Journal of Evolution and Health

Volume 1 | Issue 1 Article 7

4-20-2015

Decolonizing the Diet: synthesizing Native-American history, immunology, and nutritional science.

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Recommended Citation

Mailer, Gideon and Hale, Nicola (2015) "Decolonizing the Diet: synthesizing Native-American history, immunology, and nutritional science.," *Journal of Evolution and Health*: Vol. 1: Iss. 1, Article 7.
https://doi.org/10.15310/2334-3591.1014

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Keywords

Native American, history, teaching, hunter-gatherer, fat-soluble, immunity

Cover Page Footnote

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Introduction

Educational theorists have recently begun to call for more immersion of trainee scientists and medical practitioners in the humanities, particular through the study of history as part of their educational program. In a widely circulated analysis that first appeared in an August 2014 *Inside Higher Education* supplement, Elizabeth H. Simmons suggests that "to fully prepare for careers in science, it is essential that students grasp how the impetus for scientific work arises from the world in which the scientist lives, often responds to problems the scientist has personally encountered, and ultimately impacts that society and those problems in its turn." Every nascent scientist, according to Simmons, "should read, think, and write about how science and society have impacted one another across cultural and temporal context" because "ethical concepts absorbed" in such study will help them "hew more closely to the scientific ideal of seeking the truth." [1] Since C.P. Snow's famous 1959 Rede Lecture lamented the gap between the "Two Cultures" of the sciences and humanities, academic initiatives such as Stanford University's Science, Society, and Technology program have been founded to assert the wider societal impact of the natural sciences. [2] Yet far fewer programs and courses have been designed to show how scientific endeavors might benefit from the study of the humanities, particularly history. The newest version of the Medical School Admissions Test (MCAT 2015) now encompasses questions on the psychological, social, and biological determinants of behavior to ensure that admitted medical students are "prepared to study the sociocultural and behavioral aspects of health." But as Simmons notes, while "pre-medical and engineering students are being required to learn about issues linking science and culture, most students in science fields are still not pushed to learn about the human context of their major disciplines."[3]

As Dean of the College of Liberal Arts at Michigan State University, Simmons may well know that her state's own educational system incorporates a project with important implications for the nexus between the humanities and the sciences. The *Decolonizing the Diet* project at Northern Michigan University has begun to show how the study of early American history - particularly Native American history - can inform public policy and healthcare paradigms, while also impacting the agenda of cutting edge research in the biological, nutritional, and ecological sciences. In the project, students and local community members have learned how the move away from their ancestral nutritional principles has been detrimental to the health of Native Americans and the wider ecology of the Great Lakes region of North America. Aware of disproportionate instances of diabetes, heart-disease, depression, fertility problems, and chronic inflammatory conditions, project members have studied and then simulated pre-European contact Native American diets, using historical and anthropological methods. They have even begun to produce medically-relevant data on improvements in health and well-being after their nutritional intervention. A similar project, the American Indian Health and Diet Project (AIHDP), has been inspired by the work of Devon Abbott Mihesuah, a Choctaw historian and writer. Through her teaching and writing, Mihesuah has used the study of history, anthropology, and literature to inform contemporary health and nutritional practices - coming a little closer to the diets that many Native American communities consumed prior to European contact. [4]

The Decolonizing the Diet project is currently restricted to the Great Lakes region, where the authors of this article reside and work. As a professor of history and a researcher in biological science, we aim to show how a model course in the University of Minnesota system might offer a new pedagogical paradigm for the study of ancestral health principles. The course builds on the aims of the existing projects detailed above. But it also synthesizes their methods and objectives with the latest peer-reviewed research in evolutionary health and nutrition, bringing about new insights and research paradigms relating to the link between nutrition, metabolic health, and immunity to infectious disease. Some recently founded nutritional programs have aimed to educate public-sector workers in order to prevent a mismatch between their optimal nutrition, as understood from within an evolutionary health framework, and their current eating habits. [5] This article demonstrates how the same public health agenda might be explored from within a large public research university system, led by a joint effort between professors in the humanities and teachers and researchers in the biological sciences.

The 1862 Morrill Land-Grant Acts defined the American public research university's ongoing mission "to promote the liberal and practical education of the industrial classes in the several pursuits and professions in life." [6] From the 1950s scientists used the land-grant system to ally their scientific and nutritional research with new policies that came to be promoted by the federal government. Within the University of Minnesota system, for example, Ancel Keys famously sought a new research agenda in order to question the health benefits of fats from animals, fish, and dairy. Contrary to those who highlighted the problematic medical implications of foods that were readily converted into glucose, as well as the potential inflammatory effects of polyunsaturated fats, Keys and others used their land-grant mandate to promote research that supported the government of the day in its stated desire to increase agricultural output in soy, wheat, corn, and seed oils. [7] Scholars, scientists, public policy analysts, and journalists have begun to suggest that the resulting federally recommended food-pyramid has worsened certain aspects of American public health, particularly through the associated growth of metabolic disorders such as diabetes, and even in the prevalence of certain forms of heart disease (though the exact effects of the Diet Heart hypothesis on public health are still currently being debated by scientists). [8]

This article examines the present state of historical research in early American studies in order to assess whether similarly problematic associations and health markers appeared among Native American communities many decades – and even centuries – before the development of the problematic modern American food pyramid. It considers historical evidence that correlates a decline in Native American health and fertility with ruptures to indigenous food systems following European colonization. It suggests novel and interdisciplinary ways in which advanced undergraduate or graduate level students might examine the correlation between breached indigenous nutritional practices and a decline in Native American health. These learning objectives bring together students of history and natural science in one classroom and entail new ways of synthesizing hitherto separate scholarly enterprises. In light of the most cutting-edge scientific literature on nutrition, metabolic syndrome, and immunology, they require a new consideration of the historical association between Native American health and indigenous food systems.

DOI: 10.15310/2334-3591.1014

In the centuries after European contact, many Native American communities were forced to move away from diets that had been comparatively high in animal proteins, animal fats, and fat-soluble vitamins, and which also often incorporated important starch and plant sources such as wild rice, tubers, chenopods, beans, seeds, maize, squash, berries, and leafy vegetables. Notwithstanding regional variations, the pre-contact Native American diet was thus relatively nutrient dense; incorporating varied macro-nutrients and micro-nutrients through hunting and gathering practices and indigenous forms of horticulture that were subsequently disrupted. [9] Thanks to the deleterious and often deliberate effects of colonization, which can only be understood through careful historical study and analysis, deeply-rooted food systems were ruptured. From as early as the sixteenth century, new post-contact circumstances forced many Native Americans to adopt diets that favored imported European grain cultivars, to maintain greater calorific reliance on New World maize species, and to reduce their consumption of traditionally hunted animals and fish and cultivated plant sources. [10]

It is important to avoid any crude interpretative framework that might “exoticize” pre-contact Native American communities as having avoided any form of managed agriculture, crop monoculture, or organized land husbandry. [11] Recent historical research, after all, has often employed the metaphor of “gardening” to question the notion that pre-contact Native Americans relied solely on hunting and gathering methods for sustenance. [12] It is also imperative to avoid eschewing the distinct variations between indigenous food cultures both during and after the period of European contact: veering between the cultivation of maize, tubers, and starchy seeds alongside hunted animals in the Southwest to a relatively homogenous reliance on fats gathered from hunted meats and fish in the sub-Artic; as well as many gradations in between, such as the cultivation of wild rice alongside more traditional hunting and gathering patterns in the Great Lakes region.

Yet this article - and the proposed educational course it defines - attempts at least some degree of generalization in discussing the differences between indigenous food systems and those that were introduced after European contact; and in discussing how students and researchers might view those distinctions in light of the modern scientific literature on metabolic and nutritional health. In questioning crude definitions of pre-contact Native Americans as noble hunter-gatherers – including those that are sometimes used by advocates of ancestral health and Paleolithic nutritional principles – it is important to avoid going to the other extreme by de-emphasizing the relative environmental and dietary importance of hunting and gathering systems in many different parts of North America immediately prior to, and even after, European contact. While indigenous agricultural activities were present throughout the American continent, hunter-gathering practices were also continued to a far greater extent than in post-Paleolithic Europe and the Middle East – potentially heralding important ecological and nutritional differences between the two regional populations over the following centuries. Those differences may inform our understanding of the role of nutrition in evolutionary health, particularly by comparing the pre and post-contact history of Native Americans.

Questioning the ‘Biological Exchange’ thesis in the history of Native American health and nutrition

(i) Zoonotic disease and European colonization.

