Diet as a Double-Edged Sword:

The Pharmacological Properties of Food Among the

Waorani Hunter-Gatherers of Amazonian Ecuador

by

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A Dissertation Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

Approved October 2012 by the
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ARIZONA STATE UNIVERSITY

December 2012

ABSTRACT

Food system and health characteristics were evaluated across the last Waorani hunter-gatherer group in Amazonian Ecuador and a remote neighboring Kichwa indigenous subsistence agriculture community. Hunter-gatherer food systems like the Waorani foragers may not only be nutritionally, but also pharmaceutically beneficial because of high dietary intake of varied plant phytochemical compounds. A modern diet that reduces these dietary plant defense phytochemicals below levels typical in human evolutionary history may leave humans vulnerable to diseases that were controlled through a foraging diet. Few studies consider the health impact of the recent drastic reduction of plant phytochemical content in the modern global food system, which has eliminated essential components of food because they are not considered "nutrients". The antimicrobial and anti-inflammatory nature of the food system may not only regulate infectious pathogens and inflammatory disease, but also support beneficial microbes in human hosts, reducing vulnerability to chronic diseases. Waorani foragers seem immune to certain infections with very low rates of chronic disease. Does returning to certain characteristics of a foraging food system begin to restore the human body microbe balance and inflammatory response to evolutionary norms, and if so, what implication does this have for the treatment of disease?

Several years of data on dietary and health differences across the foragers and the farmers was gathered. There were major differences in health outcomes across the board. In the Waorani forager group there were no signs of infection in serious wounds such as 3rd degree burns and spear wounds. The foragers had one-degree lower body temperature than the farmers. The Waorani had an absence of signs of chronic diseases

including vision and blood pressure that did not change markedly with age while Kichwa farmers suffered from both chronic diseases and physiological indicators of aging. In the Waorani forager population, there was an absence of many common regional infectious diseases, from helminthes to staphylococcus. Study design helped control for confounders (exercise, environment, genetic factors, non-phytochemical dietary intake). This study provides evidence of the major role total phytochemical dietary intake plays in human health, often not considered by policymakers and nutritional and agricultural scientists.

DEDICATION

I would like to dedicate this dissertation to the three people without whose help I would likely never have finished this work. I would like to thank my wife Taxa for having the courage and faith in me to accompany me into the deep reaches of the Amazon jungles and confront without complaints the extreme isolation, poisonous snakes, insects and very different hunter-gatherer existence we became accustomed to while I did my research. Taxa put up with five years of my work in graduate school, with my eyes glued to a computer screen, things that only a wife of a graduate student would understand. Thanks a million for all your patience and support. To my mother Elizabeth Margaret Stuart London, who gave me support and encouragement throughout my life, including graduate school and the dissertation process. I only hope I give in the same manner and measure to my children as my mother has done for me. Mom, you have always been there. Finally my advisor Dr. Takeyuki (Gaku) Tsuda who went above and beyond the call of duty as committee chair and advisor in providing advice, intellectual and professional support through very difficult challenges throughout the entire dissertation process and all the many stages and years that proceeded it in graduate school. As I continue my career I will always look at Dr. Tsuda as a great example of how academia should be, and will try to give support and encouragement to my students and colleagues in the same manner as Dr. Tsuda.

~ My admiration, respect and affection towards all of you are beyond words ~

ACKNOWLEDGMENTS

I would especially like to thank my dissertation committee members Dr. Bonnie Beezhold, Dr. James Eder, and Dr. Dan Hruschka. I have been very fortunate, compared to most graduate students, to have a model dissertation committee. They all offered support and enthusiasm, and gave many hours of personal time to help with this multifaceted dissertation project. Not one of them ever missed an office visit with me or a dissertation deadline in spite of their very busy schedules, which is truly remarkable. Talking to other students I realize how fortunate I am to have such a group of scholars who give a lot of time to students and yet are top researchers in their field.

I would like to thank my Waorani study assistant Ima Enqueri who spent many months in the rain forest with me cutting through the undergrowth to identify plants and animals. I would also like to thank my other Waorani students, Oyowa, Omeway, Kemo and Winame from whom I learned more from than I was able to teach. Also Kai and Aneaneto, great Waorani hunter-gatherer warriors and leaders who invited me to be the first foreigner to stay in their community and have continued to welcome me back to Kawymeno over the years. Many thanks go to Jack Jaramillo, Ministry of Education teacher. While officials in the outside world neglected the Waorani, Jack has been an ally and advisor to them for decades. I hope the people Jack has helped so much appreciate the sacrifices and lifelong dedication to Waorani welfare he has made.

In addition I would like to thank my Kichwa Assistants who performed the same role as my Waorani assistants but in the Santa Teresita Kichwa community.

Kichwa assistants include Yasuni National Park Rangers and native Kichwa guides, Belezario and Juan Carlos.

Special thanks also go to the staff of the Franklyn Tello Hospital working in the remote Amazon rain forest, particularly to Dr. Manual Ammunariz, director of the hospital, for his valuable assistance with data collection and logistics. Also appreciated is collaboration from the Ministry of Health and the Ministry of Education, and Fulbright Foundation of the government of Ecuador.

Many thanks to Amazonian ethnobotany specialist Dr. Chris Canaday and his wife Teresa Shiki, biologists and indigenous plant use experts at the Omaere Ethnobotanical Park in Puyo, Ecuador who assisted me with the identification and scientific names of food plant species. Thanks to colleagues who helped with editing and statistics of the dissertation, especially Alanna Ossa who generously helped me for several years as well as Jason Scullion, Emma Starling, Jennifer Pinney and Kara Gill. Thanks to Arnie and Lois Tepfer for their great help at the end of this dissertation process and Donald Kelly and Zeenat Hasan for their wonderful logistical support during the entire dissertation process.

Finally, I would like to thank the following institutions for their generous financial support without which this research would not have been possible: The Wenner-Gren Foundation, the Fulbright Foundation, the U.S. Department of Education, and my own department The School of Human Evolution and Social Change at Arizona State University.

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INTRODUCTION

This study used a plant-human, co-evolutionary health model to compare and evaluate the relationship between hunter-gathering and farming food systems, and health across two Ecuadorian Amazon indigenous groups, the last true Waorani hunter-gatherer group in Ecuador, and the other, a remote neighboring Kichwa indigenous community practicing subsistence agriculture. Under consideration is the pharmaceutical rather than just nutritional properties of human diet, and the impact on human physiology of natural plant phytochemicals present in foods humans have consumed daily throughout human evolution. Ancient ethnic food systems such as those of the Waorani forager population may not only be nutritionally, but also pharmaceutically beneficial because of high dietary intake of varied plant phytochemical compounds. A modern diet that reduces these dietary plant defense phytochemicals below levels typical in human evolutionary history may leave humans vulnerable to diseases that were controlled through a foraging diet. This dissertation defines phytochemicals as biochemicals that plants produce to survive, which interact and influence relationships with other life forms rather than serve an internal structural, physiological or nutritional function for the plant itself. Phytochemicals are the focus of this dissertation. Few studies consider the health impact of the recent drastic reduction of plant phytochemical content in the modern global food system, which has eliminated essential components of food because they are not considered "nutrients". The antimicrobial and anti-inflammatory nature of the food system may not only regulate infectious pathogens and inflammatory disease, but also affect all microbes in human hosts, including those that are beneficial to normal

human biological functioning, thus reducing vulnerability to certain chronic diseases, as well as infectious disease. This may explain why Waorani foragers seem immune to certain infections and have very low rates of chronic disease. Does a return to certain characteristics of a foraging food system begin to restore the human body microbe balance and inflammatory response to evolutionary norms, and if so, what implication does this have for the treatment of disease?

