced from Bethke 2017, table 2, 808.)*

Distance (km)	Precontact Sites (%)	Contact Sites (%)
0.5	17	44
1	6	5
2	6	7
5	16	11
10	14	5
20	41	28
Minimum Distance	0.00	0.00
Maximum Distance	89.9	61.8
Mean Distance	14.5	9.2

Table 2–*The distance of camps to wooded areas decreased following European contact.* (*Source: data reproduced from Bethke 2017, table 3, 808.)*

The horse also appears to have resulted in many campsites becoming situated in protected river valleys (Peck 2010). Unlike domesticated dogs, horses do not require humans to survive on the Plains. As a result of this, it was necessary to utilize protected areas to ensure that horses did not run away from their owners. The topographic intricacy of river valleys, coulees, and foothills may have

provided natural enclosures while further protecting horses from theft (Bethke 2017; Peck 2010).

Furthermore, Peter Fidler (1769–1822), a European explorer who spent a winter season in the late eighteenth-century living with the Piegan of the Blackfoot, produced accounts that suggest members of the Blackfoot participated in controlled burning due to the grazing needs of the horse (Oetelaar 2014; Haig 1991). Although Fidler partially attributed the prairie fires he saw to lightning strikes, the fact that he was travelling through Southern Alberta in winter and early spring—a time when there are few lightning storms—makes this unlikely (Oetelaar 2014; Haig 1991). Fidler observed that many of these fires often took place near camps where thousands of horses could later be found grazing (Oetelaar 2014; Haig 1991). It appears likely, therefore, that these were controlled fires set for the purpose of creating grazing land for horses (Oetelaar 2014). This ecological control would not have been unusual for the Blackfoot, as controlled fires were often used to sustain winter foraging pastures for bison (Oetelaar 2014; Barett and Arno 1982). It is important to note, however, that fire chronologies of Northern Plains' primary forests, constructed through tree-scarring, indicate that controlled fires did not increase significantly following the introduction of the horse (Barett and Arno 1982). This data calls into question whether controlled burning set for grazing pastures was common practice (Barett and Arno 1982), or if perhaps the focus on bison foraging shifted to a focus on horse foraging, thus keeping the level of intentional burning consistent. Irrespective, there is little doubt that the introduction of horses altered the Blackfoot's relationship with the land by influencing where the Blackfoot lived and for how long, and their chosen methods of ecological control for subsistence practices. Just as horses transformed how the Blackfoot used the land, horses further modified the dynamics of Blackfoot socioeconomic and cultural practices.

REMODELLED HIERARCHY IN BLACKFOOT SOCIETY

Trade, religion, and war were all affected by the adoption of horses. As the Blackfoot could now travel with greater speed and ease, their lives were granted more flexibility (Bastien and Kremer 2004; Bethke 2017). The horse allowed Blackfoot economic networks to expand. Horses were used to traverse trade routes between communities and many of these trade routes were further utilized to exchange horses for material goods (Bethke 2020b; Hämäläinen 2003). The Kiowa of the Central and Southern Plains, for instance, traded horses to Northern Plains groups such as the Blackfoot via the trade network of the Comanche peoples (Hämäläinen 2003).

The increased movement abetted by the horse allowed for more trade between the Blackfoot and other Northern Plains groups, while still permitting the Blackfoot to be mostly independent of the fur trade (early seventeenth-century to mid-nineteenth century) (Bethke 2020a; 2020b; Foster and Eccles 2019). Bethke (2020b) argues that the Blackfoot could instead selectively choose when their interactions with fur traders took place on a beneficial basis. However, supposing that any Indigenous peoples could always dictate their interactions with Europeans is an oversimplification referring purely to trade and some of the benefits offered to those who possessed horses. The fur trade was frequently one-sided in favour of European settlers; in instances of epidemics or territory conflicts, the Blackfoot often had no choice in the form in which their interactions with Europeans took place. Hämäläinen (2003) contends that the introduction of the horse on the Northern Great Plains allowed for the expansion of the fur trade, as newly mounted hunters were able to efficiently contribute bison robes to the market. Horses were further used as an

exchange for European-introduced products, such as ammunition and guns (Bethke 2020b).

In addition to altered trade networks, horses changed Blackfoot religion and spirituality. For example, new spiritual organizations centered around the horse were created within the Blackfoot culture (Bethke 2020a). Early Europeans noted that one Blackfoot religious society was for the mending of both humans and horses (Bastien and Kremer 2004). Blackfoot religious foundations that had once centered themselves around the bison now further incorporated the horse (Bethke 2020a). The horse was incorporated into these spiritual aspects of life as it had mystical abilities. Horses were believed to be a gift from Morning Star, the Water Spirits, or Thunder (Bastien and Kremer 2004). In Blackfoot culture, the horse became a part of almost all religious elements, including the sacred pipe and medicine bundles (Bethke 2020a; 2020b). In these respective religious features, pipe bundles are used in pipe ceremonies, which may be conducted for many reasons, such as to give strength to horses or for success in war and hunting (Bethke 2020a; Crowshoe and Manneschmidt 2002). Medicine bundles are meant to help individuals by providing them with power from animals, such as the horse (Bethke 2020a; Crowshoe and Manneschmidt 2002).

Furthermore, as travel could be undertaken farther and faster with the horse, distant groups previously not connected physically were brought together in religious ceremonies, such as the Sun Dance or Okan, which typically includes hundreds of people (Zedeño, Ballenger, and Murray 2014). Although an in-depth explanation of the Sun Dance is beyond the scope of this paper, this complex spiritual ceremony, often related to celestial events such as the summer solstice, is held for a variety of reasons, such as to gain luck and give sacrifice and prayers (Ewers 1948; Hollabaugh 2017; Kehoe and Kehoe 1977). Alongside bringing distant groups together at traditional locations for religious ceremonies, horses further created new locations of religious importance. Some of these spaces, such as Kobell Coulee— now within Montana's contemporary boundaries and the Blackfoot Indian Reservation— are believed to make horses stronger and continue to be visited by horses and their owners in the winter months (Bethke 2017; 2020b).

Gradually altering several aspects of daily life, the horse further changed warfare among the Northern Great Plains. Although the effectiveness of mounted combat allowed certain groups, such as the Lakota, to evade the harshness of colonialism for longer than others, there were now new reasons for wars between Indigenous groups due to the horse (Hämäläinen 2003). For instance, the Blackfoot and Atsina faced increasing pressure from the Flatheads and Shoshones, who, after acquiring horses, pushed into Blackfoot and Atsina hunting territory (Hämäläinen 2003). This infringement resulted in a series of wars to drive the Flatheads and Shoshones back south (Hämäläinen 2003). Within the Blackfoot culture, battles such as these were often depicted in paintings on features such as wooden bowls, where horses would be a central aspect of the artwork (Hovens 2009). Hämäläinen (2003, 838) argues that many of the instances of war were because, although horses were central to the Plains' economy, the Northern Plains were relatively "horse-poor." As a result, Northern Great Plains groups were in a constant battle to obtain horses. For example, the Atsina were expulsed from their established homeland following several bouts of fighting over horses, after which many died during a severe winter (Landals 2004). Overall, dynamics of conflict changed due to the introduction of horses (Bastien and Kremer 2004). The extent of this change is also demonstrated through language, with the development of a word within the Blackfoot lexicon that communicates the act of stealing horses. The word, Naamaahkhaan, which translates to "coup," refers to taking a

horse from someone's home or getting close enough to strike someone (Bastien and Kremer 2004, 16). Taken as a whole, the horse was an active agent in altering the Blackfoot's socio-economic and broader cultural systems, which subsequently influenced the formation and structure of hierarchies within Blackfoot communities.

REMODELLED HIERARCHY IN BLACKFOOT SOCIETY

Much of the warring described contributed to the development of hierarchy within Blackfoot society. Although horses allowed for more equality in such regards as being able to transport the elderly and disabled, more than anything, the horse was a symbol of prestige and power (Hall 2020). Those that were considered 'wealthy' had dozens of horses, with some rumoured to have them in the hundreds (Hall 2020). As horses had become essential to life on the Great Plains, those without horses found themselves reliant on horse-wealthy community members for access to bison (Hall 2020; Bethke 2020b). As horse-rich individuals held a status and position of power over horse-poor individuals, wealthy people would often maintain more horses than they or their families needed (Hall 2020). Well-off individuals did this with the knowledge that they could then call in favours following the loan of their horses to people without horses (Bethke 2020b). Therefore, the presence of horses challenged the comparatively equitable social structures that had been common in the days of reliance on dogs (Hall 2020).

As discussed, horses increased the effectiveness of warfare and were often acquired through such conflicts. Subsequently, for individuals who were horse-poor, it was difficult to accumulate horses because those with horses were more likely to be invited to contribute to raids (Bethke 2020b). It is important to note, however, that the wealthy could easily lose their riches. Severe winters common to the Northern Plains, theft, and disease were all known to strip individuals of horses (Bethke 2020b).

Although the hierarchical ways of the horse days likely affected most people, the aspects discussed thus far have primarily focused on men. Experiences with horses were also gendered. Although Blackfoot men held specific responsibilities for horses, such as clearing holes in ice-covered water, Blackfoot women maintained their primary care (Bastein and Kremer 2004). Although the workload between men and women had once been predominately equal, the introduction of the horse required greater labour from women (Crowshoe and Manneschmidt 2002). Though the horse's introduction relieved some of the women's workloads, such as carrying belongings in camp relocations, women now had entirely new tasks (Hämäläinen 2003). Blackfoot women produced saddlebags, harnesses, travoises, and many other products that allowed for the more resourceful use of horses (Bethke 2020b). Unfortunately, due to the often-organic nature of these creations, their existence in the archaeological record is scarce. Furthermore, women were responsible for collecting bark for horses and clearing snow for grazing patches in the winter (Bastien and Kremer 2004). While an increased workload does not necessarily equate to women having less equality because of the horse, women appeared to have been responsible for these tasks as they were "below the dignity of a warrior" (Bastien and Kremer 2004, 249). Those who married into polygamous relationships were further viewed as subordinates responsible for the care of horses, while initial polygamous wives and the wives of wealthy families appeared to enjoy the horse's benefits (Hämäläinen 2003).

The differential treatment of some women was primarily the result of authority and affluence being within the control of a select few men within groups (Hämäläinen 2003). Women's role and their image changed

following the introduction of horses (Crowshoe and Manneschmidt 2002). With the mounted warrior idealized, horse-rich men dominated life on the Northern Great Plains (Crowshoe and Manneschmidt 2002). While it is vital to recognize that there continue to be numerous Blackfoot horsewomen who value horses as an intrinsic part of their culture (Bethke 2020b) and not as a burden as is postulated here, so too is it vital to recognize that the introduction of the horse was not a standardized experience.

CONCLUSION

As experiences with the horse varied across the Northern Great Plains, I have attempted to highlight one Northern Plains group, the Blackfoot, and demonstrate how their lives were altered due to the horse. Drawing on European historical accounts, the oral traditions of the Blackfoot, and the archaeological record, the introduction of the horse to the Northern Plains had a significant impact on people's lives. Specifically, horses provided a new degree of mobility and an altered relationship with the land due to innovations in hunting methods and the care that horse husbandry required. Although the horse provided Blackfoot people with greater freedom of movement, the horse's needs largely dictated where groups travelled, as their grazing habits had to be considered.

The Blackfoot further found life altered through their economic and social systems. Economically, the Blackfoot's trading relationships with other Indigenous groups and fur traders transformed due to the horse. Socially, the horse became the center of many spiritual practices and caused various instances of war and territory disputes. Lastly, horses became the highest form of monetary value on the Northern Plains and subsequently resulted in differential status and hierarchies. Although many benefitted from the horse's introduction, this was not a universal experience, and many women found themselves subject to an increasingly male-dominated society.