Recent scientific research has suggested that we may be able to locate specific loci in the DNA of some Native Americans that affect their insulin sensitivity. Individuals with certain genetic variants at these loci would be more likely to develop diseases such as diabetes following a move towards a higher carbohydrate diet, as has often taken place from the period of European colonization to the present day. Examining the Pima Indian community of Arizona as a case study, researchers have found several loci with genetic variants that confer susceptibility to diabetes. For example a genome wide association study by Hanson et al identified polymorphisms in the DNER locus that are associated with increased risk of diabetes in Pima Indians. [13] The Decolonizing the Diet project, and other similar endeavors, thus start with the hypothesis that a return to pre-European contact diets will improve the health of Native American communities, reducing hitherto disproportionately high instances of diabetes, as well as heart disease and other conditions associated with metabolic syndrome. [14]

Native American populations, indeed, have often featured as case studies among those scholars who attempt to define a "thrifty gene hypothesis" to explain why some people are prone to diabetes and/or obesity. A "thrifty" genotype, it is suggested, may have been evolutionarily successful for individuals descended from hunter-gatherer populations. Its occurrence would have allowed those populations, particularly child-bearing women, to gain fat more easily during times of abundance (particularly of starch during summer). Those with more fat may have better survived times of food scarcity, and thus passed on their genes. But during times of nutritional abundance, they would be more likely to develop metabolic syndromes such as obesity and diabetes, according to the hypothesis. In post-hunter-gathering populations, a similar paradigm has been hypothesized by Sellayah and others, who have suggested that the thrifty genotype may have appeared among those who had "undergone positive selection for genes that favored energy storage as a consequence of the cyclical episodes of famine and surplus after the advent of farming 10 000 years ago." [15]

In any class, project, or research agenda, however, it is important to avoid necessarily deterministic conclusions when assessing the correlation between recent genetic studies and epidemiological data from Native American communities (whether historic or contemporary). Firstly, more research is still needed in order to assess whether particular genetic variants for insulin sensitivity are present exclusively or at a higher frequency in Native American populations compared to other populations, or whether they are equally prevalent in other ethnic communities who were not included in present studies. Despite retaining the same genetic variants, those other communities might not suffer from diabetes to the extent of Native Americans. Secondly, moreover, greater genetic susceptibility to insulin insensitivity or any other medical condition need not pre-determine the actual onset of diabetes or other disorders, as is evidenced by the relatively positive health markers among Pima and other Native American communities prior to increasing their consumption of processed and high sugar foods. [16]

The notion that Native Americans have suffered from particular genetic predispositions might also prove problematic in encouraging students, scholars, and researchers to adopt an overly deterministic account of health outcomes, eschewing the disrupting role of human interventions against ancestral food-ways – either in exacerbating Native American susceptibility to metabolic syndromes and/or infectious disease or even as a primary factor in their increasing mortality and declining fertility after European contact.

Examining - and problematizing - the link between modern disease susceptibility and genetic predispositions should prepare students for a related scholarly endeavor: assessing the potential tensions and pitfalls associated with the concept of a "biological exchange" of infectious diseases at the period of contact between Europeans and Native Americans (roughly from the late-1500s to the late-1700s). Here too a focus on abstract biological forces risks overlooking the role of human interventions in determining the inevitability (or otherwise) of demographic decline in the face of disease. Historians, notably and most famously Albert Crosby, once defined the decimation in number and health of post-contact Native American communities according to a metaphor of biological exchange. Here, we have been told, Native Americans in a "virgin land" were unable to cope with the pathogens inadvertently introduced by Europeans after the arrival of Columbus. [17] These great killer diseases, introduced by germs, spores, and parasites from European and African sources, included smallpox, measles, influenza, bubonic plague, diphtheria, typhus, cholera, scarlet fever, trachoma, whopping cough, chicken pox, and tropical malaria. [18] Yet as the most advanced historical scholarship now suggests, human interventions were necessary to bring about the marked decline in Native American

DOI: 10.15310/2334-3591.1014

health and fertility, and the increase in mortality, in the centuries after the arrival of Columbus in the western hemisphere – as distinct from the notion of an amorphous biological exchange involving a mismatch between European and Native-American immunity. [19]

There is no doubt that Native American communities and Europeans retained different immunities during the period of contact. [20] But suggesting that Native Americans were predisposed to *near-total* demographic collapse solely due to their relative lack of immunity may lead students and scholars to eschew any further assessment of their nutritional disruption as a co-factor in such a phenomenon; just as modern studies of genetic loci for diabetes might lead researchers to eschew the role of post-colonial interventions in late-nineteenth century and twentieth-century Native American food patterns, which affected their insulin sensitivity above and beyond any genetic predisposition.

Scholarship of global infectious disease has shown that societies have most often been able to recover demographically from near collapse following massive outbreaks, usually in around 150 years. Disturbances such as epidemics have tended to result in only short-term demographic decline, with populations returning to pre-disease levels of growth, decline, or stability. Describing the response to the European "black death", for example, McNeill points out that "the period required for medieval European populations to absorb the shock of renewed exposure to plague seems to have been between 100 and 133 years."[21] As Gottfied has demonstrated, fourteenth and fifteenth century Europeans suffered multiple epidemics including the Black Death, Typhus, influenza and measles, yet their populations were able to recover demographically after around a century. [22] Herring has even shown that early twentieth century Native American populations outside reservations were able to recover numbers following influenza, smallpox and measles epidemics. [23]

Taking these general studies as a starting point, students and researchers in biology and public health policy would gain a broader understanding of immunology and epidemiology through a joint course with historians and anthropologists. Rather than assuming that certain communities are more prone to metabolic syndromes and diseases, whether from genetic loci or a comparative lack of exposure to certain pathogens, they would be able to consider the ways in which human interventions – particularly in foodways – exacerbated demographic decline in the face of disease; both in terms of reduced immunity prior to infection and reduced ability to fight pathogenic invasion. Let us now consider how students might use case studies in Native American history to illustrate such a phenomenon, before turning to the ways in which contemporary scientific studies might then inform their analysis of the role of nutrition in enhancing or reducing the potential for recovery after mass epidemics.

Historians of Native-American health and fertility have drawn methodologically and conceptually from general epidemic studies in order to question the Biological Exchange thesis for demographic decline between the 1500s and 1800s. Near total demographic collapse, according to a developing historiographical consensus, was made possible by the rupturing of ancestral social mechanisms by European colonization – rather than simply as a result of differing immune capabilities among the two populations. The failure of Native American populations to return to pre-epidemic demographic numbers, many scholars now assert, derived from human interventions that accompanied the spread of disease, rather than simply the diseases as singular factors. One such human intervention lay in the domesticated agricultural practices that were prescribed by European colonization after first contact with Native Americans. The disastrous decline in Native American demography was partly affected by the growing mismatch between their long-evolved ecological frameworks and European cattle-pens and agricultural methods. The latter exacerbated the spread of diseases that Native American communities were already struggling to fight off due to their impaired immunity. [24]

According to the pioneering paleo-archeological work of Armelagos, such a phenomenon has commonly affected societies as they have transitioned to concentrated agricultural settlement and animal husbandry. Examining paleo-archeological evidence in European and Middle Eastern populations, Armelagos has noted the problems that followed relatively sudden proximity to domesticated animals and to human and animal waste in newly agricultural societies. Such proximity increased the spread of parasitic disease. In previous hunter-gatherer populations, frequent migrations limited the contact of individuals with human waste. In more sedentary populations, concentrated around grain production and domesticated animals, human and animal waste became more likely to contaminate drinking water. In pre-agricultural societies, zoonotic disease disproportionately affected those who came into contact with animals and their products during hunting and gathering. In Neolithic and post-Neolithic European and Middle Eastern societies, conversely, a greater proportion of individuals came into close contact with concentrated animal pens and therefore became more liable to infection from diseases that followed their byproducts. [25] As Polgar has shown, indeed, the domestication of animals has historically increased the spread of zoonotic diseases including anthrax, tuberculosis, and even types of influenza. [26]

Students and researchers should consider the paleo-archeological insights above as they try to understand why Native Americans were often so vehement in their immediate opposition to European agricultural models that concentrated cattle in farms and/or stored grain in newly constructed central warehouses. The development of those models, after all, accompanied the growth of massive disease outbreaks among Native Americans from the 1500s. The primary historical sources unearthed in the work of Anderson and Cronon, for example, would provide one point of reference: in New England, enclosed farms set up by seventeenth-century English settlers seemed to encourage the spread of infectious diseases, whether zoonotically or due to the increased concentrations of peoples. [27] Bovine strains of tuberculosis arrived with European cattle, as did tuberculosis bacilli and influenza strains in Swine, as well as the trichina worm.[28] Spanish settlers in California and the Southwest created ranches with similar effects, albeit in a slightly different colonial context. [29] Native Americans, according to one 1674 colonial report, perceived English cattle as “Unwholsom for their Bodies, filling them with sundry Diseases.” As Anderson has suggested in a discussion of human diseases that seemed to correlate with animal outbreaks, those Native Americans “who survived an initial bout of disease often emerged in a weakened state, vulnerable to subsequent ailments that would not necessarily have imperiled a healthy individual.” [30] New England Native Americans caught up in King Philip’s War (1675-78) often “began their hostilities with plundering and destroying cattle,” according to one witness. Large-scale killings of domestic animals continued throughout the war, and Native American hostility to the animals – and their owners – extended to mutilation and torture of cows in particular. [31]

Assessing the imposition of domesticated agriculture by Europeans during early contact, Cherokee-American anthropologist and historian Russell Thornton has thus suggested that “the reasons for the relatively few infectious diseases in this [western] hemisphere [prior to European contact] surely include… the existence of fewer domesticated animals, from which many human diseases arise” - unlike those that later grew up due to grain storage and transit patterns which differed from hunter-gatherer lifestyles as well as their own pre-contact forms of land-management and crop cultivation. [32] As biological anthropologists have shown, some pre-contact Native American communities were likely familiar with the association between cultivated animal lots and disease, albeit in more isolated settings. Pueblo Native Americans had witnessed the spread of diseases in areas contaminated by turkey dung, most probably salmonella and Shigella. [33] Turkeys had been domesticated in the northern Southwest, likely from populations of Merriam’s wild turkey. In most cases Pueblo communities demonstrated the capacity for mixed land use between animals and cultivated crops, without zoonotic diseases. But their example at least suggests that some communities may have been aware of the potential disease association, if conditions became less optimal. [34]

To be sure, there remain significant risks in using a conceptual distinction between Paleolithic hunter-gatherers and Neolithic agriculturalists to understand changing Native-American health outcomes after European contact. The link between negative Native American responses to European domesticated farming and the problematic health patterns associated with

DOI: 10.15310/2334-3591.1014

Neolithic agriculture must not be emphasized too specifically, of course; not least because the latter occurred between 8,000 and 10,000 years prior to the Native American encounter with colonial-European agriculture. Yet it is at least possible to draw broad conceptual associations between the two studied periods. Just as in paleo-archaeological records detailing the rise of Neolithic grain production and animal husbandry, source material relating to the Native-American-European encounter demonstrates the potential for zoonotic diseases to proliferate in regions that were required to adapt to more concentrated forms of land use (whether in animal lots or grain storage facilities in close proximity to newly concentrated dwellings).