The paradoxical nature of food due to its phytochemical rather than nutritional content implicitly underlies much of the dissertation and is referred to as "a double-edged sword" in the title. The case is made that the beneficial phytochemical aspects in human dietary intake while balanced in a hunter-gathering diet are transformed into a double edged sword beginning with the start of subsistence agriculture and magnified by more recent radical food system changes brought about by industrialized agriculture and modern food systems. The potentially devastating effects on human chronic and infectious diseases caused by ignoring the phytochemical content of food is emphasized throughout the dissertation.

We lived for several years with these isolated indigenous Amazonian communities, camping in the rainforest, many days travel from the nearest town. Data on dietary differences between the foraging and subsistence farming groups and their potential health consequences was gathered. My data was assembled from among others: medical examinations, including vision and blood pressure, lab tests including, urine and stool samples, anthropometric measurements such as BMI and MUAMC, activity and exercise levels, public health data, dietary surveys, food system surveys,

including mapping out of all food species consumed by both groups, language analysis describing food flavors and smells and finally, participant observation of hunting, fishing, gathering, food preparation and daily life. In the forager group, there were no signs of infection in serious wounds such as 3rd degree burns and spear wounds that penetrated through the entire body. The foragers had over a one degree Fahrenheit lower average population body temperature than the Kichwa farmers. There were major differences in health outcomes across the board. For instance, there was an absence of chronic diseases among the Waorani, in addition vision and blood pressure did not change markedly with age in the Waorani, while Kichwa suffered from both chronic diseases and many physiological indicators of aging. In the Waorani forager population, there was an absence of many infectious diseases, from helminthic parasites to staphylococcus aureus, which are common to the Kichwa and other neighboring isolated Amazonian indigenous subsistence agriculture populations. The study design helped control for confounding variables such as exercise, lifestyle, environmental, genetic factors and non-phytochemical dietary intake. There is evidence from multiple facets of this study of the major role total phytochemical dietary intake plays in human health outcome, something that is usually not considered by policymakers or nutritional and agricultural science.

Study results will contribute to public health dietary intake recommendations for dietary-related diseases in modern food systems, as well as contribute to recommendations for inclusion of phytochemicals in food production for the agro-food industry, nutritional science and the U.S. (and other countries) Department of Agriculture.

Overview of the contents of the dissertation chapters

This dissertation has 24 chapters and is almost 700 pages long, thus, a brief review of each chapter's content is provided below to help the reader locate the particular topic that they wish to view. The dissertation interweaves the complexities of two food systems and two sets of corresponding population health outcomes. Outstanding and long-term collaboration on the part of the study participants produced a wealth of data to cross-analyze and synthesize. This dissertation presents extensive primary evidence from the field while at the same time advancing theory by creating a potential dietary paradigm to explain primary study data results and evidence through an interwoven theoretical framework spanning a number of scientific disciplines often not linked together.

Chapters 1 and 2 of the dissertation start with an overview of previous research on ancestral diets including evidence that links hunter-gatherer diets to positive human health outcomes. A literature review compares hunter-gatherer food systems and agriculture food systems.

Chapter 3 introduces a core focus of the rest of the dissertation, the co-evolutionary relationship between plants and humans. The physiological and biochemical interactions between the production of phytochemicals by plants and their ingestion by humans is covered. Discussion includes the change in health status that may be due to greatly modified phytochemical ingestion as humans leave the ecological systems they have lived in for 99% of human history and move into agricultural systems largely divorced from former phytochemical links to the surrounding natural environment. Key topics include the role of

phytochemicals in plant defense against other plants, parasites and herbivores. The pharmacological impact of phytochemicals in the human body is another topic started in chapter 3, specifically what effect natural phytochemical pesticides have when ingested particularly on microbial and parasite populations in human hosts and any resulting microbial or parasitic based disease. In addition the role of phytochemicals in plant-human communication and the existence of phytochemicals outside of plant-based foods in animal flesh are also discussed.

In chapter 4 the dissertation moves into description of the actual field sites in the Amazonian rain forests of Ecuador and study populations, namely Kawymeno Waorani hunter-gatherers and Santa Teresita Kichwa subsistence farmers, covering both past history and modern situation. Included in the chapter is the unusual opportunity presented by the field site to control confounding non-phytochemical factors, which is followed up in later chapters.

In chapter 5 the study hypotheses and methodology is reviewed. This dissertation study is very much a mixed methods study spanning quantitative and qualitative methodology from various disciplines, utilizing techniques from the fields of medicine, nutrition, anthropology and public health. Techniques include ethnographic participant observation, laboratory tests, medical and physical examinations, diet and health focus groups and population surveys and extensive ethnobotanical data on the characteristics of both food systems' edible species. In addition novel study methods are justified and data analysis techniques are explained.

In chapter 6 the novel dissertation methodology of giving back to the community through the training of community health promotors, while simultaneously collecting study data is described. The benefits and a few disadvantages of providing community aid coupled with data collection are discussed.

Chapters 7-11 describe and compare both Kawymeno hunter-gatherer and Kichwa subsistence farmer food systems making extensive use of charts, tables and photos. Chapter 7 compares the overall dietary differences and similarities across the Waorani hunter-gatherer and Kichwa farmer study groups including a table identifying and characterizing all food species used by both the Waorani and Kichwa communities. Additional comparisons are made across study food systems, among others the effect on dietary intake of phytochemicals of factors such as intake of wild versus domestic food species, diversity of food species, frequency and type of edible food species consumption, and preparation of food. Chapter 8 focuses on the advantages and disadvantages of the ingestion of several classes of food in terms of quality of phytochemical intake and potential health implications. Plant food flavor and to some extent animal food flavor until recently was often a property of the phytochemical content. Among others the negative health implications of eating phytochemicals from non-fruiting vegetables versus fruit is discussed. Chapter 9 discusses animal food sources and the food chain that links animal foods eaten by hunter-gatherers and farmers back to these previous animals consumption habits and retention of plant phytochemicals all the way along the food chain. Other topics include the

relationship between plant fruiting seasons and the resulting rotating phytochemically based animal flesh flavor/scent that can actually drive human dietary intake decisions in the case of the Kawymeno Waorani hunter-gatherers. Chapter 10 focuses on the spider web-like wild food chain of phytochemical tapestry with the wealth of biochemicals is distributed in a circular function in comparison to the more linear-like food chain in agriculture. Chapter 11 describes the large vocabulary the Waorani have for taste and smells of phytochemicals in food, which may provide clues as to how a sense of taste and smell may be programmed through evolution to aid in dietary intake of appropriate phytochemicals that actually maintain health by preventing disease. Further discussion involves the way an evolutionary based sense of taste and smell may become maladaptive when humans are placed in a modern food system bereft of foods with tastes and smells based on phytochemical content and replaced by foods with flavors unrelated to the actual food being eaten.