Exploring the horse's influence on the Blackfoot is important because it gives us a glimpse into the power that animals hold over people's lives. Additionally significant, the history of the horse on the Northern Plains is a lesser-known topic amongst archaeologists and generalists alike. Here, I have endeavoured to compile much of what is currently known on this topic concerning the Blackfoot. As the horse had wide-reaching impacts across the Northern Great Plains, future research will undoubtedly consider the unique relationships that other Indigenous Northern Plains groups formed with the horse. Moreover, I have not addressed the contemporary impacts of horses on Blackfoot lifeways, thus highlighting the need for upcoming papers to display the Blackfoot's relationship with the horse not as a relic of the past, but rather, as one which has evolved and persevered throughout the austerity of colonialism. This paper has sought to demonstrate that, despite thriving for generations without horses, the Blackfoot rapidly adapted to suit an animal that became the center of many of their lifeways.

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REVIEW ARTICLE

Corporate Social Responsibility: An Anthropological Approach to Understanding CSR as Global Governance

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ABSTRACT
Corporate social responsibility (CSR) has become a crucial element of development projects, and this has led anthropologists to speculate on the unintended consequences of positioning big business as givers of aid. Supported by international law and governments that deregulate businesses who practice CSR, corporations move freely across borders into countries whose communities become dependent on corporate aid dollars. Corporations assert their financial might by funneling their aid dollars through partnerships with non-governmental organizations (NGOs) in the countries where they operate. An examination of the structure of partnerships formed between and among corporations, governments, and NGOs shows that they are imbalanced in their power structure and this imbalance extends to the target populations of CSR programs. This paper examines the ramifications of these power imbalances through an assessment of Coca-Cola's activity in India and Israel alongside a review of the work of anthropologists in the area of CSR. Through this examination, I argue that CSR programs are instilling corporations with political influence that enables them to vie for global governing power, demonstrating that this dynamic has dire consequences for both the communities with whom corporations are interacting and the environment.

Keywords: corporate social responsibility, Coca-Cola, partnership, governance, NGOs, anthropology, sustainability

INTRODUCTION

On a recent episode of *Shark Tank* an up-and-coming business declared that in an effort to offset any potential harm their business activities would have on the environment, they would be donating a portion of their profits to charitable organizations that focus on conservation (Shark Tank 2020). The practice of attempting to negate one's bad deeds with a seemingly ethical offset is prolific in business, not only in new businesses just starting out. When Coca-Cola was presented with evidence that their business practices were leaving villagers in India without clean water, something that threatened the villager's health and livelihoods, Coca-Cola put forth a report in which the company glazed over the ill effects of their practices and drew attention instead to their aid work. Rather than address concerns surrounding water usage, Coca-Cola's report outlined their financial support of various agencies working in India, including UNICEF, who carry out projects surrounding HIV/AIDS (Raman 2007, 109). The question of whether corporations inherently carry social responsibility for their actions permeates popular culture. As comedian Jim Gaffigan laments, "McDonald's is like, excuse me, we sell burgers and fries . . . what do you want

from us America?" (Gaffigan 2020, 8:00). Further, Anthropologist Dinah Rajak asserts that not only do the public have expectations of corporations' social responsibility, but much of academia is positing corporations as the next step for development initiatives (2016, 30).

In 2002 at the World Summit on Sustainable Development, corporate social responsibility (CSR) was predicted to be the panacea for development issues (Dolan and Rajak 2016). CSR has since become the norm in both development and transnational business (Dolan and Rajak 2016) and anthropologists are in a position to examine the reciprocity of the relationships that CSR programs create with local populations. In "Corporate Social Responsibility and Development: An anthropological perspective," John Sharp argues that the role of anthropologists in the study of CSR should be to speculate on the implications of positioning big business as engines of development. He asserts that currently academia is too focused on whether or not CSR is functioning in the way that corporations claim it is and not enough attention is paid to the process of how they are attempting CSR (2006, 213). By looking at the work of anthropologists Robert Foster (2014), Dinah Rajak (2016), and Ravi Raman (2007), as well as sociologist Tamar Barkay (2011), it is revealed that much of the research surrounding CSR for consumer goods businesses has focused on the operations of the corporations themselves. A further assessment of CSR programs demonstrates that the impacts of corporate activities have serious implications not only for the people in the communities in which they operate but also for the environment. Partnerships, policies, and international laws favor corporations and create power imbalances that impede governmental and community action aimed at addressing sustainability issues inherent in consumer businesses. With a focus on Coca-Cola, a company that had a head start on globalization and is now in over 200 countries and territories (The Coca-Cola Company Investors 2019), I assess corporations' global influence. This paper examines the ramifications of the rise of corporations as engines of development and shows that positioning corporations as givers of aid infuses them with political and financial power over the communities and organizations with whom they partner.

IN PARTNERSHIP TOWARDS CSR: CORPORATIONS, GOVERNMENTS, AND NGOS

Anthropologists Rajak (2016) and Foster (2014) both maintain that partnership is the umbrella under which CSR functions and maintains itself. While corporations have formed partnerships with many outlets, including governing bodies, it is with non-governmental organizations (NGOs) that they have found their most productive home. Foster traces the birth of partnerships between corporations and NGOs to the 1999 Seattle World Trade Organization protests. Following the protests, the public relations firm, Edelman PR Worldwide, conducted a survey that concluded that NGOs hold positions of trust among the public at twice the rate of corporations (Foster 2014, 250). According to Foster, partnerships operate as a way for corporations to divert attention away from critiques of their business practices (2014, 243). He provides two examples of partnerships that Coca-Cola has maintained, which appear to pander to this goal. One of the examples, World Wildlife Fund (WWF), with whom they partner to address water conservation, is an NGO. The other example that Foster provides is Coca-Cola's partnership with musical front man will.i.am. for a lifestyle brand called EKOCYCLE, in which sports apparel is marketed as having been made with recycled bottles. Coca-Cola claims the goal of this initiative is to educate the public about recycling and responsible buying (2014, 243). This example shows the differing ways that corporations can use partnerships. While

projects like EKOCYLE satisfy customer concerns, it is partnerships with NGOs that corporations use to quiet their critics.

Foster delves deeper into the role of partnerships in CSR through his examination of the writing of Coca-Cola's 2004–2008 CEO, Neville Isdell, who coined the term *connected capitalism*. In his assessment, Foster describes connected capitalism as a system in which those who form partnerships are working together towards their own interests and proposes that the partnerships maintained by Coca-Cola extend beyond self-interest to a type of "postpolitical governance" (2014, 250). Arguing that Isdell's system relies on the assumption that corporations have personhood, Foster contends that the nature of partnership is reciprocal and that in a reciprocal relationship the person, "precedes the relationship of partnership" (2014, 248–249). However, he points out that corporations as artificial persons do not have all of the rights or responsibilities of a person. The person, therefore, is usually a representative of the company such as a corporate executive (2014, 249). As a corporate executive has limited liability, this caveat reinforces their role as simply an actor within the corporation. The structure of a corporation, which provides protection of the individual, inhibits any responsibilities tied to that individual's actions. The personhood then is found in the corporation as a single entity, who acts in partnerships with other single entities, such as NGOs. Thus, through these processes, the definition of personhood is redefined in relation to partnerships. Foster asserts that postulating personhood onto corporations may have unintended consequences that will, "end up enlarging the corporation's rights, privileges, and immunities" (2014, 250).

Dinah Rajak also explores the role of partnerships in CSR. In, "Theatres of Virtue: Collaboration, Consensus, and the Social Life of Corporate Social Responsibility" she asserts that while partnership has always played a role in development projects, the appeal of partnerships has broadened in the practice of CSR (2016, 32). Her field work on the subject takes place in what she refers to as the "social life" of CSR, namely, conventions, conferences, and awards ceremonies of the global elite, who act as representatives of corporations, governments, and NGOs (2016, 31). These conventions are commonplace, and her description shows that they resemble any other kind of business conference with shiny pamphlets and luxurious breakfasts. However, Rajak asserts, these gatherings are where the players of CSR enact their global corporate citizenship (2016, 31). The ability for corporations to enact global citizenship is accelerated by their relationships with governments. Both Foster and Rajak assert that the role of governments in partnership with CSRs is one of de-regulation, with Rajak citing former British Prime Minister, David Cameron, who promised to reduce regulations for businesses who practice CSR (Rajak 2016, 35; Foster 2014, 243). Deregulation provides clearance for partnerships between corporations and NGOs that absolves governments of their own obligations to development work and allows them to shift responsibility to corporations. Further, governmental action is hindered by international treaties that include Investor-State Dispute Settlement (ISDS) systems, which discourage governments from introducing regulations that may impact the finances of foreign corporations. ISDS systems allow foreign corporations to sue host governments if those governments enact regulations, including environmental protections, that lead to a loss of income for the corporations (Jovanovic 2017, 155). The threat of legal action combined with deregulation allows corporations to move across borders in ways that governments cannot. This freedom of movement further solidifies corporations as suitable partners for NGOs.

THE BALANCE OF POWER

Partnerships forged between corporations and NGOs are imbalanced in their power structure. The asymmetric nature of this relationship can be understood in gendered terms, as is demonstrated by interpreting Rajak's (2016) ethnography through the lens offered in Sherry Ortner's, "Is Female to Male as Nature is to Culture." Ortner (1972) argues that the universality of women being considered inferior to men stems from an association of women with nature, which is socially devalued in comparison to culture, with which men are associated. As the projects of NGOs often involve addressing environmental issues, these entities are associated with the earth and placed in an affiliated role with nature. Additionally, human rights initiatives undertaken by NGOs position them as caretakers, much as women in many societies are the caretakers of children. Conversely, cultural activities, as described by Ortner, create artificial resources, which sustain the culture of a society (1972, 16). The activities of corporations, for example, wealth accumulation and the creation of consumer goods, maintain and contribute to the cultural activity of the global economy and marketplace. Ortner asserts that women are not "'in reality' any closer (nor farther from) nature than man," but rather, the association of women with nature is expressed by the devaluing of women's roles within society (1972, 28). NGOs are similarly devalued as their association with nature activities places them on the outskirts of the economic marketplace. Corporations subsequently feminize NGOs and assert their dominance by othering and excluding NGOs who do not co-operate wholly with their vision.

The role that governments play in development work also perpetuates the feminization of NGOs. Governmental policies, particularly those aforementioned relating to the deregulation of corporations, lead to governments shirking their responsibilities for development work onto corporations. As such, the partnerships between governments and corporations sustain the imbalance because as the governments withdraw their support, NGOs become dependent on corporations for the monetary resources they hitherto received from governments. Rajak (2016) speaks with a representative of WWF who asserts that it is necessary to work with corporations to effect change, as the only solution to sustainability will be a *common solution*. However, Rajak points out that when NGOs disagree with corporations, they are accused of being adversarial and uncooperative (2016, 40). Those who argue against specific CSR programs are accused of being reckless and destroying corporate reputations (2016, 41). This attitude leads to critics being either silenced or excluded from the conversation around CSR. Similar to Ortner's description of subversive women, symbolized as witches and castrating mothers (1972, 26), the accusations mounted against NGOs portray such critiques as the "overreactions", of an "hysterical" woman. Therefore, both the formation and maintenance of partnerships between corporations and NGOs are influenced heavily by the corporation's position of power, which is effectively levied by the respective government, and through the feminization of NGOs. This structure leaves NGOs vulnerable to having their funding slashed if they do not act in accordance with the will of corporations.