Rather than highlighting a simple biological exchange of disease, then, students could point to the specific interventions of European enclosure and domesticated cattle-raising, which made infectious maladies even more potent and widespread. [35] They would consider the methodologies and conclusions of Armelagos, as well as those provided by other scholars of the move from Paleolithic ecology towards Neolithic agriculture. Having done so, they would be in a position to draw general inferences – and even conclusions – as they assess historical source material for the Native-American-European encounter and the growth of zoonotic diseases, over a relatively wide geographical basis and a relatively broad space of time.

(ii) The relationship between Horticultural and Hunter-Gathering practices.

The purported difference between Native American hunter-gatherers and European pastoralists becomes rather more problematic if it is used to de-emphasize the role of indigenous agriculture and formal crop cultivation (horticulture) *prior to* European contact. In order to avoid such a crude assertion, students would do well to assess our developing understanding of the "Hopewell tradition", which describes the various aspects of the Native American cultures that developed along rivers in the northeastern and Midwestern United States from 200 BCE to 500 CE. In these regions, tropical domesticate species of gourds, such as *Cucurbita pepo*, were introduced from Mesoamerica, well before the 2000 to 1000B.C period that scholars once linked to the first domestication of North American plants in the region. Scholars have recognized *Curcurbita* at the subspecies level and have thus made the convincing suggestion that the Hopewell cultures of North America created a second independent center of domestication for the species, just as they did with other plant species: Pumpkins, marrows, and other gourds were first domesticated in Mesoamerica, while acorn squashes, scallop squashes, fordhooks, crooknecks, and a variety of gourd species were then cultivated in North America. The domestication of indigenous eastern North American seed plants can thus be categorized in four species: *Cucurbita pepo, Helianthus annuus, Iva annua, and Chenopodium berlandieri*.[36] During the summer and fall periods, for example, pseudo grain seed-like chenopods (a relative of quinoa and spinach) became an important starch source for some Native Americans from modern-day Arkansas to eastern Kentucky, at latitudes from northern Alabama to central Ohio, from ca. 1800 B.C. until ca. A.D. 900 or later. Evidence suggests that hunter-gathering practices in these regions were supplemented by the domestication of those and similar chenopods (prior to the intensification of maize-based agriculture, which will be discussed separately below). [37]

Thus it is increasingly clear that many North American societies modified parts of their ecological environments even prior to the proliferation of maize production. The latter responded to demographic distress on the one hand, but also may have contributed to certain declining health outcomes, on the other hand (see below for further discussion). The four indigenous species that were cultivated prior to and even after the introduction of maize, conversely, were likely the product of a much larger context of "stable long-term adaptations and broadscale niche construction efforts that were carried out in the absence of any carrying-capacity challenges or seriously compressed and compromised resource catchment areas." Their cultivation, alongside other "crops" such as berries and tubers, had required, among other things: differential culling of trees, expanding natural strands of floodplain seed plants, artificial fires, and establishing "orchards" of fruit and berry-producing species. [38] Similar patterns of cultivation could also be detected in other regions, such as California and the American Southwest, as well as the wild rice regions of the central Great Lakes (see sections on starch sources and the link to modern metabolic science below). In 1541, in what is modern-day eastern Texas and western Louisiana, Spanish colonizers such as Hernando de Soto noted that communities of Karankawas cultivated corn, beans, squash, sunflowers, and tobacco. [39]

From around A.D. 900 in the riverine "horticultural villages" on the Great Plains, along the Missouri and its tributary rivers flowing into the lower Mississippi, beans, squash, melon, corn, and sunflowers were cultivated by Caddoan speaking Native American communities. Each village also maintained hunting territories where animals were stalked from the late-summer onwards. Thus, here and elsewhere, it is inaccurate to highlight a dichotomy between indigenous horticulture and hunter-gatherer patterns prior to the period of first European contact. [40] Pre-contact horticultural communities often "retained hunting and gathering practices as regular supplements and insurance against occasional shortages." [41]

After European contact, to be sure, many North American horticulturalists tried to revert to "full time hunting and gathering" as a means for sustenance; even while some in New England, among the Cherokee of the South, and the Navajo of the Southwest, remained as pastoralists. [42] Greater reliance on hunting and gathering after contact represented an indigenous response to the curtailment of horticulture, or its problematic limitation and enclosure, by new European forms of crop rotation and animal husbandry. That response, however, set up a chain of circumstances that resulted in the permanent loss of autonomous access to hunted meats *and* indigenously cultivated plants by the second half of the nineteenth century. From the late-sixteenth century, Spanish, French, and English settlers in coastal North America tended to overlook the possibility for symbiosis between hunter-gatherer and horticultural methods of sustenance, which often oscillated in relative importance according to the season. Instead, Europeans noted the Native-American reaction to their presence – a reversion to hunting and gathering and revulsion for their own domesticated agriculture – and erroneously assumed that they *solely* engaged in nomadic hunting patterns. This attitude "contributed to the notion that removal of eastern nations to Midwestern reservations would solve problems of conflict between expanding Euro-American populations and the Indians' loss of hunting lands." Among English colonizers in the eastern seaboard, the view that Native Americans refrained from land cultivation was indeed key in defining the territory as *res nullious* – empty of privately managed land and thus legitimate for colonial settlement. A similar assessment took place among Spanish colonizers in present-day California and the Southwest, albeit on a different scale. [43]

As they moved towards an increasingly central migration trajectory in the face of European colonization, various indigenous communities from the East, the Great Lakes, and the West often adopted European firearms and horses to hunt in new nomadic patterns. Shoshone tribes from the central and northern Mountain West adopted Spanish horses and introduced them to other indigenous communities in the Great Plains. Algonquians such as the Blackfeet, Gros Ventres, and Araphos, as well as some Cree and Ojibwa tribes, "abandoned forest hunting and gathering to become mounted nomadic hunters on the Great Plains" – thereby interacting with other tribes who had adopted Spanish horses as a means to hunt for new food sources. A northern Athapaskan group, the Sarsis, as well as some Comanches, similarly adopted horse nomadism. By the later-eighteenth century, previously horticultural Cheyenne communities entered the Plains, coming to rely on hunted buffalo and bison. Siouan and Caddoan horticulturalists along the streams and rivers of the eastern Great Plains sometimes also switched to horse-nomadic hunting-gathering practices after their traditional forms of plant cultivation and hunting were threatened by the interaction between European settlement and Native American warfare. Pawnee Indians, as well as some Hidatsas on the upper Missouri, moved towards horse-mounted nomadism. Through the eighteenth century, Siouan-speaking tribes gravitated from horticulture towards bison hunting, shifting west and leaving the bottomlands of the Ohio and Mississippi rivers. In most of these cases, as Snow has pointed out, "people were not just responding to the

DOI: 10.15310/2334-3591.1014

attraction of nomadic hunting. There were by this time [around 1700] also strong direct and indirect pressures from the east, brought on by European settlement and expansion." Initially, health profiles (measured through average height) seemed to increase among various new Plains Native American communities. As Heckel has argued, using data from births between the 1830s and 1870s on the Great Plains, their new proximity to bison and other animals likely benefited the association between greater height and nutritional density. Yet as these communities adopted new forms of hunting, competition with European settlers in the region coupled with over-efficiency so as to diminish their access to the area's sources of animal protein and fat. By the later part of the nineteenth century, therefore, many Native Americans found themselves unable to rely on traditional nutritional interactions between horticultural and hunter-gathering products. Worse, they soon began to lose access to micro-nutrients and macro-nutrients from fast-diminishing populations of bison. Relative to other European settlers, indeed, their height advantage diminished somewhat. [44]

The narrative above raises further implications for students and researchers, beyond the issue of zoonotic disease and concentrated settlements: if hunting and gathering as well as indigenous forms of crop cultivation were disrupted by the imposition of European agriculture in North America from the late-1500s, how else can we measure the historical symptoms and effects of declining health following the change to the Native American ecological landscape? Assessing the central nutritional role of indigenous agriculture alongside that of hunting and gathering might well suggest that malnutrition, rather than simply the spread of diseases through concentrated settlement, made communities less likely to recover from infectious epidemics. According to Snow, had "European expansion been less rapid, and had lethal epidemics not swept the landscape clear of Indian resistance as effectively as they did, the dynamics of historic cultural adaption" on the Great Plains and at the previous sites of European contact might have been different. [45] But it is worth students and researchers asking a slightly different set of questions: Did the inability to reproduce horticultural and hunter-gathering methods actively *contribute* to Native American demographic decline following epidemics, rather than simply demonstrating another unfortunate result of the Biological Exchange? Is it possible to draw any stronger conclusions in regard to direct causation, rather than more general association, in assessing the dual disruption to hunter-gathering and horticultural practices? Did the change in Native American diets following European contact directly impact the attendant increase in mortality rates – as distinct from epidemics elsewhere in the world where demography was able to re-stabilize after around a century?