The health outcome chapters compare the almost across the board differences in health status between the Kawymeno Waorani hunter-gatherers and the Santa Teresita Kichwa farmers using tables, charts, figures and photos. Chapter 12 shows how the dissertation study controlled for confounding variables such as exercise, genetics, environment, isolation from any access to sanitation and western health care, age, contact across the study groups, regional pathogens, drinking water and non-phytochemical dietary intake. In chapter 13 the remarkable absence in the Kawymeno Waorani of any signs of infection and inflammation in external wound healing processes as well as the absence of

disease and inflammatory symptoms in diseases below skin level. The presence of these disease and inflammatory responses in the neighboring Santa Teresita Kichwa farmers that are absent in the Waorani hunter-gatherers is discussed. The potential role of plentiful intake of varied antimicrobial phytochemicals in hunter-gatherer diets may have in controlling microbial infections and inflammatory responses is examined. Explanations as to why the Kawymeno Waorani seem largely immune to so many endemic microbial infections but remain vulnerable to virulent disease transmitted from outside groups is debated. Chapter 14 is devoted to the role phytochemicals may play in the curious lack of degenerative eye disease as well as absence of change in visual acuity of the Kawymeno Waorani as they age, especially in contrast to the neighboring Kichwa population's poor eye health. Studies on modern populations demonstrating dietary phytochemical impact on eye health are debated. Chapter 15 discusses why the Kawymeno Waorani have one of the world's lowest recorded blood pressures and how the ingestion of wild rain forest phytochemicals known to lower blood pressure may impact cardiovascular disease and blood pressure, especially relevant since this dissertation study controls for exercise and other culprits typically invoked by researchers. Other disease processes and absences such as malaria, leishmaniasis, dental health, venomous snakebite and fungal diseases are discussed in chapter 16.

Dissertation study results demonstrate an absence of helminthic worm parasites in a Kawymeno Waorani hunter-gatherer population with the world's highest recorded IgE antibody levels while nearby Kichwa communities have

ample helminthic infestations and lower IgE antibodies. This conflicts with a theory called the Helminth Hypothesis. Chapters 17 through 21 take a critical look at the Helminth Hypothesis, a key underpinning of modern medical theory and practice, by critically examining the linking of the supposed increase in IgE levels and protection against disease due to the presence of these parasitic helminthic worms. Evidence from modern hunter-gatherer literature, archeological evidence of Paleolithic hunter-gatherers along with modern medical studies are all critically reexamined and synthesized with dissertation study results. The case that dietary intake of phytochemical rather than helminth presence provides a better explanation for increased IgE and protection against disease is presented.

Going beyond chronic and infectious diseases, the final chapters 22 and 23 discuss how phytochemicals, and the plants that produce them may have had some control over human hormone cycles, particularly reproductive cycles in ancestral hunter-gatherer humans. A history of unusual birth spikes for 15 years occurring in the same month every year coincides with the peak season of *Curarea tecunarum* 9 months beforehand in the study hunter-gatherers group. The potential link to modifying male Waorani fertility hormone levels through high dietary intake of phytochemicals from the plant used to make curare blowgun dart poison (Curarea tecunarum) is discussed. Extracts from the vine *Curarea tecunarum* are known to affect fertility hormones in other Amazonian tribes.

The conclusion chapter provides policy recommendations based on evidence from this dissertation study. Recommendations regarding modifying the dietary intake of industrialized humans to promote appropriate individual phytochemical consumption are given. On a more macro-scale recommendations for specific techniques for producing agricultural crops with a healthier variety and balance of phytochemicals are provided. This chapter also details modern obesity's links to satiation problems that may be created by the occupation of receptors in the human body, which are evolutionarily designed to receive phytochemicals but in modern society are replaced with ingredients that mimic plant phytochemicals, namely artificial and novel ingredients from modern food systems and drugstore pharmaceuticals.

CHAPTER 1

ANCESTRAL DIET RESEARCH

Twentieth Century Research on the Ancestral Diet

This dissertation study adds to the fields of public health, medicine and nutrition. However, this dissertation topic is most closely related to Ancestral Diet Research, which is often brought under the umbrella of the research field called Darwinian Medicine or Evolutionary Medicine. The underlying view of much of the work in Evolutionary Medicine is that natural selection has not caught up with the principal new change in modern humans, namely the rise of agriculture (Eaton, et al., 1988, 1994). This derives from the theory that human physiology is adapted to a lifestyle similar to that of ancestral hunter-gatherers.

The diet of hunter-gathers was a subject of minor interest for those concerned with improving human health, perhaps because it was assumed, until very recently, that agricultural diets were superior to hunter-gather diets. In any case prior to the 1960s there were very few quantitative studies on nutritional components of hunter-gather diets anywhere in the world and the literature on hunter-gatherer diets consisted mostly of ethnographic accounts. These ethnographic descriptions make up the vast bulk of literature on hunter-gatherer health and nutrition up until the mid-20th century.

The modern field of nutrition did not start until well into the 20th century, the term vitamin was not coined until 1911, and most individual vitamins and essential amino acids were identified much later.



Figure 1. Kawymeno Waorani Hunters Returning from a Hunt

It was not until 1943 that the US Food and Nutrition Council published its first attempt at a table of dietary standards, which even today is a work in progress. The food pyramid and other visual attempts to educate the public about what was believed to be a good diet came out of this era.

Thus, there was very little primary research on specific nutritional requirements of hunter-gatherers in the 20th century. The direct connection between diet and disease was usually not a primary focus of these past hunter-gatherer studies. Most scientific scrutiny of nutrients was focused on domesticated plants. The effect of diet on infectious disease was largely restricted

to body growth, body composition and body function in subsistence ecology studies of hunter-gatherers.

The field of subsistence ecology was one of the dominant focuses of hunter-gatherer food studies in the late 20th century. Subsistence ecology focuses on the dynamic interplay of biological evolution, cultural adaptations and the environment in hunter-gather societies (Lee and DeVore, 1968; Dalberg, 1981; Sahlins, 1972). Twentieth century work on diet and health of hunter-gatherers has been synthesized by a number of authors (Lee, 1968; Hayden, 1981; Cohen and Armelagos, 1984; Cohen, 1989; Kelly, 1995; Sackett, 1996; Eaton, et al., 1997).

However, while the focus of the research literature on hunter-gatherers was on subsistence ecology, an interest in diet – going beyond just being a factor in shaping subsistence behavior – only began to emerge in the late 20th century. There is a growing awareness in the 21st century that the real baseline and norm of the human diet is hunter-gathering, which this dissertation will refer to as the Ancestral Diet. Ancestral Diet research provides potentially invaluable insight into the connection between dietary intake and health outcomes in modern societies that may be difficult or impossible to get through other types of research.

In the United States and most Western countries, diet-related chronic disease represents the single largest cause of morbidity and mortality and afflicts 50-65% of the adult population, yet these conditions are rare or non-existent in hunter-gatherers and many less-Westernized populations in individuals who attain the same advanced ages (Cordain, 2005; Eaton, 1985; Leaf, 1987; Simopoulos, 1991).

However, food systems that involve a more strict hunter-gathering diet have dwindled from inclusion of almost all humans throughout 99% of human history to scattered examples in the 19th and most of the 20th century, to extremely rare in the 21st century. Examples of existing diets that rely primarily on hunter-gathering still exist in small numbers in remote parts of the Amazon rainforest in South America and perhaps New Guinea.