Rajak describes a similarly imbalanced relationship between corporations and activists that is explored in greater detail by Ravi Raman (2007). Raman conducts his study of CSR in India where Coca-Cola has been accused of depleting water sources that villagers rely on. He examines how the claims Coca-Cola presents in their documentation interact with the lived experience of both local populations and those communities for whom Coca-Cola states their programs are developed. Two years after Coca-Cola set up a bottling plant in Plachimada in Kerala, public health officials told villagers that the local water supply was

no longer safe for consumption. Many villagers, however, were already plagued with skin and stomach disorders (Raman 2007, 108). In response to the accusation of groundwater depletion, and the presence of heavy metals in the environment as a result of their bottling practices, Coca-Cola said, "We take these concerns seriously and we continually work to ensure that our products and practices are world class and safe" (Raman, 2007, 109). Although Coca-Cola attempted to assuage fears, their focus remained on the safety of their products and not on how their actions were affecting those in the communities in which they operate. Additionally, while Coca-Cola insisted that they not only follow but exceed legal standards, Raman points out that when the high court in India ruled that the water belonged to the citizens, and that the government had had no right to allow access to private companies, Coca-Cola continued their extraction (2007, 109–110). Raman writes that in their report *Corporate Responsibility Review*, Coca-Cola maintains that they listen to both NGOs and their critics (2007, 106). However, when informed by community members that their activities were causing harm, Coca-Cola did not cease their operations (Raman 2007, 108). Coca-Cola's refusal to address the concerns of the locals, and their disregard for the high court, led to an initiative of protests referred to as the Anti Coca-Cola Campaign (Raman 2007, 108). This campaign received support from various human rights activists and as the protests grew, other communities joined in what Raman referred to as a "Solidarity of 'everyday' forms of resistance" (2007, 109).

The shift from people as actors in the target populations of CSR programs to activists affects the relationships between corporations and community members. As community voices morph into those of protest, their message is devalued and is purposefully left out of the conversation of CSR. Rajak describes a situation during the conference, "Spheres of Influence: Understanding human rights in business," that surprised her fellow convention goers and which at first glance appeared to be giving marginalized activists a voice. Protesters who had gathered outside of the conference hotel were invited in and briefly given a platform to speak. The activists, who had travelled from Thailand to London to protest the convention, contradicted the theme of the gathering by declaring that claims that community members were giving consent to corporate planned projects were false. They asserted that within their community people were not in co-operation with corporations and were being "forcibly removed from their land" to make way for a pipeline (Rajak 2016, 36). The activists appeared to have circumvented the high entrance fees that normally present a barrier to having their voices heard, and Rajak states that the unusualness of this was pointed out by paid conference attendees who exclaimed that they had never seen anything like it (2016, 36). The effectiveness of the activists' trouble was short lived, however, as their presence took up only a small paragraph in the conference report, which declared simply that they had been there and had voiced their displeasure (Rajak 2016, 36). Allowing the activists in to speak but silencing their words postscript highlights how presentation of moral character contributes to maintaining partnerships. As NGOs have different relationships with activists than corporations do, allowing the activists in was likely designed to placate the NGOs and to sell them on corporations' good intentions. As Foster writes, Edleman asserts that fostering relationships between corporations and NGOs helps to protect the global reputations of corporations and aids in averting negative press (2014, 250).

GOVERNING POWER

To further the preservation of their reputations, corporations utilize language from NGOs for their CSR programs. This works to borrow from the trust that NGOs have built

with the public. However, Rajak asserts that it is appropriation and amounts to a colonization of the language (2016, 43). Arturo Escobar states that, "Language is alive, its meaning always dictated by the context" (1995, 169) and corporations guide the life of the language of CSR. Raman asserts that the discourse surrounding CSR is constructed by the corporations themselves (2007, 105). The language used by corporations further contributes to a power imbalance and allows for corporations to increase their governing power. In India, for example, Coca-Cola termed their hazardous waste byproducts, 'biosolids' and gave them to local communities to use as fertilizer (Raman 2007, 112). These byproducts, however, were found to contain toxic metals and other materials that could lead to a host of medical problems. Raman asserts that Coca-Cola's terming of their hazardous waste byproducts as biosolids showcases the "Power politics played by hegemonic forces" (2007, 109). Foster further argues that the allegations against Coca-Cola in India highlight the purpose in partnerships between corporations and NGOs as being one of harm reduction and he specifically addresses Coca-Cola's relationship with WWF. Foster describes the partnership between Coca-Cola and WWF, which began in 2007 with a purpose of water conservation and climate protection, as representative of Isdell's ideas of connected capitalism (2014, 252). The benefits of these partnerships are succinctly described by Rajak, who asserts that alliances between corporations and NGOs are an exchange of moral capital for monetary capital (2016, 43). WWF receives monetary benefits for helping Coca-Cola to, "Minimize their water and energy use throughout their supply chain" (Foster, 2014, 252). The criticism of this exchange, Foster points out, lies specifically with the language Coca-Cola used by promising to minimize their use of water to make bottles of water. Language is used by corporations to elevate their actions and Foster points to what Benson and Kirsch call corporate oxymorons, alleging that Coca-Cola's use of language is designed to minimize their harm and protect their reputation, similar to terms such as, "safe cigarettes" and "sustainable mining" (2014, 252).

Sharp however, argues that these practices are not merely a smokescreen to hide corporate intentions, rather, CSR is, "An orderly system of knowledge and practice that embodies particular ways of interpreting and acting on the world" (2006, 215). The discourse of CSR changes the path of development from the government model of categorizing beneficiaries as those entitled by citizenship, to one whose recipients are stakeholders in host communities (Sharp 2006, 215). As corporations gain power in governance their decisions in "host communities" begin to usurp those of the local governments. This is demonstrated by Sociologist Tamar Barkay in her study of Coca-Cola's presence in Israel in, "When Business and Community Meet: A Case Study of Coca-Cola." Coca-Cola's CSR programs in Israel included A Child's Smile, a program that provided monetary and fundraising support to fourteen women's shelters. However, even though the shelters had become dependent on Coca-Cola's funding for their operations, in 2004 Coca-Cola's marketing office in Atlanta determined that A Child's Smile did not properly integrate community programming with their business interests, and it was de-funded (Barkay 2011, 282). Coca-Cola decided instead to begin renovating parks, as this was a community project more closely aligned with their "healthy lifestyle" programing. Barkay's study of the project showed that while Coca-Cola partnered with local government officials, who suggested certain parks badly in need of renovation, Coca-Cola quickly overruled their suggestions and sought instead parks with high visibility for the logos that they incorporated into the design of the park. Barkay asserts that Coca-Cola took liberty to frame and define the community's needs, a direct demonstration that corporations'

CSR projects benefit their own branding and marketing needs over the needs of the target populations of their programs (2011, 284).

Barkay (2011) interviews two key players in the projects that showcase the intricacies of government and corporate partnerships. First, she speaks to a government official who laments that every year they have less funding from municipalities, and, as such, are dependent on outside sources of funding. Second, she interviews a representative of Coca-Cola. The representative complains that recipients of funding do not anticipate new CSR practices and instead expect donors to be like old style philanthropists, who gave money with no expectation of participation in the projects. The participation of corporations in the execution of CSR programs, coupled with the governments increasing dependence on them for development, form what Barkay says in the literature is a type of new governance, which she refers to as, "a configuration whereby state and non-state stakeholders share authority and divide social tasks between them through dialogue, learning, and cooperation" (2011, 285). However, as demonstrated, while corporations posit themselves as partners, these partnerships, whether with NGOs, governments, or community members, operate with a power imbalance that favors the corporations. The cooperation that Barkay speaks of, while present, is controlled by corporations that strong-arm the other parties. Corporations take no responsibility for this as Isdell accuses governments of lagging behind corporations and NGOs as they form strong partnerships with each other (Foster 2014, 253). Furthermore, if "new governance" entails competition, as Barkay asserts it does (2011, 280), then governments are playing a role that will ultimately benefit corporations as they contribute to a dependency on corporate money for development, leaving the door open for corporations to pick and choose their target demographics based on their bottom lines.

The bottom lines of corporations have evolved beyond profit to encompass political power. Friedman, whose 1970 essay Foster refers to, calls social responsibility "A fundamentally subversive doctrine" (Friedman 2020, 4). Friedman argues that because corporations are responsible to their stakeholders, any money spent on social responsibility is money that belongs to someone else— namely the stakeholders. As such, social responsibility forms a kind of tax system where corporations' appropriate stakeholders "tax" dollars for aid programs. He contends that as this should be a function of government, social responsibility runs the risk of "Taxation without representation" (Friedman 2020, 2). As corporations access increasingly larger pools of money and expand their roles as givers of aid, their political influence increases and perpetuates dependency in the communities in which they are present. Moreover, the fulfilling of corporations' bottom lines brings with it an additional cost. Just as bottom lines have evolved from financial purposes to governing power, the cost of granting corporations these rights and freedoms has evolved beyond risks to local communities to encompass risks surrounding global climate change.

SUSTAINIBILITY AND ENVIRONMENTAL IMPACT

Coca-Cola's former CEO Neville Isdell laments, "As if companies owe society a debt for making a profit" (Foster 2014, 250) and anthropologists have uncovered that corporations are not paying their debts to the communities in which they operate. Furthermore, corporations cannot return to the earth those resources which they deplete from it. When Coca-Cola implements environmental programs aimed at water preservation they are not working for the environment, or for the people from whom they have taken the water. Rather, they are working to fill their bottles, manufacture their bottles, and to make a profit.

Coca-Cola's product is dependent on the use of water in both production and design. Without water, Coca-Cola has no product and as a consumer business, they rely on consumption of a product and thus, they rely heavily on water. Coca-Cola set an objective of increasing the efficiency of their water use within their manufacturing practices by 25% from their 2010 usage (The Coca-Cola Company 2018). However, not only is a 25% reduction from overuse still overuse, but the reduction is based on a per bottle system. As such, any increase in sales increases the number of bottles manufactured, which negates any reduction in water usage. In fact, ten years after their pledge, in their second quarter earnings in 2021, Coca-Cola reported an increase of 14% in soda sales and a 25% increase in their juice and dairy products over their 2019 numbers (Lucas 2021). Increasing consumption is fundamental to the success of consumer business plans and this introduces a conflict of interest for corporations who wish to address climate change.

Corporations seek to address the issue of overconsumption with sustainable manufacturing. However, the overuse of resources cannot be managed by sustainable manufacturing if corporations' business models are based on increasing consumer consumption. The United States Environmental Protection Agency (EPA) touts sustainable manufacturing as a solution for businesses looking to minimize environmental impacts while improving their brand ideation (EPA 2020). "Sustainable manufacturing" continues the trend of corporate oxymorons presented by Foster (2014) and discussed earlier. Manufacturing inherently involves the use of resources and as such, challenges the notion of sustainability. For example, the company Etee, promises to manufacture their products using only sustainable materials. Instead of plastic containers, their soaps are encased and shipped in biodegradable beeswax (Etee, 2021). While this model addresses the issue of after-product pollutants, it does not address the resource extraction that would be required to provide this product worldwide. The EPA suggests that sustainable manufacturing involves focusing on competitiveness rather than efficiency (EPA 2020). This presents a problem for companies, like Etee, who are addressing global environmental issues, as competitiveness relies on growing their consumer base. As consumption of Etee's product increases so too will the need for beeswax and eventually the balance of sustainability will shift.