In order to consider such a possibility, students and researchers should turn to the literature on medical anthropology, paleo-archaeology, and modern experimental data on the link between health, immunity, and the consumption of (often fat-soluble) vitamins and important minerals. Disrupted access to macro-nutrients and micro-nutrients – whether derived from hunted and gathered animals and plants, from indigenous agricultural practices, or a combination of both – might be defined as a co-factor alongside specifically pre-determined genetic loci and/or the biological exchange of diseases. Infectious diseases began to ravage Native American populations from the moment of first contact. But an inability to recover immunity and/or fertility, according to a working hypothesis, might have been exacerbated by declining access to ancestral sources of food. To assess these possibilities in greater detail, and how they might be understood by researchers and students, let us turn to more specific examples that relate to the hunting of animal products and the gathering and/or managed cultivation of vegetables, fruits, tubers, and seeds. They allow a potentially fruitful synthesis between early-contact history and modern research in evolutionary medicine and nutrition.

Greater reliance on maize and declining access to vitamins and minerals after European contact: historical data and modern peer-reviewed science.

(i) Animal Proteins and Fats

Emphasizing the role of colonial human intervention rather than an amorphous biological exchange, modern historical scholarship provides further evidence of the problematic impact of European domestic agriculture on Native American health and fertility after contact. Aside from its greater propensity to affect the spread of infectious diseases, we now know that the proliferation of small enclosures of cattle and grain physically disrupted hunting and gathering practices, as well as pre-contact forms of plant horticulture, and reduced their attendant nutritional gains. According to biological anthropologist Clark Spencer Larsen, the emphasis on disease in the biological exchange thesis "has overshadowed a host of other important consequences of contact such as population relocation, forced labor, dietary change, and other areas."[46] Meister similarly notes that "later population decline resulting from disease was made possible because Indians had been driven from their land and robbed of their other resources [including hunted animals and cultivated crops]."[47] According to Anderson, "before long, the expansion of livestock-based agriculture ceased being a model for Indian improvement and instead served almost exclusively as a pretext for conquest, a very different expression of the cultural impact of distinct farming practices" among Europeans and Native Americans in eastern North America from the 1600s. [48] As Kunitz has pointed out in a discussion of the paleo-epidemiology of southwestern Native American communities, and their malnutrition following subsequent European colonization, "one does not need to invoke large-scale dramatic epidemics; prosaic entities like malnutrition… are more than sufficient to do the job [in demographic collapse]."[49] Though it remains difficult to address the direct triggers for final mortality, Thornton has assessed much evidence on the history of Plains Native Americans in the two centuries after contact and concluded that their "mortality and fertility" was severely impacted "when the great herds of buffalo were destroyed" by European agricultural patterns, Native American over-hunting in response to curtailed nutritional sources *elsewhere*, and open warfare. Other scholars concur that an association can be drawn between worsening health, the declining ability to hunt animals and/or cultivate plants, and a new reliance on European agricultural production as animals on the Great Plains came to be over-hunted. [50]

Before turning to cultivated plants, let us now consider how students and future researchers might understand the ways in which declining access to hunted animal products reduced the consumption of important minerals and fat-soluble vitamins, and affected overall health, immunity, and fertility. We would begin with a historical assessment of the role of hunted animals in Native American history. Particularly during the winter, many Native American communities relied on hunting and gathering fatty cuts of meat for optimal nutritional health, long after Neolithic-era Europeans had moved towards domesticated animal husbandry and grain production. Frison's classic work on the pre-historic practices of the High Plains, Great Plains, and Rocky Mountain regions, for example, suggests that nutritious organs and fats from buffalo meat were favored over and above other portions. [51]

Having considered the importance of hunting in ancient populations, students might then turn to seventeenth-century and eighteenth-century European observations of indigenous communities in the northernmost parts of continental North America. Hunting and gathering patterns in those regions were less altered by colonization, and so provide a more accurate picture of their ancestral nutritional profile within their regional context. Their populations relied on fats from fish and land animals as a greater proportion of their diet due to their climate and ecology. [52] Students could then move on to observational studies from pioneering ancestral health theorists such as Weston A. Price, as well as those from more recent anthropologists who have worked in regions such as British Columbia and sub-Arctic Canada.

DOI: 10.15310/2334-3591.1014

Consider, for example, the case of Samuel Hearne, an explorer writing in 1768, who described the preparation of caribou among indigenous populations around the Hudson Bay area in Canada. The populations he encountered had maintained a hunter-gathering lifestyle in contrast to their southern neighbors suffering from European interventions:

> "Of all the dishes cooked by the Indians, a *beeatee*, as it is called in their language, is certainly the most delicious that can be prepared from a deer only, without any other ingredient. It is a kind of haggis, made with the blood, a good quantity of fat shred small, some of the tenderest of the flesh, together with the heart and lungs cut, or more commonly torn into small shivers; all of which is put into the stomach and toasted by being suspended before the fire on a string. . . . it is certainly a most delicious morsel, even without pepper, salt or any other seasoning."

As Hearne noted elsewhere, community members tended to select only the fattiest parts of the animal, or nutrient-dense organ meats, throwing the rest away: "On the twenty-second of July we met several strangers, whom we joined in pursuit of the caribou, which were at this time so plentiful that we got everyday a sufficient number for our support, and indeed too frequently killed several merely for the tongues, marrow and fat."[53]

Students might then examine oral histories, archival collections, archeological records, interviews, and participant observation of contemporary practices, using methods and materials from ethnographers such as Richard Daly, who has noted the historical preference for fish fats among Delgamuukw indigenous peoples in British Columbia, going back several centuries in communal memory. According to Daly, fat "rendered from salmon heads was prepared in summer, hung in bladder pouches in the rodent-resistant family meat caches, and saved for winter use." Oils were "prepared from fatty fish and meat such as oolichan, salmon and beaver. Special processes were involved in preparing the heads- drying or boiling them for oil-as well as the eyes, bellies and eggs". Moreover the "arrival of the oolichan. . . was traditionally announced with the cry, 'Hlaa aat'ixshi halimootxw!' or, 'Our Saviour has just arrived!'" Ooligan grease was thus a prized gift in feasts and between neighbors.[54] Surveying modern communities of Native Americans, Weston A. Price's 1939 *Nutrition and Physical Degeneration* noted a similar preference for animal and fish fats, and organ meats, and suggested its provenance in ancestral food patterns that dated back centuries and even millennia. The indigenous communities Price encountered were seen to prize the fattiest parts of meat and fish, including organ meats, rather than muscle-cuts. As Fallon Morell and Enig have summarized, Price linked a diet high in fats from mammals and fish to "an almost complete absence of tooth decay and dental deformities among native Americans who lived as their ancestors did… [including among] the nomadic tribes living in the far northern territories of British Columbia and the Yukon, as well as the wary inhabitants of the Florida Everglades, who were finally coaxed into allowing him to take photographs… Skeletal remains of the Indians of Vancouver that Price studied were similar, showing a virtual absence of tooth decay, arthritis and any other kind of bone deformity…" [55]

Ironically, in order to move beyond conjecture when discussing declining health markers after European contact, paleo-anthropological and paleo-archaeological evidence for the *pre-contact* Native American consumption of maize provides students and researchers with a helpful framework. Evidence for diminishing health following the introduction of maize raises the hypothesis that consumption of the grain came at the expense of more nutrient-dense calorie sources from animals and other plant species. Familiarity with such a hypothesis should help students and researchers to examine a similar – albeit greatly increased – association between the intervention of colonial European agriculture and the failure of Native Americans to recover demographically from infectious diseases in the three centuries after contact (when maize became more prevalent, alongside other European grains, and access to hunted meats and previously cultivated plants declined).

In eastern North America from A.D. 800 to 1100, a shift towards maize-centered agriculture took place in regions as far afield as the Southwest and the Eastern seaboard. Hunted and gathered meats, as well as nutrient-dense crops such as gourds, seeds, and tubers, declined as a proportion of overall calorific consumption. Across the South Atlantic and Gulf Coastal plains, the shift towards maize cultivation as a vital source of calories was associated with the development of "socially ranked societies" and "fortified civic ceremonial centers" placed near maize storage centers. Corn came to be central to the activities of Iroquois confederations stretching from the east coast to the Ohio River valley, as well as in the Mississippian chiefdoms that grew along the river-ways of the Southeast and Midwest. [56]

It is tricky to evaluate the effects of the shift to maize on Native American health. On the one hand, the cost-to-yield ratio of pre-contact maize cultivation may have become seemingly more attractive because of an increased demographic pressure on both wild and domesticated resources. That is to say, increased mortality due to food scarcity from hunted and gathered sources might have been diminished by the calories provided by maize. [57] Yet on the other hand, there is a growing scholarly consensus that health and immunity decreased following the indigenous production of maize among North American communities around 2000 years ago, particularly in the American southwest. It may well have provided a source of energy to keep Native American communities alive. But those communities, when compared to populations who had preceded the demographic pressure placed on hunter-gathering, seemed to register declining health markers. That which saved them from death through famine was not necessarily nutritionally optimal as a dominant calorie source. To be sure, we can find historical records from the contact and pre-contact era that suggest several indigenous Native American methods to increase the nutritional profile of corn, some of which may have been introduced in pre-historic communities as they shifted towards the grain. These include soaking it in lye made from wood ashes, in order to make it more easily ground. Doing do also likely made the protein and niacin (Vitamin B3) in corn more bioavailable, due to the alkalinizing effect of the wood ashes/slaked lime solution. Greater absorption of Niacin is associated with greater bioavailability of important minerals such as Calcium and Potassium. Nonetheless, the production of "hominy" from corn in this way may not always have been enough to counteract potential nutritional deficiencies associated with the shift toward the grain. [58]