Nutrition is still a young science in 2012 compared to many other human health fields of research. For example, infectious disease has been the focus of research for centuries, while the interest in the connection between diet and disease has attracted a lot of interest more recently. Medical doctors up until recently received no training in nutrition in their medical curriculum. Nutritional sciences do not have a functional evolutionary foundation. Biological sciences such as nutrition are supposed to be founded and based on the theory of evolution and its tenant of natural selection. Thus, I would argue the nutritional sciences are still not a true biological science. If nutritionists adopted evolutionary theoretical grounding, which ancestral research requires, this would provide an overall guiding structure for the entire discipline. Furthermore, by considering the hunter-gatherer food system as the evolutionary base, that would put all nutrition research more firmly into the fold of biological science and make all nutritional findings more coherent and theory-driven.

Evolution, Natural Selection and Ancestral Diet Research

The central tenants of natural selection form the foundation from which the Ancestral Diet argument is built. Futuyma succinctly describes the key points of natural selection that are pertinent to the Ancestral Diet rationale:

> Characteristics selected (through natural selection) here and now are not necessarily the best of all possible characteristics; they are simply the most suitable of those currently available. The characteristics evolved under one set of circumstances may prove inappropriate for subsequent environments, yet because prior evolution determines the evolutionary paths that a species can subsequently take, the species may be stuck with inappropriate features. Organisms cannot evolve adaptations for future events that are different from past events to which they have already adapted. Current genotypes are random with respect to future advantage. Consequently, the direction of evolution can vary as the environment fluctuates and extinction is a major function of evolution. (Futuyma, 1997, p. 19-32)

As Futuyma states in the final line of the quote above, the direction of evolution varies when environmental changes require different physiological abilities to survive and creatures such as humans cannot undo the genetic realities and complexities that are built into them when they adapted to a previous food chain and surrounding ecological reality. This is because, unlike microbes and plants, humans are particularly slow to adapt genetically to change. Many researchers studying the ancestral diet have suggested that humans must re-create a connection to a food chain and accompanying eco-system similar to what

humans were genetically programmed to live in (Eaton & Konner, 1985; Eaton et al 2002).

Ancestral diet research. In a series of papers starting in the 1980s up to the present, S. Boyd Eaton, Loren Cordain and many colleagues have developed a model for what they argue is a valid description of the central tendency of hunter-gather diets (Carrera-Bastos, et al., 2011; Cordain, 1999; Cordain, et al., 2001, 2002, 2005, 2006; Eaton & Cordain, 1997; Eaton & Eaton, 2000; Eaton & Konner, 1985; Eaton et, al., 1988, 1992, 1998, 2002, 2002a, 2003; Leaf & Weber, 1987; Strassman & Dunbar, 1999). Their work is based on previous research by Hayden and Lee as well as other authors who studied modern hunter-gather groups in the 20th century whose work is cited in the previous paragraphs (Hayden, 1981; Lee, 1968). This group of Ancestral Diet researchers has put together a remarkable picture of what the hunter-gatherer diet and life may have been like in prehistoric times, a composite that has had great influence recently on the general public's dietary habits and is shaping the way researchers think about the diet-disease connection. However, there have been few actual primary studies on living hunter-gatherers to confirm their theories and few of these authors have ever worked with a hunter-gatherer group. In fact, not all of their ideas are supported by primary research results from this dissertation. The Evolutionary Medicine's basic premise regarding ancestral diets is: "our genes determine our nutritional needs and the selective pressures of our Paleolithic diet shaped our genes" (Eaton, et al., 1988). The commonly expressed truism "we are what we eat" is familiar to most Westerners. In a nutshell,

researchers studying the Ancestral Diet have augmented this truism to state that "we are more than what we eat; we are also what our ancestors ate".

Eaton suggests that most of the human genome comprises of genes selected during the Paleolithic Era in Africa, which lasted from 2.5 million years ago to about 11,000 years ago (Eaton and Konner, 1985; Eaton, et al., 1988). Eaton further suggests that the modern changes that occurred in diet and lifestyle, particularly the post-industrial agricultural period up to the 21st century, have created a diet and lifestyle vastly different than the evolutionary human norm, and on too recent an evolutionary timescale for humans to have made adaptations or compensations either genetically or physiologically.



Figure 2. Stem Used by Waorani as Knife to Cut Everything from Umbilical Cords to Peccary Meat

However, researchers interested in Evolutionary Medicine and the Ancestral Diet need to take into consideration the fact that most of the human genome predates hominoids. Genetically, humans have influences from their pre-human ancestral line proceeding the 2.5 million year Paleolithic era, an important critique on Eaton and other researchers' assumptions (Strassman and Dunbar, 1999).

The enormous differences in dietary intake and lifestyle between the Paleolithic human diet and modern human diet are still being cataloged and

recognized by Ancestral Diet researchers. Loren Cordain, S Boyd Eaton, and more recently many other authors, have combined forces to put out a series of seminal papers listing in increasing detail what hunter-gatherers ate and the health consequences for modern humans (Carrera-Bastos, et al., 2011; Cordain, 1999; Cordain, et al., 2001, 2002, 2005, 2006; Eaton & Cordain, 1997; Eaton & Eaton, 2000; Eaton & Konner, 1985; Eaton, et al., 1988, 1992, 1998, 2002, 2002a, 2003; Leaf & Weber, 1987; Strassman & Dunbar, 1999). The specific tendencies of what ancestral hunter-gatherers' dietary intake may have looked like according to their research is elaborated in the food system results chapters.

These Ancestral Diet arguments rely largely on a comparison between hunter-gathering and modern large-scale agricultural diets, whereas subsistence agriculture is largely ignored in the scholarly literature. The results presented in this dissertation suggest that some profound changes in human health outcomes occurred during the transition from hunter-gathering to subsistence organic agriculture that proceeded large-scale agriculture and food production, which adds to and modifies present state of the art Ancestral Diet conclusions.

A compact version Ancestral Diet research rationale summarized by Eaton and other researchers is stated below:

1. Our gene pool was shaped by natural selection for environments that are far different from the ones in which we now live (Irons, 1998; Strassmann, 1999).

2. There have been some genetic changes since the beginning of agriculture, but natural selection is slow, especially in the case of chronic degenerative disease, so most of our genome remains adapted

for environments in which humanity no longer lives in (Trevathan, 1999).

3. The resulting mismatch between our ancient bodies and the vast and rapid changes in modern life fosters development of chronic degenerative disorders (Wagner, 1998; Waxman, 1998).

"Evolutionary Health Promotion" and Dietary Intake

A group of scientists from a broad range of scientific disciplines interested in the Ancestral Diet have come up with methods for utilizing information gleaned about hunter-gathering life to improve modern human health through public health measures. This method is called Evolutionary Health Promotion (Eaton, et al., 2002). Evolutionary Health Promotion takes a prescriptive role, including modification of modern dietary intake, to reduce the dietary mismatch caused by humanity's agricultural food system experiment.

The Ancestral Diet rationale in the previous section answers the more theoretical "why" question regarding the increasing occurrence of chronic diseases in modern populations. Another set of simple evolutionary-based research rules suggest how to apply knowledge gained from the study of ancestral diets to the pressing public health problems of the 21st century, as summarized by Eaton below (Eaton, 2002; Mayr, 1961):

1. Characterize differences between patterns of human life in ancient and modern environments.

2. Identify which of these are involved in the initiation and progression of specific diseases.

3. Use this information to design innovative studies of the "proximate" pathophysiology.

4. Integrate epidemiological, mechanistic and genetic data with evolutionary principals to create an overarching formulation upon which to base persuasive, consistent and effective public recommendations.