Coca-Cola and Etee's "sustainable manufacturing" practices are implemented and regulated by the companies themselves. By showcasing Coca-Cola's disregard for their impact on community member's health in India, Raman demonstrates that allowing corporations like Coca-Cola to self-regulate has had detrimental outcomes. While Coca-Cola asserts that they follow local laws (Raman 2007, 109), they do not acknowledge that local laws vary from country to country and do not take responsibility for those countries unprepared for the impact that corporate activity brings to their communities. Developed countries have strict laws and policies surrounding corporate governance and corporations do not inherently carry those policies into the developing countries where they manufacture and set up aid programs. Additionally, treaties that include ISDS systems not only lead to further de-regulation, but most ISDS claims are made against the governments of developing countries by corporations who hail from established economies (Varghese 2017, 6). ISDS systems disadvantage developing countries by limiting their governments' options for recourse once the corporations have established business practices in their country. If governments wish to enact policies that interfere with the profits of foreign corporations, it leaves governments financially responsible for those corporations' losses. Further, continuing a trend of self-regulation of environmental impacts places corporations in opposition with themselves.

The financial outcomes of consumer corporations are dependent on access to resources, such as the water that Coca-Cola is reliant on. Self-regulation with any hope for a meaningful impact on climate change would require corporations to initiate regulations that restrict access to the resources that they utilize in their products. As governments and international laws encourage deregulation, corporations are left with no oversight but their own. This leaves communities, NGOs who partner with corporations, and those who care for the environment in a position of reliance on corporations to choose to undermine their own consumer growth and ignore opportunities to seek financial gain through legal recourse.

CONCLUSION

The work of the aforementioned social scientists demonstrates that corporations are superseding governments in development, in both action and financing. Corporations carry increasing influence in the countries where they operate, and that influence goes beyond consumer habits and into governance. Imbalanced partnerships between corporations and NGOs further increases corporations' influence as they pick and choose which NGOs will be able to continue operating based on whom they choose to fund. Governmental policy and international law have provided opportunities for corporations to become the main funders in community projects; however, as Raman and Barkay point out, projects undertaken by corporations often ignore the needs of the community. So, while there may be representation, the interests by which a corporation's development dollars are distributed are determined by the corporations themselves.

Partnerships between corporations and NGOs have created a system where corporations are not dependent on the communities in which the resources they need are housed, but rather the communities become dependent on corporations for their development dollars. Rajak writes about corporations' involvement in local projects and global partnerships stating, "The service of local development have proved a particularly powerful tool for recruiting support from noncorporate actors, while marginalizing dissenters from the arenas in which these cosmopolitan alliances are forged" (2016, 40). When corporations gain credibility as instruments for social change, those who oppose them become increasingly marginalized. If deregulation continues and corporate power increases, the checks and balances will belong to the corporations themselves and global decision making will be in the hands of artificial structures, posited as people, with limited liability to either humanity or nature.

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REVIEW ARTICLE

Rheumatoid Arthritis: An Examination of Arthropathy in Antiquity

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ABSTRACT
Arthropathy – or joint disease – is the most common post-cranial pathological change found in skeletal remains, both today and in the past. Responsible for a great amount of pain and discomfort in modern populations, arthropathy continues to be highly researched in current clinical and paleopathological studies. Despite its frequency in an archaeological context, differentiation between various types of arthropathy can prove challenging. Rheumatoid arthritis (RA), for example, is historically underrepresented in the archaeological record. This may be due to a combination of the poor preservation of hand and foot bones (the locale where the bony alterations of RA begin), the non-specific appearance of RA lesions on bones, as well as other biases inherent in the bioarcheological record. This article analyzes the origins and antiquity of RA, as well as some of the issues with differential diagnosis using clinical and paleopathological literature, including probable and potential cases.

Keywords: rheumatoid arthritis, arthropathy, paleopathology, bioarchaeology, spondyloarthropathy

INTRODUCTION

Joint disease, also known as arthropathy, is the most common post-cranial pathological skeletal change found in past and current populations (Aufderheide and Rodriguez-Martin 1998; Black et al. 2012; Bašić et al. 2017). Regardless of the prevalence of joint disease in skeletal remains however, rheumatoid arthritis (RA) is historically underrepresented in the archaeological record. Today, the worldwide prevalence has been estimated at 0.24 percent (Cross et al. 2014), with estimates of RA prevalence in the United States and Europe being typically higher at 0.5 to one percent (Myasoedova et al. 2010; Hunter et al. 2017). RA visibility in skeletal remains is hampered by the poor preservation of small hand and foot bones, where the bony alterations of the disease begin. Additionally, the non-specific appearance of the lesions RA leaves, which are commonly confused for other arthropathies, has led to a lack of differential diagnoses indicating RA in the archaeological record (Black et al., 2012; Roberts and Manchester, 2005). Lastly, RA is three times more common in females than in males (Cross et al., 2014; Waldron, 2008; Roberts and Manchester, 2005). Due to differential preservation, female remains preserve less readily than those of their male counterparts due to gracility and sexually dimorphic bone density (Roberts and Manchester, 2005; Aufderheide and Rodriguez-Martin, 1998). This differential preservation means that if the disease was present in ancient populations, it is less likely to be found due to lack of preservation (Roberts and

Manchester, 2005; Waldron 2008). As a result, this paper examines the origins and antiquity of RA, as well as some of the issues with differential diagnosis using clinical and paleopathological literature, including probable and potential cases.

MEDICAL HISTORY OF OSTEOARTHRITIS (OA)

Joint disease is responsible for a great amount of pain and disability in modern populations (Waldron, 2008). Clinical studies reveal that degenerative joint disease or osteoarthritis (OA) was one of the earliest disorders to be identified and characterized clinically (Lieverse et al. 2007; Lieverse et al. 2016; Scott, 2019; Gay et al. 2019; Horak et al. 2011). Numerous Neanderthal remains dating from around 250,000 to 35,000 years ago show signs of osteoarthritis, suggesting that joint disease was present in prehistoric populations (Boule and Vallois, 1957). Some of the earliest written records of arthritic diseases lie in the Ebers and Edwin Smith papyri (Nuki and Simkin, 2006; Schwartz, 2006). Both of these examples date from around 1550 BC and reference writings of Imhotep from 1000 years earlier wherein the symptoms of osteoarthritis are described. This finding suggests that the concept of arthritis existed even in the early centuries of Egyptian civilization more than 4,500 years ago (Nuki and Simkin, 2006).

Today, in modern clinical samples, OA is most commonly seen in the knee, hip, and hands (Waldron, 2008). OA affects as much as forty percent of people aged seventy years or older, making it more prevalent than any other form of arthritis in modern populations (Valdes and Spector, 2011). This prevalence in modern samples helps to explain why OA is also found so frequently in ancient skeletal materials (Rogers et al. 1987).to be found due to lack of preservation (Roberts and Manchester, 2005; Waldron 2008). As a result, this paper examines the origins and antiquity of RA, as well as some of the issues with differential diagnosis using clinical and paleopathological literature, including probable and potential cases.

MEDICAL HSITORY OF RHEUMATOID ARTHRITIS (RA)

Rheumatoid Arthritis (RA) was first recognized in French clinical literature in 1800, in Augustin Jacob Landré-Beauvais' (1772-1840) MD thesis. In this thesis, Landré-Beauvais described signs and symptoms of an unknown disease that he referred to as goutte asthénique primitive or primary asthenic gout (Landré-Beauvais, 1800; Landré-Beauvais, 2001; Tsoucalas and Sgantzos, 2017; Waldron, 2008). He described an affliction that was more common in women, involved many joints from the onset (notably in the hands and feet), and followed a chronic progression. Landré-Beauvais was confident that he had identified a new form of joint disease, and it is believed today that he was describing the signs and symptoms commonly associated with RA (Waldron, 2008).

The lack of RA recognition before the work by Landré-Beauvais signaled to some researchers and clinicians that RA was a relatively new disease, although, there have been suggestions that some historical figures such as Mary Queen of Scots (1542–1587), suffered from the disease (Wallace, 1964; Waldron, 2008). There is also paleopathological evidence for the antiquity of RA. Cases have been identified from the medieval and post-medieval periods of England, for instance, (Waldron, Rogers and Watt, 1994; Hacking, Allen and Rogers, 1994) and seventh to ninth-century France (Blondiaux et al. 1997). In addition to these numerous 'suspected' cases of RA in antiquity, see Table 1.

DIFFERENTIAL DIAGNOSIS OF ARTHROPATHIES

Joint diseases can be divided into those that proliferate – forming bone – and those that are erosive – taking bone away (Waldron,

2008). This section outlines the various joint diseases that can present similarly to RA in skeletal remains but reflect diverse underlying etiologies. The causational and diagnostic differences will be highlighted and discussed in the subsequent sections to better understand the difficulties in differentially diagnosing some of these diseases in antiquity, especially RA.

Degenerative Joint Disease: Osteoarthritis

Osteoarthritis (OA) is the most common joint disease found in modern and ancient populations. As a result of this disease prevalence, OA has been researched extensively, both in clinical and archaeological literature (Crubézy et al. 2002; Dürr et al. 2004; Gay et al. 2019; Horak et al. 2011; Lieverse et al. 2007; Lieverse et al. 2016). For the purposes of this article, I summarize the pathophysiology and etiology of this disease, while placing emphasis on skeletal diagnostic criteria and OA's classification as an erosive joint disease as these aspects pertain to OA's differentiation from RA and other arthropathies.

OA is a progressive joint disease that results from several complex co-occurring factors leading to subchondral bone changes and the loss of articular cartilage (for a thorough review of OA see Scott 2019). These factors include, but are not limited to, age, genetic predisposition, biological sex, obesity, trauma, and repetitive movement (Waldron, 2008). One or more of these factors will initiate a pattern of inflammatory events leading to the appearance of OA in the joint and ending in joint failure. The earliest visible manifestation of the disease is the loss of articular cartilage (Jurmain and Kilgore, 1995; Rogers and Waldron, 1995). As the disease progresses, bony changes develop as a result of this loss of protective articular cartilage including marginal osteophytes, the formation of new bone along the joint surface, pitting along the joint surface as a result of subchondral cysts, changes in joint contour, and eburnation (Waldron, 2008).

Earlier research states that OA is a non-inflammatory joint disease of the elderly that overuse or mechanical stress places on particular synovial joints (Rogers and Waldron, 1995; Roberts and Manchester, 2005; Jurmain and Kilgore, 1995; Felson, 1988; Freedman et al. 2012). However, recent research recategorizes OA as an inflammatory joint disease that is known to affect individuals of varying age categories (Resch, 2003; Wood et al. 2013; Horak et al. 2011; Lieverse et al. 2016; Scott, 2019). Although OA is now categorized as an inflammatory joint disease, and inflammation does play a role in the early stages of the disease, OA does not cause inflammation to the same degree as other inflammatory arthropathies, such as RA, which will be discussed in the following sections (Resch, 2003; Wood et al. 2013). OA inflammation may be the result of trauma or other micro-injury (Black et al. 2012), with trauma severity being directly linked to OA risk factors (Wood et al. 2013; Resch, 2003; Jurmain and Kilgore, 1995).

It is also important to acknowledge that OA can be further differentiated into primary or secondary OA, depending on disease initiation. Primary OA affects joints with no known cause and is also referred to as idiopathic (Caroll, 2016). Secondary OA affects joints as a result of external trauma (injury) or disease (Capuano et al. 2015; Waldron, 2008). For example, secondary OA is often found in the joints of patients diagnosed with RA. Although OA is no longer considered a "wear and tear" degenerative disease of the elderly, due to the relatively low degree of inflammation in comparison to the other arthropathies, OA has been placed in its own distinct category.