In order to understand the distinction between famine-prevention and optimal nutritional health, students and researchers would be able to consider a number of different case studies. From the Great Lakes region to the southern plains, and from eastern coastal to Pacific populations, for example, the regular consumption of bison, deer, and fish likely prevented protein and iron deficiencies that later accompanied the reliance on maize for a greater proportion of the daily calorie output of Native American communities. [59] Analysis of bones from prehistoric North America reveals that, long before European contact, potentially problematic indicators followed the move towards maize consumption. Several studies have focused on growth retardation and suggested its negative association with health markers more generally. Declining stature has been correlated with the onset of agricultural production of maize during the first centuries of the Common Era. Archaeological evidence from late prehistoric Dickson Mounds populations in west-central Illinois show that agricultural intensification led to a decline in skeletal weight and height. In the Lower Illinois Valley children under six in nascent maize producing societies have been found to have suffered growth retardation compared to hunter-gathering communities from nearby excavations. [60]

Evidence for iron deficiency following the shift to maize, according to important paleopathological studies by Martin and other scholars, is provided by indicators of porotic hyperostosis, a skeletal gauge that has been extensively studied in archaeologic populations of Native Americans in the Southwest and elsewhere. The latter can be measured through lesions on parietal and orbital bones of the cranium; bones that are the most active in producing red blood cells and which are thought to be affected by anaemia. [61] The general distribution of the lesion corresponds with increasing reliance on agricultural products such as maize, which are low in

DOI: 10.15310/2334-3591.1014

bioavailable iron, and which can be detected through chemical and isotopic signatures in human remains. Lallo and co-workers, for example, have evaluated changes in rates of porotic hyperostosis for ancient Mississippians (in present-day Illinois) living during the twelfth century, finding that its prevalence increased dramatically in the transition from hunting and gathering to maize agriculture. A nearly four-fold increase in parietal lesions (caused by non-specific infections) in Mississippian burials spanning the transition is said to have resulted in large part from iron deficiency following an over-reliance on maize in the diet. [62]

Modern research highlights a link between iron deficiency and greater susceptibility to infection. Students might well consider such an association in assessing the greater reliance on maize at the expense of previously hunted meats after European colonization. A *far greater* decline in iron consumption after contact might have diminished immunological health and heightened Native American susceptibility to suffer from infectious diseases – a more nuanced assessment than the traditional Biological Exchange thesis. [63] Paleo-archaeological assessments of porotic hyperostosis and immunity thus provide a useful working hypothesis that can be applied to understand the health of Native Americans from the 1500s – when they came to rely on maize and other newer European grains to an even greater extent than their previous experience.

Students and researches could also consider the effect of other micronutrient deficiencies on immunity in order to synthesize contemporary medical research with the historical anthropology of Native American communities. Archaeological evidence of skeletal remains from Ancestral Puebloans in the American Southwest at least suggests a coincidence between newly evident nutritional deficiencies, aside from those which were demonstrated through instances of porotic hyperostosis, and the shift towards maize cultivation. It has highlighted evidence that suggests a concomitant increase in scurvy, dental cariesporotic hyperostosis, and *cribra orbitalia*. Scholars have also suggested a deficiency in vitamin B12 among Puebloans as they began to cultivate maize at the expense of meat consumption from between 500 AD to 1000AD (and proposed B12 deficiency as opposed to iron deficiency as the major cause of porotic hyperostosis in this population). [64] Vitamin B12 scarcity, thought to compromise immunity in infants, may have contributed to their community's decreased immunity more generally. [65] It has even been hypothesized that the depletion of wild game and an over-reliance on maize was perceived as problematic by Ancient Puebloans, who became keen turkey farmers during this period in order to alter their nutritional intake. Doing so would have likely beneficially increased their consumption of vitamin B12, iron, and protein. [66] The above declines in health can also be informed by modern scientific studies that have linked protein energy malnutrition to a significant impairment in immunity – a decline that was potentially exacerbated following European interventions after contact. [67]

Thus, if we can detect a decline in health and immunity among pre-contact Native American communities who moved away from their ancestral nutritional traditions, it seems reasonable to apply a similar hypothesis to the post-contact era, when those traditions were uprooted *to a far greater extent* – whether in relation to hunted animal proteins and fats or in relation to indigenous plant sources (implications of the latter are discussed in the section below). Our understanding of the health outcomes associated with the shift to maize should help us to consider subsequent contact history in light of the developing scientific literature on micro-nutrient absorption, its necessary co-factors, and its relationship to immunity and fertility. A healthy immune system – partially supported through optimal nutrition - would have likely provided at least some defence against total demographic collapse following the biological exchange of diseases.

Modern scientific scholarship, for example, has begun to suggest the importance of DHA from Omega 3 Fatty Acids in human evolution and health. Fatty-cuts of pasture raised wild animals and wild fish have been shown to contain far higher proportions of those fatty acids than the food sources that apparently became more abundant in Native American diets after European contact.[68] Fat-soluble vitamins are abundantly found in fish eggs and fish fats such as Ooligan grease, which as we have seen were prized by Native Americans in the Northwest and Great Lakes regions, as well as in similar forms among California communities who relied on marine life. Access to these nutrient sources diminished as a part of their diet after Europeans gained access and control of many waterways; whether the Spanish in California, or the French and British in the Great Lakes region of North America. [69] Masterjohn and others have highlighted the important role of Vitamin K2 in ancestral diets (likely what Weston A. Price referred to as "Activator X" in his study of indigenous communities) in combination with other vitamins. [70] Vitamin D, also vital for health and immunity, is found in fish fats and eggs (particularly salmon) as well as organ meats – all of which declined in consumption among various Native American communities who were prevented from carrying out traditional hunting practices, and who often came to rely on European supplies of muscle meats and grains by the eighteenth century. As students would note, low vitamin D levels correlate with susceptibility to infectious diseases.[71]

It is also worth considering studies that suggest the potential compromise to infant immunity in agricultural societies, in comparison to hunter-gathering or more traditional horticultural contexts, as a result of early weaning onto foods such as wheat and corn. Such a comparison might inform another working hypothesis for students: if Native American hunting and gathering practices were further disrupted by European interventions, both physically and culturally, their nutritional degradation might have reduced the quality of breast milk, while also encouraging earlier weaning in poorer nutritional sources. As a result of these related phenomena, infant immunity would have likely suffered, further raising susceptibility to infectious diseases. [72]

Students and researchers might also examine the ways in which more subtle changes to animal consumption may have affected health, fertility, and immune system function, heightening susceptibility to disease and increasing mortality rates among infants and parents. For example, the move away from hunted meats towards grains, or a reliance on lean muscle meats from newly domesticated European cattle, could have compromised immunity through deficiencies in Zinc, Magnesium, and Vitamin A. [73] Deficiencies in amino acids such as glycine may have been equally problematic. Glycine, which would have been obtained from organ meats that were prized by many Native American hunter-gatherers, likely decreased in the diet as a result of disrupted hunts and/or diminished access to full animal carcasses following European colonization. Glycine has recently been suggested to be a semi-essential amino acid: analysis of metabolic pathways indicates that the body may not be able to synthesize adequate amounts of the amino acid to maintain long term health, and that inadequate glycine consumption may lead to premature aging and sub-optimal health. In particular, it is thought that pregnant women may suffer from glycine deficiency if inadequate glycine is consumed in the diet. Given the requirement of glycine for immune function, students might note, it is possible that expectant mothers, already vulnerable to glycine deficiency, could have suffered decreased immunity due to a further diminishment after European contact. Organ meats, particularly liver, is also relatively high in folate, another vitamin whose reduction is associated with problematic fertility and pregnancy outcomes. [74]

(ii) The threat to plant-based micro-nutrients: Magnesium, Folate, and other essential factors in immunity and reproductive health.

Aside from some Artic and sub-Arctic indigenous communities, pre-contact Native Americans rarely relied solely on animal fats and proteins as a nutritional source. [75] Many communities increased their consumption of maize to counteract calorie deficits following their diminished access to hunted meats after European colonization. But as we have seen, Native Americans gathered, and even cultivated, plant nutritional sources *other than* maize long before the 1500s. Thus Native American populations resented European agriculture not only because it was associated with zoonotic diseases, or because it disrupted seasonal hunting of meat and fish. From the eastern coast of North America to California, the historical record also shows that

DOI: 10.15310/2334-3591.1014

Native Americans perceived the imposition of European farming as a physical and ecological disruption to their gathering – *and cultivating* - seeds, tubers, plants, and acorns, especially from spring to fall. [76]

Throughout the seventeenth century, for example, during the period of first contact between Native Americans and English settlers in Pennsylvania and New England, indigenous communities became aware that de-pasturing sheep and hay-gathering impacted the ecology of grasses, tubers, and squash. [77] In the American Southwest, similarly, we have evidence of the seasonal consumption of nuts and fruits prior to European contact. In summer and fall, communities would consume prickly pears, tepary beans, wolfberries, mesquite pods, mustard seeds, cholla blossoms – whether from wild or semi-cultivated sources. There too, Native Americans were suspicious of European settlers whose ranches and farms threatened these plant gathering and horticultural practices. [78] Through as late as the eighteenth century, California Native American communities regularly complained to Franciscan missionaries that settler livestock destroyed their acorn and chia supplies. As Milliken has shown, Native American raids on European livestock in the region were often motivated by these specific problems. [79] By the nineteenth century, remaining California communities of hunters and gatherers were finally shut out by fences that enabled cattle and sheep to consume wild grass seeds and acorns. According to a European settler's account in 1856, Native American "spring and summer food…[has] been this season, and will hereafter be, consumed by cattle, horses, and hogs. …" – a final act of colonization that prevented the consumption of ancestral sources of starches and seeds. [80] Thus Native Americans came to resent the advancement of non-indigenous seeds and livestock into regions where ancestral starch sources, vegetables, and seeds had hitherto been gathered; just as they also resented the loss of habitats to hunt animals for their fat and protein.