Critiques of Evolutionary Health Promotion

Dissertation results suggest that the present Ancestral Diet paradigm crediting human evolution as the driving force that has created a mismatch between present and past diet is an over-simplification. Evolutionists like to keep theory simple, direct and avoid the complications within which the social sciences operate. However, dissertation results suggest that the dietary intake mismatch between modern diets and human dietary history is co-evolutionary, not evolutionary, with plants, microbes and other eco-system factors taking a central rather than peripheral position to human evolution. This concept is elaborated on throughout the dissertation. Actually, this more complex co-evolutionary perspective creates hope for solutions to urgent modern dietary-based health problems. Modifying the results of human evolution is not possible in the short term, however modifying the relationship between plants, microbes and humans is feasible and has already been achieved, as the existence of agriculture and biomedical interventions demonstrate. Work on holistic food system modification rather than just changing human dietary behavior creates many more avenues for change.

This dissertation suggests that too much of the emphasis of Evolutionary Health Promotion policy is focused on changing an individual's diet and there is too little focus on creating innovative ideas to modify the modern agricultural food system. There are universal, systemic flaws specific to the modern agricultural food production systems (London, 2005). Systemic food system deficiencies cannot be easily adjusted via modifying individual dietary habits if all the food "choices" are similarly deficient. In addition, the policy by public health institutions of giving nutrition education lessons – such as the USDA Food Pyramid – directed towards individuals is an ineffective intervention if all the food "choices" advocated as healthier come from a food production system with some universal flaws. I have already published in a previous article a systemic rather than individual approach to dietary modification via a functioning agricultural model (London, 2005).

Agriculture and Evolution Agricultural science has made amazing technical advances but at the same time has no long-term sustainable road map and historically reacts to crisis rather than plans proactively or preventatively. An example of the static nature of agriculture discussed earlier is the reliance on crops developed from the Neanderthal age for almost all of the world's human caloric needs (Harlan, 1992). Agricultural science has reacted successfully to the recent worldwide food shortage crisis with the Green Revolution but is clearly not producing food that provides a health outcome even close to a hunter-gatherer system (Murphy, 2008). An excellent guideline exists that provides detailed evidence of how human food systems have existed successfully for millennia –

our hunter-gather dietary heritage. Unfortunately, agricultural science, while clearly an improvement in quantity over hunter-gathering, still operates on the assumption that agriculture is also an improvement in dietary quality over hunter-gathering, when the evidence is to the contrary in almost all food system comparisons including this dissertation's results. While the enormous modern human populations of the 21st century cannot revert to a hunter-gather food system, adoption of some of the most critical components may be within our technical repertoire if we make changes pro-actively. Taking an evolutionary perspective to agricultural production, in addition to nutritional science as discussed earlier, is an important step to developing a theory-driven agricultural discipline that can predict the next food crisis scenario and focus on sustainable solutions.

CHAPTER 2

HUNTER-GATHERING VERSUS AGRICULTURE

Understanding humanity's evolutionary dietary heritage is critical in an era where health costs due to dietary related disease are soaring. This is in part because nutritional science is still a young science and government backed dietary suggestions to the public are founded on growing, but still partial, understanding of dietary needs. The connection between diet and disease is of more than of academic interest; it is vital to the health and future of our society and modern world. Challenging unquestioned dogma that has founded nutritional research core beliefs is important to stimulate conversation in the area of dietary related disease. This dissertation's results make a case that foods have components that are beneficial and right next to each other are other components of the same food that are harmful. Further, sometimes the quantity rather than what the actual food component defines whether the food component fall across the toxic or nutritional/medicinal side of the line. Foods are both nutrients and medications at the same time, as powerful plant-based natural pharmaceuticals are found along with nutrients in all foods. Plant bodies have chemicals designed to preserve plant life, which may or may not benefit those that chose to eat the plant body. To appreciate the paradoxical nature of food necessitates learning about humanity's food system heritage, which is the theme of this chapter.

Hunter-Gathering

For 1.7 million years, from the rise of *Homo erectus* onward through the evolution of *Homo sapiens*, 99% of humanity's existence has been as hunter-

gatherers. The most significant cultural change in the human diet occurred half a million years ago with the beginning of the use of fire, which was used to (1) reduce toxins, (2) kill parasites (3) improve nutrient availability, and (3) soften and preserve foods (Stahl, 1984). During the vast majority of the time humanity has existed, the most successful, adaptive way to survive was to forage in small bands that exploited a diverse range of faunal and floral resources. Such strategies were especially well suited to the turbulent Middle Paleolithic era with its sudden and drastic changes in climate, resulting in a rapid extinction of eco-systems with their constituent plants and animals (Lisiecki, 2005). The mid- to late- Holocene Era climactic period from about 11600BP carrying into the present day appears to be an exceptionally stable global climate compared to other periods in this planet's history. The present stability in the weather may have encouraged the growth of agricultural food systems over the last 10,000 years as agriculture relies on predictable climates (Houghton, 2004). That is not to say that there were no serious climatic variations in the Holocene era, sometimes lasting centuries such as climatic events in 5200BP and 4200BP, and if another such climatic dip occurred now it might end the present existence of modern agriculture.

The archeological record on hunter-gatherer health. Somewhat surprisingly, our study results regarding the exemplary health of hunter-gatherers line up more with what archeologists concluded and less with what anthropologists working with present-day acculturating hunter-gatherers have argued. There are indications from the archeological record that hunter-gatherers were in better health than contemporary early Neolithic farming communities who

co-existed in the same region in similar historical periods (Angel, 1984; Hole, 1992).

There is skeletal and other archeological evidence that the spread of agriculture that often displaced a hunter-gatherer lifestyle produced waves of new diseases (Cohen and Armelagos, 1984a). With intensification of agriculture in the Neolithic Period, this skeletal evidence suggests increased malnutrition and disease became widespread as humans moved away from hunter-gathering and into agricultural lifestyles and diets (Roberts and Manchester, 1995; Cohen and Armelagos, 1984; Cohen and Armelagos, 1984a; Goodman, et al., 1984).

Archeologist George Armelagos and his former graduate students, such as John Lallo, have excavated a fascinating North American site called Dickerson Mounds. In Dickerson Mounds these archeologists excavated a pre-historic population that started as hunter-gatherers and gradually over many generations transitioned to maize farming over many generations. This was a rare opportunity in archeology to examine a single genetically stable group of human's transition into a different food system (Goodman and Armelagos, 1985; Lallo, et al., 1978; Lallo, et al., 1980). Lallo found that following the introduction of agriculture there was a twofold increase in the percentage of children and infants with severe anemia in the farming group compared to their hunter-gatherer predecessors (Lallo, et al., 1978; Lallo, et al., 1980). More than half the infants and children in the farming group had severe anemia as evidenced by type of lesion called porotic hyperostosis, which is a sign of severe nutritionally based anemia and is most easily discernable in thinner bones, such as the skull.