Immune and Inflammatory Joint Disease: Rheumatoid Arthritis (RA)

Compared to OA, RA is rarely seen in the archaeological record (Roberts and Manchester, 2005). RA is a chronic inflammatory autoimmune disease in which the body's immune system mistakenly attacks the synovial joints of the body (Caroll, 2016). RA affects synovial joints symmetrically, beginning in the smaller joints of the hands and feet, before progressing to the larger joints of the body, specifically the hip, knee, shoulder, and elbow joints (Waldron, 2008). The symmetrical appearance of the disease is used to distinguish RA from other forms of arthritis, such as OA (Capuano et al. 2015; Caroll, 2016).

Clinically, it is understood that an immune complex is formed when the Rheumatoid Factor (RF) in the blood binds with immunoglobin G, triggering an inflammatory response (Capuano et al. 2015). In cases where this RF is present in the blood, this is known as seropositive rheumatoid arthritis (Capuano et al. 2015). Today, RF in the blood is used as a diagnostic hallmark of the disease; however, cases of RA have been diagnosed with no traces of RF in the blood, both through physical examinations, or anti-CCP counts in the individual's blood. These circumstances are known as seronegative RA (Rogers, 2000).

RA affects approximately 0.24 percent of the world's population, with approximately fifty percent of adults being unable to work within 10 years of disease onset, making it an incredibly debilitating disease (Meng et al. 2017; Cross et al. 2014). Today, the cause of the formation of the immune complex and development of RA is unclear, although a genetic component appears to be likely. Additional risk factors for the development of RA include sex, age, and environmental and behavioral factors. RA is found in every sex, age, and ethnic group; however, an estimated seventy percent of those diagnosed are women (Oelzner et al. 2008). This means that women are three times more likely to be afflicted with the disease. Women diagnosed with the disease are typically diagnosed between the ages of thirty and sixty. This has been attributed to female hormonal levels, which may contribute to developing RA (Oelzner et al. 2008). Men with RA are commonly diagnosed later in life, typically between forty-five and seventy years of age, with their overall risk increasing with age (Zias and Mitchell, 1996).

The etiology and pathogenesis of RA are not completely understood, but RA is known to involve the synovial joints and leads to progressive joint destruction. As RA progresses, chronic inflammation leads to a loss of bone density around the joints and throughout the body, causing thin, brittle bones (Bromley and Woolley, 1984; Hochberg, 2009; Mcgonagle et al. 1999; Schett and Firestein, 2010; Vis et al. 2013). Visible macroscopic lesions that accompany RA can differ depending on the affected joint size. In smaller joints, such as those of the hands and feet, subluxation is often present in life. This is seen in skeletal remains by the extension of the articular surfaces of joints and marginal lipping (Roberts and Manchester, 2005). In larger joints, osteoporosis is commonly seen in the articular ends of bones with resorption of the subchondral bone. Lytic foci are also found, representing the remnants of subchondral cysts (Roberts and Manchester, 2005).

Immune & Inflammatory Joint Disease: Psoriatic Arthritis (PsA)

Psoriasis is a common skin condition in modern populations, affecting approximately one to three percent of the general population, and about five percent of sufferers develop joint changes (Waldron, 2008; Roberts and Manchester, 2005; Rogers, 2000). Clinically, males and females are affected equally, and the average age of onset is between twenty and forty years. Although its cause is unknown, genetic, nutritional and infectious factors likely play a role in disease development (Szentpetery et al. 2016; Gladman et al. 2005).

Few definitive examples of PsA have appeared in the archaeological literature (Rogers, 2000; Pasero and Marson, 2006; Zias and Mitchell, 1996). Given the prevalence of PsA in modern populations, it is safe to assume that its obscurity in antiquity likely reflects misdiagnosis of this disease for different erosive joint diseases. Such misdiagnosis may be the result of missing hand or foot bones (where the distinctive lesions of the disease present), or non-specific lesions on other bones that cannot be distinguished from those of other conditions. Another difficulty in the diagnosis of PsA in skeletal remains has to do with the highly variable nature of the disease (Rogers, 2000).

PsA can affect any synovial joint in the body, and a variety of clinical subsets of PsA have been identified and described, depending on the number of affected joints and the distribution of bony joint changes (Waldron, 2008; Szentpetery et al. 2016). In the majority of clinical cases, PsA presents as an asymmetrical erosive arthropathy, or a symmetrical polyarthritis, similar to RA (Waldron, 2008; Roberts and Manchester, 2005; Szentpetery et al. 2016). Tendon and ligament attachments to bone are also commonly involved, causing new bone formation or the development of enthesophytes (Pasero and Marson, 2006; Waldron, 2008; Gladman et al. 2005). The phalanges of the hands and feet become eroded at the joint surface and margins. PsA is often identified by distinctive 'pencil and cup' deformities in the distal interphalangeal joints and new bone formation on the phalanges, metacarpals, metatarsals, carpals and tarsals of the hands and feet and around the joints (Roberts and Manchester, 2005). Additionally, there can be involvement of spine and sacroiliac joints with ossification of vertebral ligaments (Roberts and Manchester, 2005).

Immune & Inflammatory Joint Disease: Ankylosing Spondylitis (AS)

Ankylosing spondylitis (AS) is a progressive inflammatory disease affecting the axial skeleton (Roberts and Manchester, 2005). It is the most common spondyloarthropathy recognized in skeletal remains (Waldron, 2008). Spondyloarthropathies are distinguished from other arthropathies as they involve inflammation of the joints of the spine. Although the prevalence estimates of AS vary from 0.25 percent to 4.5 percent in living populations, the frequency of the disease in the past has not yet been determined (Duyar, 2019). This disease of unknown etiology affects males two to three times more than females (Rogers, 2000), with an age of onset between fifteen and thirty five years (Roberts and Manchester, 2005). There are known genetic predispositions for the development of AS, including the HLA–B27 antigen (Wendling et al. 2018; Keat, 2012). Individuals with AS are at a fifty percent risk of passing the disease onto their children and are more commonly found among European and North American Indigenous populations (Vosse et al. 2013; Waldron, 2008).

AS is characterized by the involvement of the synovial and cartilaginous joints, entheses, and the erosion and fusion of multiple joints (Roberts and Manchester, 2005). Involvement and symmetrical fusion of both sacroiliac joints are considered to be the hallmark of the disease (Roberts and Manchester, 2005). The synovial joints of the spine begin to fuse, followed by the vertebral bodies, beginning in the lumbar spine and moving superiorly with no "skip lesions", or normal vertebrae interspersed between those that are fused (Waldron, 2008). As the spine fuses, vertebral bodies remodel and lose their normal shape. In addition to the vertebral changes, there is marked ossification of the inter- and supraspinous ligaments, as well as the formation of vertebral syndesmophytes (Rogers and Waldron, 1995). As AS progresses, it causes the spine to fuse and is characterized by a 'bamboo spine' appearance, wherein the vertebral bodies become square and smooth, connected by the thin, vertically oriented syndesmophytes, giving the vertebral column a bamboo stalk

appearance (Rogers and Dieppe, 1990). Peripheral joints are additionally affected, with the hip, shoulder, knee, ankle, wrists, hands and feet being most common. The costovertebral joints may also be involved, where the ribs become fused to the vertebrae (Rogers and Waldron, 1995).

Immune Joint Disease: Diffuse Idiopathic Skeletal Hyperostosis (DISH)

Like AS, diffuse idiopathic skeletal hyperostosis (DISH) also affects the spine. However, it has specific bony changes elsewhere in the body that accompany the disease and distinguish it from AS (Rogers and Waldron, 1995). Statistically, men are affected slightly more than woman, and the average age of onset is typically fifty years or older. There is no known cause; however, clinically, DISH is often found in association with Type 2 diabetes and obesity (Roberts and Manchester, 2005; Waldron, 2008, Saffo et al. 2017; Khan et al. 2010; Cammisa and De Serio and Guglielmi, 1998). Physiologically, there is complete fusion of the spine, particularly in the thoracic region. The integrity of the vertebral body surfaces is maintained, as well as the joint spaces and apophyseal joints (Roberts and Manchester, 2005). Osteophytes are formed and produce a "dripping candlewax" appearance that is a hallmark of the disease (Resch, 2003). Cartilage also commonly ossifies, particularly around the cervical spine, and the ribs (Waldron, 2008). It is important to note that the fusion of four contiguous vertebrae is necessary for accurate diagnosis in an archaeological context (Roberts and Manchester, 2005).

Inflammatory Joint Disease: Septic Arthritis

Septic arthritis is often discussed in conjunction with tuberculosis, as it can be triggered by Mycobacterium tuberculosis; however, septic arthritis can be triggered by other pathogenic microorganisms such as Streptococcus or Staphylococcus, as well (García-Arias, Balsa and Mola, 2011). The bacteria causing non-specific joint infections can spread one of two ways, through the blood to the joint cavity or from adjacent skin or bone to the joint (e.g., secondary to osteomyelitis) (Roberts and Manchester, 2005). Septic arthritis typically affects one joint – commonly the knee or hip – but other joints can be involved (Roberts and Manchester, 2005; Aceves-Avila et al. 1998). In a "healthy" joint, the synovial fluid nourishes the joint. In the case of septic arthritis, due to intra-articular pressure the cartilage is restricted of blood and nutrients, ultimately resulting in cartilage degeneration (García-Arias, Balsa and Mola, 2011).

Septic arthritis that is not identified in conjunction with tuberculosis (non-specific) is characterized by erosion of the bone marginal to the articular surface and often less destructive to the surfaces of affected joints (Rogers and Waldron, 1995; Roberts and Manchester, 2005). On the other hand, septic arthritis found in conjunction with tuberculosis commonly erodes the joint surfaces and primarily affects children more than adults (Rogers and Waldron, 1995). In general, septic arthritis is infrequently identified in the archaeological record, and differentiation between non-specific septic arthritis and septic arthritis found in conjunction with tuberculosis is incredibly difficult in skeletal remains (Waldron, 2008).

Metabolic Joint Disease: Gouty Arthritis

Gouty arthritis is considered much less common than some of the joint diseases that have been briefly summarized above. Archaeologically, there are no more than a few definitive cases of the disease in antiquity (Elliot-Smith and Dawson, 1924; Rogers, 2000; Rothschild and Heathcote, 1995). In modern clinical populations, gouty arthritis has a prevalence between one and three percent (Rogers, 2000; Roberts and Manchester, 2005; Yoo et al. 2011). Gouty arthritis is characterized by a

high level of blood uric acid, or “hyperuricemia", which in turn is caused by reduced kidney function. This obstructed function results in an excess of uric acid production in the kidneys, which normally act to excrete uric acid (Heathcote, 1995; Waldron, 2008). Gouty arthritis appears to be a disease of lifestyle and is typically associated with excessive and chronic alcohol intake, a high protein and fatty diet, diabetes, and heart disease (Neogi, 2011). It is found twenty times more frequently in males than in females, and disease onset is typically initiated in individuals fifty years of age or older (Roberts and Manchester, 2005).

As the disease progresses, urate crystals form in the synovial fluid of joints, which ultimately leads to the inflammation and destruction of cartilage and subchondral bone (Messerli et al. 2011). The joints most commonly affected are those of the feet, hands, wrists, elbows, and knees with the first metatarsophalangeal joint being involved in ninety percent of all clinical cases (Neogi, 2011). Joints are affected asymmetrically, in contrast to RA, which is affected symmetrically. In addition to the morphological changes to the skeleton, urate crystals also form in tendons and ligaments (tissues associated with the joints) (Waldron, 2008). Accumulations of crystals, known as tophi, are also found in the fingertips and soles of the feet that appear as swollen, bulbous growths under the skin. (Roberts and Manchester, 2005; Messerli et al. 2011; Yoo et al. 2011).