Let us, then, consider in greater detail how students and researchers might understand the role of plant nutrition in Native American history, in order to assess how its curtailment in the examples above might have impacted health after European contact. We have already seen how we might begin to understand post-contact immunological pressures by taking into account the minerals, fats, proteins, and fat-soluble vitamins that declined as nutritional sources during the same period. We have suggested, moreover, that it is possible to draw similar hypotheses regarding the relative decline in health among those *pre-contact* communities who had shifted towards maize (notwithstanding the attendant role of the crop in preventing mortality through famine and other demographic pressures, and the much smaller scale of disease). A similar hypothesis could be generated in our understanding of the nutritional profile of indigenous plant and starch sources prior to the shift towards maize, and the potential metabolic and nutritional effects of their diminishment relative to its cultivation. As Cordell and Smith have shown, when corn began to spread more widely after A.D. 800, it pushed towards a 120-day growing season limit so that "other North American and tropical food crops, including sunflower, squash, and beans, were included more slowly and varied more in their relative importance among northern maize famers." [81] Thus archaeological and anthropological evidence for declining health after that period might also be linked to a diminished access to nutrients from non-maize plant sources; rather than solely because the consumption of nutritious animal products was reduced relative to maize. After European contact, Native American communities lost their ability to cultivate and/or gather indigenous plants and starches to an even greater degree than during their earlier shift to maize, as they came to rely on the latter as well as new European grains. We ought to consider the potential costs to immunological health and fertility.

Similar to their analysis of animal-based nutrition, and its potential relationship with Native American health, immunity, and fertility, students would consider sources of nutrients and anti-oxidants in the plants and tubers that were cultivated and/or gathered by Native Americans prior to their disruption by colonization, and the possible health implications of such disturbance. Nutrients found in beans and plant materials consumed in indigenous horticulture prior to contact are likely to have included magnesium, folate, zinc, iron, antioxidants, vitamins A, C and E, bioflavenoids, and phytochemicals. [82] Antioxidants and vitamins (particularly Vitamin C) are well known to be vital for immune function and for protection against chronic diseases. [83] Micronutrients such as iron (particularly found in beans and some green leafy vegetables), magnesium, and zinc are also known to have important roles in immune function. Several studies suggest a compromised immune response when such micronutrients are lacking. [84]

Students would do well to consider the role of magnesium from plant sources as a particularly illuminating case study. Magnesium is recognized to have a central role in human wellbeing, affecting cardiovascular, neurological, and immunological health. It is synergistic with the fat soluble vitamins A and D, and so its deficiency is likely to affect health in a similar way to their restriction, potentially even in regard to maintaining robust immunity. [85] Magnesium is vital during pregnancy: research shows that the mineral reduces the risk of complications such as preeclampsia and preterm birth. [86] Through its synergistic role with vitamin D, moreover, magnesium is known to affect skeletal health. Recent research thus shows a strong link between magnesium deficiency and osteoporosis. [87] Due to their profound role in skeletal health, we could also hypothesize that deficiency of magnesium and fat soluble vitamins may affect the growth and vitality of children. Children without sufficient vitamin D, for example, may develop serious disorders such as rickets. Females may suffer from poor pelvic development, which can have serious implications for childbearing. A reduction in magnesium consumed from plant sources, which is synergistic with vitamin D, would therefore have problematic implications. [88] Having examined the often-overlooked importance of dietary magnesium, students would assess whether and how its intake decreased in many Native American diets following colonization. Magnesium, after all, is present at high levels in sunflower, pumpkin and squash seeds, beans, and green vegetables – all foods that were consumed readily in many communities before colonization, but which became less accessible as more land was cultivated by Europeans. Indigenous communities moved from point of contact towards the Great Plains and elsewhere, losing traditional horticultural and/or plant-gathering patterns. [89] And so, diminished access to magnesium would have been likely to *exacerbate* the decline in health and fertility following the biological exchange of infectious diseases after contact.

In addition to their magnesium case study, it would be fruitful for students to consider the vital importance of plant sources of folate (pteroylglutamate, often referred to as vitamin B9) and the problems potentially associated with its curtailment as a nutritional source in Native American communities. When fertility and demography were already ravaged by infectious diseases, the ability to recover population numbers through reproduction may have been threatened by a reduction in folate among women of a child-bearing age. In addition to minerals such as magnesium, zinc, and iron, folate is known to be important for fetal development and maternal health during pregnancy. Folate is required for early embryonic development and oocyte maturation. One study highlights the importance of folate in oocyte maturation: subjects receiving IVF treatment who also received folate were found to have more mature eggs than those who did not receive folate. [90] Folate deficiency is a well-known cause of neural tube defects, and low maternal folate levels may increase risk of spontaneous abortion (miscarriage). Lack of folate during pregnancy is correlated with other complications including low birth weight, placental abruption, fetal growth retardation, and preeclampsia. [91] Some studies have highlighted the importance of folate in male fertility. For example, a double-blind randomized placebo-controlled trial found a 74% increase in total normal sperm count in subfertile men who received both zinc sulfate (66 mg) and folic acid (5 mg) daily for 26 weeks, while another study found an association between folate consumption and sperm aneuploidy. [92] Thus, a decrease in the consumption of beans, squash, and other fresh vegetables at the expense of less folate-rich calorie sources could be expected to have had a large impact on the health of the population through effects on fertility, maternal health during pregnancy, and child development (both during fetal growth and during subsequent breastfeeding and weaning).

The importance of folate can be further illustrated by research among those who suffer from genetic mutations such as MTHFR C677T, which is prevalent among many different

DOI: 10.15310/2334-3591.1014

human populations, and which has been associated with effects on health such as increased rates of miscarriage. A properly working MTHFR enzyme normally transfers 5,10-methylenetetrahydrofolate into an activated form, 5-MTHF (5-methyl tetrahydrofolate). Such a process is crucial for DNA methylation, nucleic acid biosynthesis, neurotransmitter synthesis, and the creation of signaling molecules that are central to the development of embryos in the first trimester of pregnancy. Folate plays a vital role in remethylation of homocysteine to methionine, which is essential for DNA-synthesis, DNA-repair, and DNA-imprinting processes. [93] If these processes are reduced through mutations in methylation pathways, levels of intercellular folate become insufficient, making its ready consumption potentially more vital. [94] Having familiarized themselves with the role of such enzymatic activity, including the role of folate in facilitating bodily detoxification through methylation pathways, students would be able to examine the following hypothesis: reduced folate intake from plants would have diminished the ability of post-contact Native Americans – particularly women of childbearing age – to respond through reproduction to demographic pressures caused by disease.

Having considered these case studies, students would also be encouraged to assess the *interaction* between plant nutrition and animal products. Many of the fatty acids and nutrients detailed in the previous section of this article can be found in wild animal sources (to a greater degree than in those animals raised on farms with new feed-sources that alter their metabolism and biochemical constitution). [95] But as we have seen in this section, plant sources were often important on their own terms, irrespective of their combination with animal fats. Still, students might consider recent research that has shown the extent to which some vitamins found in plants are better absorbed by humans in the presence of fats, most likely from animal sources. [96] They would do well to assess recent scientific literature on the problematic bioavailability of some nutrients found in plants, including essential vitamins as well fat-soluble carotenoid compounds such as lutein, lycopene, beta-carotene and zeaxanthin. Indeed, some research has even prioritized saturated fat over polyunsaturated fats such as sunflower oil in facilitating the bioavailablity of beta-carotene in plant materials. As horticulture declined after contact, so therefore did the consumption of plant nutrients *in combination* with fats from animal sources, which may have increased their ability to be processed and absorbed in humans. [97]

Such a nutritional paradigm would support our scholarly and pedagogical attempt to reduce the dichotomy between indigenous hunting methods and pre-contact horticulture. It would also allow us to understand one of the nutritional roles of animal products in regions south of the Canadian Arctic, British Columbia, and the northern Great Lakes; where plants, some grains, tubers, chenopods, and seeds were consumed in greater proportion relative to animal products than among northern native populations. Where climate, season, and ecology permitted the consumption of calories from cultivated and/or gathered plants, their nutritional benefits might have been maximized through *their combination* with animal sources. The latter were gained from hunting practices that continued much later in Native American history than among Neolithic and post-Neolithic European populations. Thus the susceptibility of Native Americans to European diseases may have been further amplified by their disrupted access to certain meats and fishes, as well as a diminished opportunity to consume them in combination with cultivated plants; so as to decrease health, immunity, and fertility even prior to infection.

(iii) The threat to plant-based macro-nutrients: Non-maize seasonal starch sources, resistant starch, and metabolic health.

Aside from the potential decline in vitamins and anti-oxidants from indigenously cultivated fruits and vegetables, and their potentially greater absorption in the presence of fat, it is also important for students to consider *metabolic* distinctions between previously cultivated plant sources and the grains that Native Americans came to rely upon more greatly following colonization; whether any correlation can be drawn between forced changes in starch consumption and declining health markers in post-contact Native America; and whether these changes in the metabolic nutritional profile of their food compromised Native American immunological health with respect to infectious diseases.