In addition, serious bacterial infections were three times as common in the Dickerson farmers as the Dickerson hunter-gatherers (Lallo, et al., 1978; Lallo, et al., 1980). The Dickerson farmers had a threefold increase in the percentage of individuals that had periosteal lesions in their Tibia (shin) bones over their hunter-gatherer forbearers. Periosteal lesions are a sign of persistent bacterial infections. These periosteal lesions also occurred with more severity in younger agriculturalists while younger hunter-gatherers did not have many of these lesions. There were critics of the bone disease interpretation (Wood, et al., 1992) but Armelagos has come out on solid ground with a seminal study.

The dissertation is a comparison of living human beings from two different food systems. This dissertation comparison between Waorani and Kichwa is a living human version of the archeological studies on human hunter-gatherer versus subsistence farmer at Dickerson Mounds. What is interesting is that our results and conclusions are similar to the archeologists and in disagreement with many anthropologists studying food systems of living hunter-gatherers. The archeologists agree that food systems matter and the transition from hunter-gatherer to farmer has had a large and often negative impact on human health. The bottom line, food systems matter and a change to an agricultural diet from hunter-gathering has negative effects on human health such as a food system related increase in infectious disease and malnutrition.

With a living population of hunter-gatherers and agriculturalists this dissertation study is able to go further than the Armelagos's archeologists by assembling an entire detailed overview of all foods eaten, when eaten, how

frequently eaten, how prepared and so on, all this coupled with extensive testing of the health of live humans in these food systems.

Agriculture: social evolution or adaptation to temporary environmental circumstances

Agriculture did not represent a more practical alternative to hunter-gathering in terms of amount of effort and time exerted. Through the millennia societies never adopted farming, and in recent evolutionary history many societies that began farming later abandoned it to take up hunter-gathering again, a more reliable, less labor-intensive means of subsistence (Harlan 1976). Humans did not seriously contemplate alternatives to hunter-gathering until they had compelling reasons to do so.

Farming is not an easier existence than hunter-gathering. Harlan demonstrated this in 1960; a small family equipped with a typical Paleolithic stone sickle could gather enough wild einkorn (a species of wheat) in three weeks to supply all their food needs for a full year (Harlan, 1967). In another example, a study of contemporary !Kung bushman from the Kalahari desert, showed the !Kung spent less than 2.3 days per week in gathering or hunting food, thus, the rest of the week they were free to indulge in other pursuits (Lee, 1968). Similarly, the Kawymeno Waorani of this dissertation study only worked 2-3 days a week hunter-gathering, and non-married Kawymeno members were not required to work at all to obtain food because there was no need for more than a few hunters and a few more gatherers to supply the whole Kawymeno Waorani community with food year-round. Study Santa Teresita Kichwa farmers worked more hours on survival and food issues than the Kawymeno Waorani, although hours of

activity are similar across study groups. Both study groups activity levels are compared later in the health outcome sections of the dissertation.

The move from hunter-gathering to agriculture has never been an inevitable or progressive relationship. Many hunter-gather groups at different times in recent history moved beyond manipulation or semi-cultivation to actual domestication of certain plants while at the same time it is generally accepted by archeologists that many farming groups later reverted to hunter-gathering.

Farming communities that have sprung up and vanished in relatively recent human evolutionary history. For instance, an encampment on the Galilee shore was found with stone grinding tools to process wheat and barley, as well as an oven hearth, indicating flour dough was being baked in 23,000BP (Piperno, 2004; Nadel, 1999**,** 2004). This 23000BP site is the earliest known case of plant domestication. This pushes back earlier estimates of the beginning of agriculture, which many researchers had considered to be 12,000BP, in the village of Abu Hureyra in modern-day Syria. However, agriculture may have started much longer ago than even 23,000BP. The rise and fall of many larger complex agricultural societies in the last 10,000 years is historical evidence that agricultural societies have difficult maintaining themselves. As the following sections will demonstrate our modern agricultural system is also unsustainable and precarious in nature. The vanishing point of these lost agricultural societies such as the Maya in the Guatemala and Mexico occurred during a prolonged change in climate coupled with an agriculture system with similar vulnerabilities as our modern agricultural system today. Many of these more recent agricultural

societies used a large scale farming food system with a very restricted variety species of food plants.

Modern technology is challenged in its ability to change the natural course of human history, which requires the creation of a sustainable food system. For modern agriculture to survive, obstacles to be overcome including vanishing energy resources for chemical inputs such as fertilizers, pesticides, herbicides, the danger of climate change and finally an overdependence on a narrow selection of food staples planted together in vast connected farming regions, that are thus both genetically and geographically vulnerable to both widespread disease and draught (Murphy, 2008).

Restoring Hunter-Gatherer Diets to Agriculturalists. There have been relatively few studies on the actual health effects of removing access to the modern food system from acculturating former hunter-gatherer populations and restoring them to their previous hunter-gatherer diet. The few studies on the reintroduction of aspects of the hunter-gatherer diet provide evidence that introduction of modern food systems has had a particularly devastating effect on indigenous people that can be reversed with a return to a hunter-gathering lifestyle. There have been a limited number of studies comparing these types of food systems that use an actual study intervention namely restoring a hunter-gatherer diet. The results of these diet restoral studies offer particularly strong evidence of the benefit of a hunter-gathering diet over a modern diet.

Studies of Australian Aboriginals have shown that populations following ancestral lifestyles are significantly less prone to chronic conditions such as

obesity, hypertension, diabetes mellitus, coronary heart disease and insulin resistance than Aboriginals using a Westernized diet (O'Dea, 1991).

O'Dea conducted a seven week trial reversion of urbanizing, full blooded, diabetic, former hunter-gather aborigines back to a time-honored Australian Aboriginal hunter-gathering diet and lifestyle, re-located in their traditional environments (O'Dea, 1984). Even this brief return to a traditional hunter-gatherer environment, diet and lifestyle, either greatly improved or completely normalized the metabolic abnormalities of Type II diabetes in these modernizing Aborigines. Since only moderate exercise was required during the trial, exercise did not appear to be a factor in their health recovery.

The Tohono O'odham Native Americans have the highest rate of diabetes in the world, with 50% of the adult population affected. The rise in diabetes coincided with Tohono O'odham transition from a diet based on wild plant foods, to a Western diet (Nabhan, 2004). When these native wild plants that were originally an integral part of the Tohono O'odham traditional hunter-gatherer Native American diet were reintroduced, positive changes took place, blood sugar levels slowly rose and there was a lower insulin response (Balick, 1997; Nabhan, 1989, 2004). Exercise is often considered as an equally or more important factor than diet in the improved health of hunter-gathers. These studies with Tohono O'odham found the restoration of original indigenous diets improved symptoms of diabetes even in the absence of return to other hunter-gather lifestyle factors associate with health benefits including exercise (Balick, 1997; Nabhan 1989, 2005; Williams, 2001). Data on the two dissertation study groups demonstrates

that exercise is also not a principal explanatory factor in the health differences between the hunter-gatherer and farming groups of this study. Exercise across groups is discussed in the health outcome chapters of the dissertation.

In addition, a long-term study (1988-2001) of 575 Pima Indians compared the use of Anglo/Western diet and traditional desert foods of the Pima and their effect on Type II diabetes. The study suggested that an Anglo diet increases by up to 250% the risk of developing type II diabetes in Pima Indians (Williams, et al., 2001).

Another study with isolated Tarahumara foragers in Mexico found even temporary introduction of aspects of Western diet increased symptoms of chronic disease in a group that practiced hunter-gathering (McMurry, 1982).