DIAGNOSTIC CRITERIA FOR RA

The diagnostic criteria for RA in the paleopathological literature have evolved over time. Today the diagnosis of RA relies heavily on the presence of osteoporotic bone, subchondral bone thinning or porosity, resorptive (lytic) lesions caused by the presence of subchondral cysts, and the presence of osteophytes (Roberts and Manchester, 2005). RA is known to affect multiple joints simultaneously, beginning in the small joints of the hands and feet, before moving into the larger joints of the body (e.g., shoulder, knee, elbow, and hip joints) (Roberts and Manchester, 2005; Waldron, 2008). RA is also known to present symmetrically in skeletal remains, meaning that the left and right sides of the body should be affected equally (Aufderheide and Rodriguez-Martin, 1998). This section presents all diagnostic criteria employed in the past and present day to diagnose RA in a paleopathological context.

Clinically, RA passes through a succession of three stages, the first being simple synovitis and proliferation of the synovial membrane, followed by inflammatory lesions which result in necrosis of the synovium and a more intense inflammatory response, lastly, tendon rupture, and joint deformity (Auferheide and Rodriguez-Martin, 1998; Arnett et al. 1988; Bromley et al. 1984; Goldring et al. 2002). Despite its destructive potential, the progression of RA can be variable with some patients experiencing only mild oligoarticular illness of brief duration and minimal joint damage, and others having progressive polyarthritis with severe functional impairment and systemic manifestations (Caroll, 2016).

The diagnosis of RA in the clinical context of today relies heavily on patient history, physical examinations, and selected laboratory testing to identify characteristic features. An individual's medical history will focus heavily on joint pain, reported swelling, and the presence, location, and duration of morning stiffness (Schumacher, 1998). The longer symptoms persist, the more likely the diagnosis of RA becomes (Hochberg, 2009). A complete physical examination is utilized to assess for synovitis, including the presence and distribution of swollen or tender joints and limited joint motion (St. Clair et al. 2004). Additionally, repeated serologic analysis for anti-cyclic citrullinated peptide (anti-CCP) antibodies and rheumatoid factor (RF) are conducted (St. Clair et al. 2004). In a majority of patients, the presence of these blood markers is required

before a diagnosis of RA is established (Schumacher, 1998; Hochberg, 2009). Even in the modern clinical environment of today, diagnoses of RA are incredibly difficult. Since a clinical diagnosis of RA relies so heavily on serological analysis, it is understandable that diagnosing RA in skeletal remains, where these types of analyses are impossible, is complex and problematic.

Issues with Differential Diagnosis

One of the major issues surrounding paleopathological work lies in the fact that researchers are attempting to reconstruct the health conditions and life-pathways of individuals in past populations using inherently biased samples of skeletal remains (DeWitte and Stojanowski, 2015; Wood et al. 1992). This section will focus on the inherent difficulties that lie in attempting to differentially diagnose RA in an archaeological context, including the osteological paradox, the presence of non-specific lesions, issues with preservation, as well as gender, age, and social biases.

Osteological Paradox

In 1992, Wood et al. published "The Osteological Paradox: Problems of Inferring Prehistoric Health from Skeletal Samples". This revolutionary work challenged bioarchaeologists to consider the impact of heterogeneous frailty, selective mortality, and demographic nonstationarity in their work when making "health" inferences of past populations (DeWitte and Stojanowski, 2015; Wood et al. 1992). For the purposes of this article, I place emphasis on two of the three determinations of the Osteological Paradox. First, heterogeneity in frailty, which is the suggestion that individuals are unequal concerning their susceptibility to different disease and stressors and their risks of death (Wood et al. 1992). This becomes an important consideration when discussing the differences in disease development in males and females, with females being diagnosed with RA three times more than males. By this principle, the hidden heterogeneity of frailty would suggest that the higher chance of disease development in females will directly affect the rate of disease prevalence in the archaeological record. The heterogeneity of frailty must also be considered when discussing the age of disease onset. In females, the common disease onset lies between thirty and forty years of age, while males are typically diagnosed between forty five and fifty years of age. By this principle, the hidden heterogeneity of frailty would indicate that all individuals who develop RA in life would have lived long enough to first develop the disease, and secondly, lived long enough with the disease to exhibit the more significant lesions that would readily survive in a burial context.

The second determination of the Osteological Paradox can be applied when discussing the lack of RA diagnoses in the archaeological record is selective mortality. This is the suggestion that our data comes from samples of those who are already dead and are therefore biased representatives of the once-living populations (Wood et al. 1992). For example, the individuals bioarchaeologists observe in the archaeological record with RA are those who died at a stage of the disease that is visible on skeletal remains, therefore neglecting those who died in the early stages of the disease, and inherently erasing them from any research sample. By this standard, the examples of RA found in the archaeological record are inherently biased, and subsequently flawed. These two determinations put forth in the Osteological Paradox highlight some of the many reasons that data on the paleoepidemiology of RA in antiquity is incompletely understood.

Preservation

Taphonomic processes can mimic RA lesions or joint deformation, which contributes to the lack of differential diagnoses in the archaeological record (Waldron, 2008). Varying bone densities among men and women, the old and the young, and those with various

diseases directly influences the rates and severity in which taphonomic processes affect the individual's skeletal preservation. The burial conditions, including temperature, humidity, and soil context must be taken into account when observing skeletal degeneration in an archaeological context (Roberts and Manchester, 2005). Due to the chronic inflammatory processes that accompany RA, bones become more brittle and osteoporotic over a life course. This creates an environment wherein bones become more susceptible to different taphonomic process after death and burial. Even in cases where the bones are recovered correctly, their fragility before burial will only hasten the process of taphonomic destruction and negatively affect the preservation of the bones in a particular skeletal sample (Roberts and Manchester, 2005).

Biological Sex and Social Biases

Biological sex is critical in the discussion of RA prevalence in antiquity. As previously discussed, RA is three times more prevalent among females than males. Biologically, female bones are more gracile than their male counterparts (Waldron, 2008). This gracility is important to consider as this may account for the fact that before the 1800s, RA was rare in the clinical literature and non-existent in the archaeological record (Bašić et al. 2017). It can be argued that RA was just as prevalent in antiquity as it is today (i.e. approximately one percent of the general population), but the relative obscurity of the condition in the archaeological record is likely a result of the remains of those afflicted with the disease preserving less readily. This is due to gracility, bias in mortuary practice, and females being more likely to have metabolic issues that affect the density of bones.

Mortuary treatment as it relates to gender and social standing must also be considered when the preservation of skeletal remains is considered. Differences in mortuary treatments for males and females, children or adults, the rich or the poor, and across cultures are likely to impact the likelihood of preservation for skeletal remains (Agarwal et al. 2011). It is also important to consider the fact that those who suffered from RA in antiquity would have been without the modern medical treatments populations have today, which help to slow degeneration and make life more bearable for those burdened with the disease. This lack of medical intervention makes the likelihood of a high mortality rate convincing (Rogers, 2000). Those who would have survived long enough to show more severe forms of degeneration would have likely been more affluent or prestigious members of society, wherein compassionate care seems more likely (Bašić et al. 2017). The notion of social stratification makes well-preserved skeletons part of a select number of individuals who can be accurately diagnosed with RA in antiquity (Agarwal et al. 2011), effectively rendering the “others” in society less visible.

PALEOPATHOLOGICAL EVIDENCE/LITERATURE

To properly consider RA in antiquity, one must delve into the paleopathological literature. The origin of RA in antiquity is heavily debated, with some researchers suggesting that RA originated in the New World (Rothschild, 2001), and others arguing that RA was present in the Old World, long before Columbus ventured to the New World in 1492 (Ciranni et al. 2002). Although there are difficulties that come with trying to accurately diagnose RA in archaeological populations, there have been probable or likely diagnoses made using lesion characteristics to distinguish RA from the more typically diagnosed OA and AS (Bašić et al. 2017; Ciranni et al. 2002; Rothschild 2001; Kilgore, 1989). This section is a brief literature review of known and presumptive cases of RA in antiquity based on the aforementioned diagnostic criteria. This will include four specific occurrences of highly probable RA in antiquity

as well as the inclusion of date ranges and locations for several other presumptive cases of RA in antiquity (Table 1). These specific examples allow for a discussion of prevalence of RA in the archaeological record, which has historically been underrepresented in the paleopathological literature.

Name of Reported Case	Modern Location	Date	Age of Individual	Sex	Diagnostic Criteria
The "Braids Lady"	Tuscany, Italy	1550–1650 AD	50–55	Female	Symmetric lesions Marginal joint erosions Joint lesions of the hands Prox. Interphalangeal joint lesions Ulnar deviation Lesions of the feet Shoulder joint lesions Osteoporosis Marginal erosion
Kodiak Isle Woman	Alaska, USA	1200 AD	30–35	Female	Symmetrical Lesions Marginal Joint Erosion Possible case of JIA
Wood and Rothschild Late Woodlands Population	Ohio, USA	800–1100 AD	Various	2 females, 7 males	Symmetric lesions Proximal interphalangeal joint lesions Distal interphalangeal joint lesions Joint lesions of the carpus Joint metatarso-phalangeal lesions Detection of osteoporosis at x-ray examination Marginal erosion at x-ray examination
Kulubnarti's Woman	Sudan	700–1450 AD	50+	Female	Distal interphalangeal joint lesions Joint lesions of the carpus Marginal erosion at x-ray examination
Bennike's "Danish Man"	Denmark	400–800 AD	40–50	Male	Marginal joint erosions Distal interphalangeal joint lesions
Roman Period Man	Croatia	400–500 AD	30–50	Male	Complete ankylosis Highly osteoporotic Erosion of the joint surfaces Ankylosed hands and feet

					No new bone formation
Leden and Pearson — "Swedish Man A"	Sweden	2500–1900 BC	50+	Male	Symmetric lesions Joint lesions of the carpus Lesions of the elbows Lesions of the knees Shoulder joint lesions Detection of osteoporosis at x-ray examination Ankylosis
Leden and Pearson – "Swedish Man B"	Sweden	2500–1900 BC	30–50	Male	Lesions of the elbows Lesions of the feet Ankylosis
Rothschilds Tennessee population	Alabama, USA	3000–1000 BC	Various	6 females, 2 males	Symmetric lesions Joint lesions of the hand Proximal interphalangeal joint lesions Distal interphalangeal joint lesions Joint lesions of the carpus Lesions of the feet Joint metatarso-phalangeal lesions Joint atlanto-occiput lesions Detections of osteoporosis at x-ray examination Marginal erosion at x-ray examination

Table 1—*Examples of known and presumptive cases of RA in the paleopathological literature: (Modified from Ciranni et al. 2002)*

The "Braids Lady"

The first, and potentially the oldest, definitive case of RA is colloquially known as "The Braids Lady". This case involves the mummified remains of a sixteenth century female found in the church of San Francesco in Arezzo (Tuscany). The completeness of these mummified remains allowed for the preservation of hand and foot bones, which showcased many diagnostic criteria for RA (Ciranni and Fornaciari, 2000). The left hand revealed large erosions of the metacarpophalangeal joints of both the third and fourth fingers, metacarpophalangeal subluxation of both the third and fourth fingers and lateral deviation of all the fingers. The carpal bones showed marginal erosions, and the bases of the proximal phalanges were slightly flared (Ciranni and Fornaciari, 2000). The toes showed partially overlapped fibular deflection. Additionally, the body showed no involvement

of the sacroiliac articulation (Ciranni and Fornaciari, 2000).