Here students would be required to examine the potential distinction between micro-nutrient health effects and those associated with the metabolic effects of various macro-nutrient profiles, as defined by their relationship with energy utilization and storage in the human body. A central aspect of the metabolic profile of food is considered to be the resulting effect on blood sugar level and the concomitant production of insulin (often associated with problematic health markers including diabetes, heart disease, and lowered immunity to infectious diseases). [98]

In order to consider the question of metabolic health, students might begin by examining a number of ethnobotanic assessments of Pima Indian ancestral food patterns, which provide a rich and useful case study. Alarmed by the sudden prevalence of diabetes among the Pima communities of southern Arizona since their adoption of an American diet during the 1940s (at nearly half the adult population during the 1990s) Arizona ethnobotanist Gary Paul Nabhan has scrutinized ancestral Pima diets from anthropological sources, working on behalf of the Tucson-based Native Seeds/SEARCH foundation. Nabhan and others have noted a contrast between the starches traditionally gathered and/or cultivated by the community during the last several hundred years, which promote a much lower insulin response, and more recently consumed grains, newer strains of maize, and white potatoes (whose higher glycemic indexes thereby promote much higher levels of insulin production). Such a distinction was correlated by selecting six starchy foods traditionally eaten by the Pimas during the last millennium, and particularly prior to first European contact: mesquite pods, acorns, white and yellow tepary beans, lima beans and a traditional strain of corn. The blood insulin levels following consumption of these foods was measured in healthy, non-diabetic subjects and compared to newer starch sources consumed by the same subjects. Some of the sources analysed have been shown to contain higher-than-average proportions of amylose starch, which takes longer to break down into simple sugars than amylopectin, the predominant starch found in white potatoes and bread, thereby explaining the lower rises in blood sugar after consumption of these starch sources. [99] Prior to contact, Pima populations also consumed a cereal containing the grain-like seeds of psyllium, sometimes known as plantago, which more recent studies have linked to the potential lowering of fasting blood sugar levels. Another study has even suggested that the phytochemical composition and metabolic performance of some "dietary berries traditionally used by Native Americans" can be associated with positive health markers, including the regulation of blood sugar levels and lipid metabolism. [101]

"For Native American and other recently Westernized indigenous people," according to Nabhan, "a return to a diet similar to their traditional one is no nostalgic notion; it may, in fact, be a nutritional and survival imperative." [100] From such an analysis, at least, students of Native American ancestral health might draw a related hypothesis: following Spanish and Anglo-American colonization of the Southwest, reduced access to lower-glycemic starches in favor of maize and wheat could well have heightened the susceptibility of indigenous communities to infectious diseases and/or raised their mortality after infection. Several modern studies, after all, have suggested that the immune response might be impaired in individuals with diabetes mellitus, or even among those who have chronically raised fasting blood sugar levels. [102]

Aside from their greater reliance on less-nutritional and higher glycemic starches after colonization, Native Americans might also have suffered from reduced access to Resistant Starch (RS) – another hypothesis that should inspire students and researchers to consider the intersection between historical data and modern scientific debates in evolutionary health. As a beneficial substrate for fermentation, instead of being digested by amylases in the upper digestive tract, RS tends to pass through to the bowel, where it is fermented by bacteria into short chain fatty acids (SCFA). It has been suggested that RS is important in contributing to a healthy gut biome. [103] Interestingly, a good source of RS can be found in acorn powder. [104] We know that Native American communities throughout North America ground up acorns and ate the powder with other foods. And as we have seen, many lamented diminished access to acorns

DOI: 10.15310/2334-3591.1014

as a result of post-contact European domesticated agriculture. Recent medical literature has shown that RS may reduce the potential for Type II diabetes in populations who eat carbohydrates. As is evident in the Pima studies, a decline in the consumption of mesquite pod and acorn powder, both good sources of RS, has been accompanied by an increase in diabetes. Thus, future students and scientific researchers might ask: did Native Americans inadvertently lose important forms of RS as their preparation and consumption of acorns and other seeds and tubers gave way to wheat and corn? Or put differently, did European colonization alter the Native-American gut-biome, and did this further contribute to the decline in overall health and immunity?

Assessing the role of plant starch sources in Native America also raises the related question of their seasonality, and whether disruption of their consumption at *certain times* contributed to a decline in health, immunity, and even fertility. In New England through the 1600s, as Anderson has shown, European farming enclosures clashed with the summer gathering of tubers and squash, while tending animals in the winter conflicted with itinerant winter hunting for fats and proteins. The historical record there and elsewhere thus suggests that during summer and early fall starches were consumed in far greater number than during the winter, when protein and fat consumption increased proportionally. [105] By 1600, as another example, Western Apache communities had developed a "seasonal cycle" that veered between food gathering, horticulture, and winter hunts. They harvested mescal in spring and reactivated irrigation ditches in May. In July they harvested saguaro fruit in the Gila Valley of modern day Arizona. In July they also began a month-long harvest of acorns. Fall and winter were dominated by hunting for animal meats. [106] Similarly, on the Texas plains prior to European contact, Apache communities spent spring and summer in agricultural villages, moving towards hunting dominated nutrition in the winter. [107] While surveying indigenous communities who had avoided the level of European contact suffered by their southern neighbors, Weston A. Price's *Nutrition and Physical Degeneration* suggested that similar practices were maintained during the early twentieth century among communities living inside the Rocky Mountain Range in far northern Canada. As Price noted, they cycled between the summer cultivation of starches and fruits and far greater reliance on fats from animals (particularly organ meats and marrow) during winter:

> "…the successful nutrition for nine months of the year was largely limited to wild game, chiefly moose and caribou. During the summer months the Indians were able to use growing plants. During the winter some use was made of bark and buds of trees. I found the Indians putting great emphasis upon the eating of the organs of the animals, including the wall of parts of the digestive tract. Much of the muscle meat of the animals was fed to the dogs. It is important that skeletons are rarely found where large game animals have been slaughtered by the Indians of the North. The skeletal remains are found as piles of finely broken bone chips or splinters that have been cracked up to obtain as much as possible of the marrow and nutritive qualities of the bones. These Indians obtain their fat-soluble vitamins and also most of their minerals from the organs of the animals. An important part of the nutrition of the children consisted in various preparations of bone marrow, both as a substitute for milk and as a special dietary ration."[108]

When assessing the health and vitality of pre-contact communities in more southerly regions, students and researchers might well ask whether they gained fat mass from the insulin response to higher carbohydrates in summer and fall, before then losing part of their mass during long winter hunts.

Moving further towards speculation, or at least a working hypothesis, it is worth considering whether health declined as Native Americans were forced to consume maize and other starches during the winter months, having lost access to ancestral winter hunting grounds. After all, seasonal (rather than year round) consumption of carbohydrates could have improved health by limiting the overall production of insulin in the bloodstream (which has been linked to diabetes, obesity, and cardiovascular disease). In assessing such a hypothesis, students would be able to consult much recent research on the evolutionary dimension of obesity and metabolic syndrome. Firstly, it has been suggested that the move towards all-year round abundance of food in many populations (both before and after the Neolithic era) may have caused over-consumption at times when the human metabolism may otherwise have benefited from calorie reduction and/or greater insulin sensitivity. The latter has been linked to reduced carbohydrate and protein access in comparison to fat, often during winter. Secondly, a number of studies have shown a correlation between blood vitamin D levels and insulin sensitivity. Thus, from an evolutionary perspective, it may be postulated that some human populations may be adapted to consume more starch during those months when insulin sensitivity is higher due to raised blood vitamin D levels from available sunshine. [109]

What, then, might students make of the statements made by the Spanish colonizer Cabeza de Vaca, who lived with Coahuiltecan communities in what is now part of Texas, for eight years from 1538? During winter they hunted buffalo, deer, and javelin, while during the summer and fall they were sustained by fish, plants, and starches such as the mesquite bean. In what has been described as a "feast or famine economy", animal-based diets in winter would thus give way to gorging thanks to "the ripening of fruit, or tuna, of the prickly pears [which] typically meant days of feasting until the fruit ran out." During the winter period of hunting for animal proteins and fats, de Vaca noted the ability of Coahuiltecans to maintain aerobic activity for long periods of time: "The men could run after a deer for an entire day without resting and without apparent fatigue. . . one man near seven feet in stature. . . runs down a buffalo on foot and slays it with his knife or lance, as he runs by its side." [110]

Students might even consider the above, and other similar original source testimonies, in light of modern scientific research on fat-adapted aerobic activity, including the use of ketones as an energy source. The metabolic state of ketosis is defined as the elevation of the ketone bodies D-beta-hydroxybutyrate (R-3hydroxybutyrate) and acetoacetate in the body in response to the consumption of a diet low in glucose and high in fats, or following long periods of fasting. [111] A number of recent studies have suggested that the metabolic use of ketones may benefit long periods of medium-intensity movement by reducing the need for regular consumption of carbohydrates. They have focused on the ability of endurance athletes to maintain or perhaps even increase performance whilst consuming a high fat diet (endurance exercise, such as long hunts, may incorporate adaptations that increase fat-burning capacity whilst preserving glycogen breakdown). [112] Students and researchers might consider the possibility that some indigenous communities prior to European contact would at least have cycled between periods of keto-adaptation and period of glucose-burning, depending on the season. It has certainly been suggested that communities in the northernmost parts of Canada and Alaska have historically utilized ketogenic or keto-adapted diets, burning fat obtained from meat and fish rather than glucose as a primary fuel for many months of the year (though some have criticized these studies and suggested that Eskimo and other communities have always relied on glucose broken down from glycogen to an extent). [113]

Though much more research is needed to determine the nature of fat burning during physical exercise, a useful hypothesis can be gleaned by noting that many Native Americans undertook long hunts over several hours at just the point in the season when they may have benefited from increased endurance due to their fat-adapted metabolic states and high fat consumption. Any European disruption to winter hunts, according to such a proposition, would also have disrupted ancestral metabolic patterns that incorporated seasonal fat-adaptation, or even seasonal ketosis. Fat-adapted metabolic diets have been found to be therapeutic for a number of medical disorders, particularly but not only neuropathies. Evidence of their potential health-promoting benefits, at least in periodic cycles, might also support the hypothesis that disruption to ancestral metabolic cycles could have prevented other benefits that are as yet unknown, pending further scientific research – thus potentially exacerbating Native American susceptibility to infectious diseases following European contact. [114]