Semi-cultivation: The gray area between hunter-gathering and agriculture

Defining what a typical hunter-gatherer diet consists of has proved elusive to researchers because of the great diversity of pre-historic human food systems. Pre-historic diet varied greatly, in part because of the dramatically different environments humanity has lived in, ranging from deserts, to rainforests to arctic regions. Cultures only survived if they had a sustainable food system. A given eco-system provided the same food resources but each human hunter-gatherer culture produced a unique food system adaptation leading to wide-ranging food systems even within the same eco-systems.

In many regions around the world, hunter-gatherers have long practiced sustainable strategies such as the manipulation of plants in their environment, deliberately moving and planting but not necessarily cultivating plant species.

This semi-cultivation typical of many hunter-gatherer groups is not yet formal farming, but more complex than just gathering, hunting and fishing. The Kumeyaay of Southern California were semi-sedentary hunter-gatherers who used husbandry to manipulate their floral landscape over a wide geographical region, from coastal dunes to valleys, foothills, deserts and mountains to an extent that is remarkable (Shipek, 1981, 1982, 1991). This semi-domestication of wild plants by hunter-gatherers provided a diverse base of edible plants over a wide variety of eco-systems allowing a flexible food system strategy to survive periodic severe droughts that might devastate a particular ecosystem. Spreading their food sources among different climates was a strategy that enabled hunter-gatherers to have access to food in at least one of their eco-systems at any given time during the year (Lee, 1989). For example the Kumeyaay planted wild oak and pine groves in the mountains, while in the desert they planted groves of palms and mesquite, as well as agave, yucca and wild grapes along the coast, and cactus as an emergency supply of water near their village (Lee, 1989). Other groups of Native Americans, such as the Puite, created eco-systems where they lived by damming creeks and digging irrigation ditches to encourage the growth of wild species (Costo, 1995).



Figure 3. Kawymeno Waorani Just Cut Trees Then Plant and Leave Manioc to Survive Alone

The Kawymeno Waorani in this study are classified as "hunter-gatherers" but as with the above pre-historic hunter-gatherers, the Kawymeno Waorani also practice limited semi-cultivation of manioc, bananas and sweet potatoes. However, other than starches, the rest of the nutritional and pharmaceutical base of the diet comes from the rainforest through hunting, fishing and gathering. More acculturated Waorani in the oil company protectorate depend to a much greater extent on semi-cultivation and agriculture in addition to modern food introduced by missionaries and fostered by the oil companies that dominate the region.

The word "subsistence farmer" is used in this study to describe the Santa Teresita Kichwa, a group who farms and relies on domestic plants and animals for most of their dietary intake of nutrients and plant self-defense pharmaceuticals,

although the Kichwa augment their diet through occasional hunting and some fishing.

When does a food become toxic? Modern food production with a constant monotonous food supply represents an evolutionary abnormality with moderate, but unrelenting exposure to the same plant defense pharmaceuticals. All modern grains and vegetables, even after food processing contain at least trace amounts and often more of a reduced variety of plant self-defense pharmaceuticals. Bruce Ames produced a fascinating series of articles regarding the trade-off of consuming natural plant defense pesticides found in plants. Ingestion of natural plant pharmaceuticals are just as toxic, and often fatal in far lower doses than their human made synthetic pharmaceutical cousins (Ames, 1989, 1990a, 1990b, 1992). The monotonous frequent content of particular plant defense compounds in the modern diet may overload long-term human enzyme detoxification capacity (Freeland, 1974, 1989; Janzen, 1977). The original purpose of the Cytochrome P-450 liver enzymes, that process many human made medications, was to process many of these plant compounds that are similar chemically to human mad drugs (Gordon, 1990).

Chronic exposure to sub-lethal doses of plant-defense anti-nutritional toxicants from human crops such as maize, wheat, barley, rye and rice stimulate a human physiological response (Jackson, 1988; Jackson, 1985) creating certain endemic human diseases (Huxtable, 1980; Mohabbat, 1976; Oke, 1977; Shoental, 1968, 1982)

Celiac disease provides an excellent illustration of a pattern of disease caused by the major crops upon which humanity depends. Celiac disease is a plant self-defense pharmaceutical based disease caused by anti-nutrients accumulated through excessive and frequent intake of cereal grains (excessive at least by evolutionary norms). A plant self-defense pharmaceutical in the form of a protein found in wheat, rye and barley gluten causes Celiac disease. The particular plant self-defense pharmaceuticals that cause Celiac Disease are called anti-nutrients because they alter the ability of the human body to absorb nutrients, and enough exposure to these anti-nutrients can cause permanent organ damage. Anti-nutrients are found alongside nutrients in common modern table foods.

Celiac Disease is under diagnosed and much more prevalent than previously thought and is now identified as a common life-long disorder in the West (Niewinski, 2008). Two types of plant self-defense pharmaceuticals, which are in the form of proteins, prolamins and glutelins come from wheat, rye and barley endosperm gluten and cause Celiac Disease. In the majority of cases, removal of gluten from the diet returns the small intestine to histologically normal function (Braley, 2002). The mechanism of many disorders caused by Celiac Disease is actually a nutritional deficiency provoked by plant self-defense pharmaceutical ingestion. Damage results when an immune response to invading proteins from wheat, rye and barley, is not selective enough and is turned against proteins found in the body's own cells on the walls of the intestine, which results in the destruction of these intestinal walls and a reduced ability to process nutrients (Tuckova, 1995). Magnesium deficiency and many other nutritional

deficiencies caused by intestine wall destruction in Celiac Disease play a key role in many chronic medical conditions.

Celiac disease is associated with certain cancers, cerebella ataxia, dementia, degenerative central nervous system disease and peripheral neuropathies (Auricchio, 1985; Hadjivassiliou, 1996), auto-immune diseases, osteoporosis, chronic liver disease, short stature and infertility (Braley, 2002). Celiac disease also plays a role in neurological diseases and psychiatric disorders including attention deficit disorders, and epilepsy in which calcifications are found in cortical or sub-cortical areas of the brain (Ferroir, 1997; Gobbi, 1992). If gluten free diets are adopted, in many cases the epilepsy seizures can be reduced or eliminated, and there is an improvement in other neurological dysfunctions (Hadjivassiliou, 1996). In a meta-analysis of 50 articles in populations eating little or no wheat, rye or barley the prevalence of schizophrenia was up to 30 times lower regardless of cultural differences between populations (Lorenz, 1990). Multiple clinical studies show schizophrenic symptoms improve on gluten free diets and worsen on reintroduction (Singh, 1976).

Lack of variety: a major vulnerability of modern agriculture

While this dissertation study uses a subsistence agriculture group as a comparison to hunter-gathering, the results and conclusions of the research also have relevance for the modern agricultural system's impact on human health. Some of the vulnerabilities that relate to a move from hunter-gathering to subsistence farming are simply magnified by the addition of modern agricultural technology. The lack of variety of food species is one of a number of critical areas

in which this dissertation later on offers some practical solutions to improve human health.

Despite impressive developments in modern agricultural breeding, seventeen plant species originally developed by early Neolithic-age farmers over the last 12 millennia still remain the seventeen most important dietary items in modern global agriculture today (Harlan, 1971, 1992). Modern agriculture has not contributed a single new major crop species to the global food system and the decision to farm these seventeen cereals and tubers was made thousands of years ago by Neolithic age farmers.