This particular work by Rosalba Ciranni and Gino Fornaciari (2000) utilized imaging techniques such as normal x-ray, x-ray by mammography, total body CT, and high-resolution CT. Microscopic examination and stereomicroscopy were also used to conclude that the "Braids Lady" was affected by RA. Many of the aforementioned diagnostic criteria supported a differential diagnosis of RA. The death of this individual occurred at the end of the sixteenth century, 200 years before the first clinical diagnosis by Landré Beauvais in the early 1800s (Ciranni and Fornaciari, 2000).

In addition to this research, Fontecchio and colleagues reconsidered the "Braids Lady" in 2012. Although, the macro and microscopic evaluation of the "Braids Lady" showcased numerous diagnostic criteria for RA, some researchers have since proposed AS as a more likely diagnosis. RA and AS are human leukocyte antigen (HLA)-linked autoimmune rheumatic diseases (ARDs). Their manifestations are associated with different susceptibility genes: specifically, HLA–DRB1 alleles for RA and HLA-B27 for AS. Genotype testing was done on DNA extracted and amplified from the mummified remains of the "Braids Lady", and this genomic testing was able to completely exclude the HLA–B27 allele, and consequently the risk of this individual developing AS (Fontecchio et al. 2012). This investigation further confirms that RA existed, at least in Europe, 200 years before its first clinical description.

Kodiak Isle Woman

This example of a thirty to thirty five-year-old female from Kodiak Island, Alaska and dated to 1200 A.D. exhibits skeletal lesions that are strongly suggestive of RA. The skeletal lesions associated with the joints included porosity and destruction of joint surfaces, periarticular cystic erosion, and hypertrophic bone formation (Ortner and Uthermole, 1981). The most severe manifestations occur in the knee, ankle, elbow, hand and foot bones. However, there is minimal involvement of the spine. Interestingly, this case is postulated to be that of "juvenile rheumatoid arthritis" (JRA), often referred to clinically today as juvenile idiopathic arthritis (JIA) (Ortner and Uthermole, 1981). It is important to note that there is evidence of secondary OA found in some joints, notably the right shoulder and left knee of this individual.

This example from Kodiak Island provides additional support to the likelihood that rheumatoid arthritis has considerable antiquity. JIA is argued to be the most probable diagnosis of the skeletal lesions found in the skeletal remains (Ortner and Uthermole, 1981). A childhood age of onset would provide adequate time for the well-developed skeletal pathology seen in this case. However, the overlapping skeletal manifestations of secondary OA make a diagnosis of RA probable rather than certain (Ortner and Uthermole, 1981). Nonetheless, the Kodiak Isle Woman provides an important piece in the understanding of RA in the paleopathological literature.

Kulubnarti's Woman

The second case is that of a possible case of RA in Sudanese Nubia. This research by Kilgore (1989) revolves around a case of erosive arthritis reported in a skeleton from Kulubnarti, Republic of Sudan (c. 100–1450 A.D.). This particular burial was exhumed in 1979 and included the skeleton of a female with an age of death estimated at fifty years or older (Kilgore, 1989). It is important to mention that in addition to suspected RA, this individual also exhibits moderate to severe osteoarthritis, specifically at the shoulders, elbows, hips, and knees. Erosion is present primarily in the metacarpophalangeal joints of the wrists (Kilgore, 1989). All the metacarpophalangeal joints of both hands show arthritis involvement and lesions were present on both the distal metacarpal and proximal

phalangeal articular surfaces. Additional radiographs revealed the presence of marked osteoporosis and erosions of the underlying trabecular bone of the second and third metacarpals, marginal to the joint surfaces on both the right and left hands (Kilgore, 1989). The involvement of the carpals also manifested as pitting and lytic lesions with some evidence of proliferative change. Erosive lesions were also noted bilaterally at the temporomandibular joint and on the trochlear surface of the right distal humerus (Kilgore, 1989). Both mandibular condyles exhibited complete destruction of the posterior half of the articular surface.

This case of suspected RA was suggested based on the involvement of the skeletal elements most frequently associated with RA, particularly the symmetrical involvement of the hands and feet, the lytic lesions on the articular surfaces of the affected joints, the presence of a thin fragile cortex and loss of subchondral bone, radiographic evidence of bone porosity, and ankylosis of two or more elements (Kilgore, 1989). The mixed pattern of proliferative and erosive joints change in this Nubian skeleton is interesting. While this analysis in no-way provides a conclusive diagnosis of RA, the pattern of involvement indicates RA as a possible diagnosis, especially given the involvement of the hands and wrists.

Roman Period Man

The final presumptive case of RA is that of an adult male skeleton in a Roman period burial, located in modern Croatia and dated to 400–500 AD. This individual was found to have one of the most severe presumptive cases of RA known in the medical or paleopathological literature (Bašić et al. 2017). Moreover, the remains were found in an upper-class burial chamber, allowing for the excellent preservation. The age at death was estimated at 30–50 years. Most of the bones had ankylosed, but those which had not fused showed complete erosion of the joint surfaces. RA was definitively diagnosed based on the erosion of the odontoid process, mandibular condyles, distal humerus, proximal and distal ulna, as well as the highly ankylosed hand and foot bones (Bašić et al. 2017). There were notable ankyloses of the vertebrae and sacroiliac joint, which could point towards AS, but the lack of "typical" vertebral ankylosis, lack of typical "bamboo spine" appearance and new bone formation ultimately led to its exclusion (Bašić et al. 2017). This specific case is an example of a complete skeleton, excellently preserved and sheds light on the possible antiquity of RA. The severity of disease in this case further highlights the extensive care that would have been necessary for this individual to survive and offers evidence of differential care depending on social status, as mentioned previously.

CONCLUSION

Analysis of the Fort York National Historic Site reveals how the tourist site operates within the logics of settler colonialism. It demonstrates how the settler state continues to normalize the dehumanization, devaluation, and assimilation of Indigenous peoples, nations, cultures, and identities by naturalizing the conceptualization of Canada and Canadians as White and British spaces and beings. Furthermore, multiple uninterrupted strands of settler colonialism intersect to form a cohesive but variegated *colonial continuum,* or the tangible inertia of settler colonialism that self-perpetuates the logics of settler colonialism upon Turtle Island. Within the context of the colonial continuum, queer Indigenous theories provide the framework through which all colonized peoples could collectively recognize, deconstruct, challenge, and replace the totalizing logics of settler colonialism.

The presented analysis is, however, limited by the lack of data intensity and variety. For instance, further research should engage with the tourists at Fort York to understand how different individuals–such as British-Canadians, French-Canadians, Indigenous

peoples, immigrants, and foreigners–are actually influenced to produce their own interpretations of the site's materials. This work should also investigate the system of bureaucratic governance using methods such as *institional ethnography* to fully comprehend how the state controls the Fort York National Historic Site's materials, representations, and history. Moreover, further research should compare Fort York with diverse tourist sites around Turtle Island to find their commonalities and differences. Future inquiry could also investigate the ways in which online virtual spaces extend the dynamics of settler colonialism, empower Indigenous peoples to produce and distribute genuine self-representations, and allow the development of a new collective consciousness that is informed by the queer Indigenous framework. Lastly, further research should engage with the Indigenous communities, such as the members of the Mississaugas of the New Credit First Nation, to develop the right framework through which to study and critique the mechanisms of settler colonialism. The research should similarly explore the ways in which other non-European ontologies, epistemologies, and pedagogies could aid in the reconstruction of our collective futures.

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PLAIN LANGUAGE SUMMARY

A Multi-Method Approach to Re-Associating Fragmented and Commingled Human Remains: Plain Language Thesis Summary[1,2]

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ABSTRACT
This article is a plain language summary of a Master's thesis, completed in the Department of Archaeology and Anthropology at the University of Saskatchewan in 2020, that aimed to re-associate fragmented and commingled human remains from an Early Neolithic, about 7560–6660 years before present (HPD cal. BP; Weber et al., 2021; Bronk Ramsey et al. 2021), cemetery in Siberia, Russia. This thesis addressed the inability of existing osteological sorting methods to identify the remains of individuals from a collection that was largely broken and completely mixed. By developing a new multi-method approach, this project was able to identify the remains of seven people through the re-association process, and re-associate five of them. This was fairly close to the minimum number of nine individuals that were confirmed in this collection by counting non-repeating bones. This research has implications for the understanding of the culture-history in this area, the applicability of re-association methods to fragmented and commingled human remains, and efforts of reconciliation and repatriation.

Keywords: bioarchaeology, re-association, osteology, advancing method, Early Neolithic, Siberia

It is not uncommon for ancient (and often unmarked) cemeteries to be discovered during the development of land or through land loss due to climate change. Unfortunately, this usually results in the destruction of such cemeteries and the human remains within them.

[1] This research was conducted in the Department of Archaeology and Anthropology at the University of Saskatchewan in 2018–2020 under the supervision of Dr. Angela Lieverse (University of Saskatchewan) and Dr. Hugh McKenzie (MacEwan University), with input from committee members Dr. Terence Clark (University of Saskatchewan) and Dr. Ernest Walker (University of Saskatchewan), as well as external examiner Dr. Leslie Herrington (University of Alberta). Further thanks to the Baikal Archaeology Project (directed by Dr. Andrzej Weber) for their support and including me in their project, especially to Vladimir I. Bazaliiskii (lead archaeologist for the MNS site). Their efforts throughout this process were invaluable and greatly appreciated. Ethics approval was obtained by the research ethics boards of both the University of Saskatchewan [BIO–1881], and the University of Alberta [00089535] as a part of the Baikal Archaeology Project. Financial support as provided by the Social Sciences and Humanities Research Council, The Norther Scientific Training Program (Polar Knowledge Canada), and the University of Saskatchewan departments of Archaeology and Anthropology, and History.

[2] The MA thesis summarized here can be found via the University of Saskatchewan Research Archive Harvest (https://harvest.usask.ca/handle/10388/13041). Part of this thesis has been previously published as a research article in Journal of Archaeological Science: Reports (Bourgeois et al., 2021).

This summary details my thesis that aimed to re-associate a collection of fragmented (broken) and commingled (mixed) human remains back into identifiable individuals (Bourgeois 2020). A multi-method approach was developed using the Early Neolithic Kitoi cemetery site of Moty-Novaia Shamanka (MNS) from the Lake Baikal region of Siberia, Russia, which dates to about 6800 years ago (Bazaliiski et al. 2016). MNS is located between two other large cemeteries of this time period, Lokomotiv and Shamanka II, but it is unique in being the only Early Neolithic Kitoi site to have been found on a tributary river instead of on the coast of Lake Baikal or along the Angara River (the major drainage river from Lake Baikal). Preliminary dates from MNS also placed this cemetery at the end of the Early Neolithic Period, which makes its human remains some of the last uncovered from a visible cemetery before the onset of the Middle Neolithic Period (Bazaliiski et al. 2016). This is important because during the Middle Neolithic Period, it appears as though people stopped burying the dead in formal or visible cemeteries marking a distinct change in burial practices in this region. Over 1000 years later, this practice was started up again (Weber et al. 2021; Weber and Bettinger 2010; Weber et al. 2016).