DOI: 10.15310/2334-3591.1014

Of course, students would be encouraged to examine confounding evidence to such a hypothesis. In this case, for example, they might consider the historical record for Tarahumara communities in Northwestern Mexico, who ran great distances through the colonial era while eating comparatively few animal meat products. A similar association could be found with historic Apaches and Hopis, both of whom ran for long distances with a diet dominated by maize, squash, and beans. To be sure, it is ambiguous whether, historically, Tarahumaras relied solely on plant carbohydrates and proteins from beans, or whether such an account represents a teleological extrapolation from their diets which were examined during the second half of the twentieth century. [115] But students would certainly be able to note the association between their high starch diet and their high-distance aerobic activities (they were a subject of Christopher McDougall's popular book, *Born to Run: A Hidden Tribe, Superathletes, and the Greatest Race the World Has Never Seen*). Yet even here, other analytical indicators might become relevant. Several studies have shown low plasma cholesterol levels for modern Tarahumaras, at least in regard to HDL. But other studies have also shown relatively high levels of cardio-respiratory problems in rural populations who have maintained a high starch diet while decreasing their physical movement. That is to say, the problematic effects of high blood glucose might have been mitigated by intense exercise burning the substance for fuel rather than raising insulin to a sub-optimal level. [116]

The Tarahumara case study might even lead students to ask a further set of questions, which speak to recent research by O'Keefe and others on burning glucose during periods of aerobic endurance activity. Compared to long-distance aerobic activity in a (potentially ketotic) fat-adapted state, students might ask, what are the long term consequences of burning glucose for fuel in a high state of oxidative stress, such as long distance running and hunting? Oxidative stress can be defined as the increased production of oxidizing species or a significant decrease in the effectiveness of antioxidant defenses, such as glutathione, in association with intense consumption of oxygen during periods of activity (most often fueled by blood glucose). Even if exercise may have prevented glucose from being stored as fat among Tarahumaras, and lowered inflammatory markers, oxidative damage due to their metabolic state during exercise may have portended problematic cardiovascular health outcomes. [117]

Conclusion: Native-American history and public health education

Ongoing scientific discussions about optimal nutritional health - as defined in peer-reviewed studies – should help to inform our historical understanding of the contact period between Europeans and Native-Americans, from the sixteenth century through to the nineteenth century. Students should be in a position to question the perception of nomadic hunting as the only indigenous Native American nutritional and ecological practice in the three centuries following European contact. The regular or seasonal consumption of hunted wild animal products was not antithetical to horticultural cultivation. Both were often complementary during the pre-contact era, providing micro-nutrients and macro-nutrients that varied according to the season. Distrust of European agriculture – including its perceived association with the spread of diseases – did not require Native-Americans to conceive of themselves as a people who eschewed ecological cultivation altogether.

If any generalizations are to be made, rather, students would be better off examining the ways in which Native American populations perceived colonial farming as a threat to their own land management of crops (such as squash, seeds, and chenopods) *as well as* to their continued hunter-gatherer activities outside indigenous cultivated settlements. We ought to examine the existence of both ecological systems in order to consider their distinction from those that followed the European encounter. During the era of contact, horticulture declined. But although hunting and gathering increased in response to colonial pressure on cultivated plants, its character and regional context changed in order to accompany new European technologies, often deployed in new lands. Those communities who migrated to the Great Plains – whether from the

East, the West, or the Northern Great Lakes – eventually suffered from diminishing access to hunted animals, without the potential to mitigate that loss through renewed horticulture sustenance. The same phenomenon also often occurred among Native American communities who remained at the site of first European contact.

As is evident in the tragic history of Native American health and ecology in the three centuries after first contact, then, external interventions in the indigenous food system may well have contributed to heightened susceptibility to infectious diseases and near demographic collapse. The modern scientific literature on nutrition and health should inform our understanding of the negative health outcomes that were associated with diminished access to indigenously cultivated crops and/or hunter-gathered animals and plants. In evaluating declining health after European contact, students and researchers should assess the effects of curtailed hunting and gathering, the threat to pre-contact forms of horticulture, and the colonial misunderstanding of their symbiosis. Such an assessment could be informed by our understanding of the nutritional and ecological changes that accompanied the introduction of infectious diseases: a greater threat from zoonotically spread pathogens; diminished access to fats, fat soluble vitamins, proteins and essential minerals from animal and plant sources; an increasing inability to gather potentially beneficial indigenous starches and Resistant Starch sources; a growing threat to seasonal oscillations between winter higher fat diets and summer starches; and even a decline in cyclical ketosis in some regions. In light of current research on the relationship between nutritional density and immunity, and metabolic syndromes, diminished access to indigenous food sources can be related to the greater vulnerability to infectious diseases, above and beyond the differing historical immunities that distinguished Native Americans from Europeans.

Questioning or modifying the Biological Exchange thesis should help students and researchers evaluate an important and ongoing question in public policy: historically, since European colonization efforts, why have top-down political interventions in nutrition so often accompanied a decline in ancestral health principles, health, and fertility? Indeed, such a correlation is suggested by events following the three centuries of European colonization, from the mid-nineteenth century to the present day. They might offer important insights as a concluding section or even a postscript to the proposed course, connecting the colonial period to the contemporary era. In 1867, for example, the Treaty of Medicine Lodge required Southern Plains Native Americans to give up land in return for government annuities. The federal government then began supplying them with food handouts, using the industrial and transportation systems developed to supply troops with grains during the Civil War. [118] The containment of Native Americans in reserves severely limited the physical activity to which their communities had grown accustomed over previous centuries. It has been suggested that their decreased energy expenditure would have made them less likely to burn increasing volumes of glucose in their diet, contributing even further to the development of diabetes and other immune disorders through the twentieth century. [119]

Students and researchers would do well to examine the correlation between the Treaty of Medicine Lodge, other similar documents, and declining nutritional health among Native Americans during the post-colonial era. Aleš Hrdlička, a medic and an anthropologist, reported in his 1902 *Physiological and Medical Observations among the Indians of Southwestern United States and Northern Mexico* that obesity and associated “grave disease[s] of the liver” were “exclusively” found among Pima Indians on new reservations, rather than among those who relied on a more traditional system of hunting meats and gathering or cultivating fibrous seeds, chenopods, plants, and starchy tubers. Over the following half-century, most physicians and researchers among the Pima Indians avoided the conclusion that a more sedentary lifestyle was the decisive factor in the degradation of health on communities. Instead, many drew a correlation with the increase in processed starches and high sugar beverages among reservation Pima communities, in contrast to those who lived away from those regions that came to rely on federally-sanctioned processed foods. The health of these Native American communities, then,

DOI: 10.15310/2334-3591.1014

was impacted by new federal food and land policies; just as earlier colonial interventions impacted their nutritional lives in problematic ways. [120]

Among other resources for such a conclusion and/or postscript to their course, students could use Annual Reports of the Commissioner of Indians Affairs. The reports provide evidence from Indian Territory (Oklahoma) between the 1820s and the 1930s, describing nutritional changes, diseases, perceived health problems, and ecological and agricultural developments. Students could also assess Indian and Pioneer Papers, which detail thousands of interviews of residents of Oklahoma in the 1930s. Many of those residents were elderly and recalled nutritional, agricultural, and health developments that took place over the previous century. Students – and future researchers – might even consult advertisements from "Indian Territory" newspapers. Their proliferation of cures, tonics, and "snake-oil" medicines for digestive problems after the Civil War era might provide clues to problematic dietary changes among Native Americans; changes that resulted in part from disruptive state and federal policies that were contiguous with challenging interventions that took place during the earlier colonial eras.[121]

Into the most recent era, indeed, reservation communities have been more susceptible to certain problems that are associated with the modern western diet, as broadly defined during the second half of the twentieth century – particularly its reliance on refined carbohydrates in packaged and processed goods. From the 1960s to the 1970s, for example, medical researchers began to define a clear correlation between the appearance of obesity and Type II diabetes in Native American communities and their adoption of processed foods in federal welfare programs that targeted newly formed reservations. Reports of Type II diabetes among Oklahoma communities increased after their move into federally-mandated reservations through the 1940s. A review of literature from 1832 to 1939 by the epidemiologist Kelly West found no reports of diabetes among the Kiowa, Comanche or Apache communities living in the region (though this does not exclude the possibility that undiagnosed symptoms were present). What is certain is that by the 1960s diabetes had reached epidemic proportions. [122] Similarly, diabetes seems to have been much less prevalent among Pima Indian populations who lived *away from* reservations in the American Southwest before 1940. By the turn of the twenty-first century, however, around half of all Pima Indians have been reported to suffer from diabetes. [123]

Following their analysis of early contact history, students might consider these more recent phenomena in light of modern scientific literature on metabolic syndrome. According to federal statistics from the present day, moreover, Native American communities continue to suffer from diabetes, cirrhosis, influenza, pneumonia, and perinatal and early infancy diseases at greater rates than the general American population. [124] Yet as the USDA nutritional guidelines for the Food Distribution Program on Indian Reservations (FDPIR) program demonstrate, Native American populations will continue to receive food welfare in the form of packaged and processed starches, seed oils, and low fat animal sources – foods that have potentially contributed to increasing metabolic syndrome in the US population more generally. [125] As they try to understand possible correlations between the two scholarly fields of history and nutritional science, therefore, students and researchers might begin to think about problematic nutritional interventions and paradigms outside the Native American community, among the American public more generally. The study of early-American history and the problematic European intervention in Native American nutritional life should inform their future careers in fields such as public health, scientific research, nutritional science, and medicine.

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