Unfortunately, in the 1990s MNS, originally located atop a hill, was bulldozed for flood management. This resulted in the commingling and fragmentation of the human remains. Thus far, there has been no analysis on the bones within the MNS collection other than an initial population size estimate of 19 by Dr. Denis Pezhemsky of Lomonosov State University in Moscow, Russia (Bazaliiski et al. 2016). As a part of the Baikal Archaeology Project, this thesis (Bourgeois 2020) addressed this gap in analysis by creating and applying a multi-method approach to re-associate the fragmented and commingled human remains found at MNS. Although many bioarchaeologists have been able to successfully re-associate commingled full human bones back into individual skeletons, the high level of fragmentation at MNS necessitated a new approach to achieve the same success. Using aspects of other methods (see thesis for details), I created a four-stage approach suited to the MNS collection and the goals of this project. This approach and the following results are detailed in Bourgeois (2020) and Bourgeois and colleagues (2021).

The entire MNS collection included 1,245 human bone fragments whose sizes ranged greatly. For 71% of these fragments, I was able to identify which bone they were from and was able to refit just over 16%, much like puzzle pieces. From this collection, I partially reassociated the remains of five individuals and identified eight other groupings of fragments that were either paired or related bones from the same person. Together, these groupings represented at least seven people. This number, however, represented the amount of people identified by grouping of multiple bones. By counting non-repeating single bones, I found that at least nine people were present in the MNS collection. Within the groupings identified in this thesis there was one juvenile individual, who was approximately fourteen to eighteen years old when they died, while the rest were the remains of adults (over the age of twenty years at time of death). Within the MNS collection there were signs of osteoarthritis, chronic ear infection, and active lifestyle.

This thesis challenged the idea that fragmented and commingled human remains did not warrant the same level of analysis as complete remains and that they can typically only be looked at as separate pieces. The value of this research lies in the information that it was able to gain from the MNS collection, the potential contribution to the goals of the Baikal Archaeology Project, and the development of an approach that can be applied to a wide variety of contexts. To better study life-history, it is important to be able to tell which bones belong to which person. These values,

however, go beyond scientific ability and can contribute to efforts of reconciliation and community-based research.

Re-associating fragmented and commingled human remains into individuals is important in contexts where cemeteries (most frequently unmarked cemeteries) are destroyed during the economic development of land or environmental changes. The ability of this multi-method approach to re-associate the remains of people whose identities have been otherwise lost would, in many cases (such as in forensic and historical contexts), be extremely meaningful to families and descendant communities. This is especially true in countries like Canada where urban sprawl and resource extraction result in rapid land development. Recently, in cases where Indigenous heritage is involved, anthropological practice is often reliant on the relationship between anthropologists and the community under the umbrella of community-based research. In addition to calls of Indigenous communities, widespread stimuli for community-based research are the Truth and Reconciliation Commission of Canada's (TRC) Calls to Action (2015) and the United Nations Declaration of the Rights of Indigenous Peoples (UNDRIP) (United Nations 2007).

The goal of this thesis is relevant to the TRC Calls to Action and UNDRIP by providing a methodological basis that could contribute to matters regarding Indigenous ancestral remains from disturbed contexts. For example, the TRC Call to Action number 74 includes urging the federal government to "… respond to families' wishes for appropriate commemoration ceremonies and markers, and reburial in home communities where requested," in the case of the deceased children from residential schools (2015, 8). This is also stated more generally in Article 12 of UNDRIP as, "Indigenous peoples… have the right to the repatriation of their human remains," (2007, 12). Should a cemetery have eroded or been destroyed, resulting in the disturbance of the burials, the ability to re-associate the remains of individuals would not only make reburial or repatriation processes easier but would also be extremely meaningful to the families and communities. To address goals that are more personal than scientific, new protocols must be developed for collaboration and study beyond the basic analysis of fragmented remains as separate pieces. This thesis aimed to contribute to advancing how bioarchaeologists consider fragmented and commingled human remains and develop a practical approach that can be applied in a wide variety of circumstances.

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PLAIN LANGUAGE SUMMARY

Examining Biogenic and Diagenetic Lead Exposure with Synchrotron Radiation X-ray Fluorescence Imaging of Experimentally Altered Bone: Plain Language Thesis Summary[1,2]

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ABSTRACT
This plain language summary summarizes research recently undertaken as part of an MA thesis (September 2020) at the Department of Archaeology and Anthropology (University of Saskatchewan). This thesis set out to map patterns of lifetime lead exposure versus post-mortem lead contamination in bone samples from both modern Saskatchewan and archaeological individuals. In addition to measuring the lead levels of each sample, this thesis used a synchrotron radiation-based element mapping technique to map the distribution of lead within each bone sample on a microscopic scale. When lead is taken up into bone during an individual's life, it is incorporated into actively forming bone, leading to spatial patterns that reflect individual life histories of lead exposure. When bones are contaminated by lead in the burial environment, the lead is typically found at the outer surfaces and large pores of bone. Therefore, this element mapping technique is useful in helping archaeologists distinguish between lifetime and post-mortem lead exposure and can provide important information about individual histories of lead exposure for archaeological and modern populations alike.

Keywords: bioarchaeology; Saskatchewan; lead; diagenesis; bone; synchrotron radiation

An estimated one in three children experience some from lead (Pb) poisoning annually around the world (UNICEF & Pure Earth, 2020), with lead causing an estimated 1.06 million deaths in 2017 (IHME, 2017). Though it is an extremely harmful and toxic substance, lead has nonetheless been widely used by humans for thousands of years in everything

[1] This MA research was financially supported the Social Sciences and Humanities Research Council (SSHRC). Multiple individuals, organizations, and labs made the research summarized in this plain writing summary possible. Thank you to Drs. David Cooper, Tamara Varney, Treena Swanston, Ian Coulthard, Rimantas Jankauskas, Vaughan Grimes, and Ms. Jessica Munkittrick for their exceptional support, guidance, and collaboration. Thank you to Body Bequeathal Program and donors for permitting access to modern bone samples. The summarized research used resources of the Advanced Photon Source, a U.S. Department of Energy (DOE) Office of Science User Facility operated for the DOE Office of Science by Argonne National Laboratory under Contract No. DE-AC02-06CH11357.
[2] The thesis summarized here is available online through Harvest, the University of Saskatchewan Research Archive (https://harvest.usask.ca/handle/10388/13074). Chapters from this thesis have been previously published as review articles in Synchrotron Radiation News (Simpson et al., 2019) and Archaeological and Anthropological Sciences (Simpson et al., 2021), and as a research article in Science of the Total Environment (Simpson et al., 2021).

from paint and cosmetics to plumbing and food containers. Research into the lead burden of modern and past populations alike is instrumental to the understanding of morbidity and mortality today and in the past. The interdisciplinary thesis (Simpson, 2020) summarized here set out to investigate patterns of lifetime lead exposure and post-mortem lead contamination in bone samples from modern Saskatchewan individuals and archaeological individuals from Antigua and Lithuania.

Bones can reflect years to decades worth of lead exposure, as lead gradually accumulates in bone until natural bone remodeling processes recycle stored lead back into the bloodstream. Up to 97% of the human body's consumption of lead becomes stored in the skeleton (Barry, 1975). Because of lead's natural affinity for bone and bone's ability to survive in the archaeological record, the field of bioarchaeology (the study of past humans based on their skeletal remains) is uniquely suited to examine lead exposure in the past. Lead concentrations and isotopic ratios accumulate in an individual's bones for years to decades during their lifetime, and represent a large window into lead exposure in the past. There are several techniques at the bioarchaeologist's disposal that can measure the levels and isotopes of lead and other trace elements in bones and teeth, but these techniques often encounter limitations. First, it is difficult to account for the effects of diagenesis—the physical, chemical, and bacterial changes that bones and teeth undergo in the burial environment, including chemical contamination of bones. The bioarchaeologist must consider how much of the lead within a bone or tooth is actually from a person's exposure to lead during their lifetime, and how much lead has seeped into the bone from the burial environment. Second, when dealing with lead levels alone, these techniques often cannot give us information about the timeline of lead exposure. For instance, was someone exposed to lead consistently throughout their lifetime, or did it occur in a few acute events? Did the exposure occur earlier on in life or right before death?

Element mapping techniques are one potential means of addressing both limitations. Synchrotron radiation X-ray fluorescence imaging (SR-XFI) is a technique that can be used to map the distribution and intensity of trace elements (including lead) in bone on a microscopic scale. Because bone constantly remodels, it contains a mosaic of both mature and newly formed microscopic structures. By examining which microscopic structures in bone contain lead, researchers can gain insights into an individual's lifetime patterns of lead exposure. This mapping technique may also be used to identify areas of diagenetic contamination from lifetime lead exposure in bone (Swanston et al., 2012), though up to this point, controlled, experimental research investigating this was lacking.

My thesis used both conventional techniques and SR-XFI to answer several research questions including: Are there differences in the microscopic spatial distribution of lead for lifetime (biogenic) versus diagenetic exposure? What can we learn about lifetime lead exposure patterns from modern individuals from Saskatchewan? To answer these questions, I obtained donor bone samples from human cadavers through collaboration with the University of Saskatchewan's Body Bequeathal Program. These bones had never been buried in the ground and exposed to potential sources of diagenetic lead, and therefore reflected an individual's long-term biogenic exposure to lead during life. I kept one half of each sample unaltered, reflecting biogenic lead exposure, and simulated diagenetic contamination in the other half of each sample. I hypothesized that the respective biogenic and diagenetic lead exposure patterns observed in the modern bone samples would match the patterns observed previously in archaeological samples (Swanston et al., 2012, 2018; Rasmussen, 2019). Lead pollution in the

Canadian context peaked decades ago when lead use was far more commonplace in mainly daily life activities like leaded gasoline, plumbing, and paint. As the modern Saskatchewan individuals in my sample were older adults, they were alive during this peak era (pre-1990s) and their bones likely contained some structures that formed during this period. I hypothesized that older, more mature bone microstructures would be more enriched in lead than newly formed microstructures.

Bone samples from two archaeological individuals were also analyzed. One sample was from an individual interred in a colonial Antigua British Royal Navy hospital cemetery, where it is known that the Navy personnel experienced high levels of lead poisoning (Giffin et al., 2017). The other sample was from an individual interred in a nineteenth to twentieth-century Lithuanian mausoleum, where diagenetic lead contamination of the remains is suspected to have taken place.

The lead levels of each bone sample were measured with a technique called Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). Archaeological bone samples had lead levels roughly twenty-nine to fifty-nine times higher than the modern humans from Saskatchewan but these results provided little in the way of helping to differentiate between biogenic and diagenetic lead exposure. SR-XFI maps of lead in bone scanned at the Advanced Photon Source synchrotron showed clear differences for biogenic and diagenetic lead exposure in both modern and archaeological bone. Diagenetic lead was primarily found along the outer edge of the bone sample and in some large pores or canals, while biogenic lead was found throughout the bone sample, in microstructures that were actively forming at the time of exposure. This shows that element mapping techniques can be used to help distinguish lifetime from diagenetic lead exposure in archaeological bone, which can aid bioarchaeologists in interpreting the skeletal lead burden in past populations.

The SR-XFI element maps of lead in bone also echoed this finding of comparatively lower lead exposure among the modern Saskatchewanian individuals compared to the archaeological individuals. Within the modern bone samples, lead was either found within mature bone microstructures as opposed to newly formed bone structures or found fairly consistently across the bone sample. This suggests higher lead exposure in the past or fairly steady low level lead exposure, respectively. While the sample size of this study is too small to draw conclusions about the larger Saskatchewan population, these findings are promising from a public health perspective. This research was both the first ever skeletal lead study of a modern human population from Saskatchewan and the first application of SR-XFI to examine lead exposure in a modern Canadian population. Future research can continue to use this technique, or techniques like it, to help differentiate between biogenic and diagenetic lead in archaeological bone and explore lifetime patterns of lead exposure for modern and archaeological populations alike.

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