There are 195,000 flowering plants that have parts that humans could eat to provide nourishment but today less than a few hundred worldwide are used for food and the aforementioned group of seventeen species, mostly cereal grains, makeup 90% of the world's food supply (Cordain, 1999). Wheat, rice and maize alone make up 75% of the world's grain production (Cordain, 1999). Wheat, rice, maize and barley, the principal grains, outweigh the next 26 crops combined in tonnage produced. Beyond grains, present-day hunter-gatherer or early farmer origin domesticates also include starchy tubers such as yams and potatoes. But these tuber crops are not as versatile as cereals especially as regards long-term storage. Yet another class of Neolithic origin complementary crops, namely pulses and edible seeded legumes, also provided some useful proteins and nutrients lacking in cereals and tubers (Harlan, 1976; Harlan, 1992). Complex agricultural societies depend on grains for survival, as they are very easy to produce in bulk as well as easy to transport, store and are relatively non-

perishable. However the trade-off for maintaining a large crowd of people on grains is a less adequate diet for the individuals in the crowd as is discussed further on in the dissertation.

Cereal grain usage is an excellent, but far from unique, example of the dietary change that has occurred as humanity has shifted from hunter-gathering to increasingly large scale agricultural production. Other examples are found later in the chapter. Until very recently in human evolutionary history, cereal grains were an insignificant portion of human nutritional intake (Sinclair, 1990). Even after Homo sapiens appeared 90,000 years ago, prior to 20,000 years ago humans rarely used grains for extended historical periods (Eaton, 1988, 1997, 2002). Indirect evidence of the transition from hunter-gathering to a cereal diet includes the shrinking of the human face and reduction of tooth size (Larsen, 1995; 1997) which has been observed with early farming communities around the world, frequently a little before the formation of large formal agriculture systems 20,000 years ago (Brown, 2004).

The vast divergence from a normal human hunter-gatherer diet, first to a subsistence organic agricultural diet like the dissertation study Kichwa, and now more recently to a modernized agricultural diet consumed today by industrial age humans, plays a role in many and perhaps most human degenerative and chronic diseases (Cordain, 2005; Eaton, 1985, 2000, 2002). Toxic reactions from frequent grain consumption of plant self-defense pharmaceuticals may account for some of these chronic diseases.

The many decades of hesitation in recognizing the potential damage wheat, rye and barley have on health occurred, at least in part, because it runs contrary to established belief among early nutritional scientists and is promoted anywhere from the USDA Food Pyramid to educate consumers, to the outside of cereal boxes. The grain foods such as bread, whether the whole grain or refined version, contains these anti-nutritional plant defense chemicals, such as lectins, phytates, gluten, tannins and enzyme inhibitors (Cordain, 1999). In fact, in general cereal grains such as wheat are a very poor nutritional staple for individual humans compared to most other classes of foods but compensate at a national level though their ability as long lasting foods that can be stored in massive amounts to support enormous populations (de Meester, 2008). Unfortunately modern food production typically uses grains to feed domesticated animals, which creates meat chemically very different from the enormous quantities of meat the Kawymeno Waorani consume. One reason is fats and proteins, not carbohydrates from grains or other sources, have made up most of humanity's macro-nutrient dietary intake throughout 99% of human evolutionary history (de Meester, 2008). The problem of plant defense anti-nutritional content in grains is good starting point to understand the implication of the dissertation results although the dissertation study considers food systems as a whole.

Humanity today is restricted to a few plant species, creating a major global problem of narrowing sources of dietary diversity and widening occurrence of previously rare or less common dietary related chronic diseases (Krauss, 2000). In the US, at least four of the ten leading causes of death have strong links to diet

and annually cost over 200 billion in health treatment and lost productivity (Economic Research Service, 2001). Dietary based disease is global, affecting both the malnourished in the "developing" world and the obese in the United States. Nutritionally based diseases are the most well-known and extensively studied diet to disease phenomena. However, this dissertation goes further probing other perhaps equally important non-nutritional dietary intake causes of modern diseases.

Food processing: another double-edged sword

The methods used to process the agricultural harvest into edible food are as an integral part of any food system as the agricultural or aquacultural techniques that produced the food to start with.

Many food processing innovations have been used by humanity to improve nutrient content of foods while reducing microorganisms and eliminating plant self-defense pharmaceutical "toxins". These food processing techniques may have considerable antiquity dating back to use by early farmers who often practiced some hunter-gathering. However, food processing like agriculture is a step away from a hunter-gather food system that relied mostly on raw fruit and later after the innovation of fire, unadulterated cooked animals.

The Kichwa subsistence agriculturists in our study use many of these toxin-reducing techniques, but as the results of the dissertation indicate, suffer more from plant self-defense pharmaceuticals toxicity than the Kawymeno hunter-gatherers, who while consuming more potential plant self defense toxins,

appear to actually derive benefits from plant self-defense pharmaceutical ingestion.

Most authors in the new field of research studying plant self-defense pharmaceuticals in food take the approach that these plant defense chemicals are harmful, toxic and something to be eliminated from the diet. Timothy Johns is a leading researcher is this new field of study and emphasizes the toxic aspects of plant self-defense pharmaceutical intake, and their removal via simple food processing by early farmers in his seminal book *"With Bitter Herbs They Shall Eat, Human Ecology and the Origin of the Human Diet and Medicine"* (Johns, 1990, 1996). However, the potential beneficial properties of plant self-defense pharmaceutical intake are rarely mentioned. Beneficial properties are easier to conceptualize when one realizes that these "toxins" are also pharmaceutical chemicals (antibiotics, antioxidants, immune antibodies) used to protect the plant, and have medicinal value for humans as is discussed in detail throughout the dissertation.

While most would agree that modern food processing has negative aspects in terms of human health outcome, there is little critique of food processing of early subsistence farmers, perhaps because natural substances are viewed as safer than synthetic chemicals. However, natural chemicals are as inherently toxic as their synthetic cousins and in both the difference between being poisonous versus beneficial is a matter of quantity and frequency of consumption rather than chemical content alone (Ames, 1990a, 1990b). For instance although the toxins in foods like manioc and cereal grains are reduced

through fermentation to low-level form, these foods may still be toxic to humans over the long haul if eaten in the form of staple or principal foods in large quantities on a daily basis for many years.

Fermentation is mentioned as radically changing the physical qualities of food and can have significant nutritional benefits over non-fermented versions of the same foods (Etkins, 2006; Lorri, 1994; Steinkraus, 1998). Other early food processing methods include soaking food in mud and preparing food with the addition of small amounts of clay. These are often discussed in terms of toxin-reduction and increasing nutrient bio-availability. Soaked or repeatedly washing foods in water leaches and carries off dissolved potentially toxic compounds (Leopold, 1972; Johns, 1996). Drying, grinding, mashing, smoking, and freezing are also mentioned as effective for reducing toxins and releasing nutrients. Soaking maize in limewater is another type of processing that releases nutrients that were previously not bio-available to humans (Etkins, 2000; Hambidge, 2004; Lei, 1999).

However, all these food-processing techniques may also reduce or chemically alter antioxidants, antimicrobials, immune enhancers and other beneficial types of plant self-defense pharmaceuticals “toxins”. So in addition to agrarians consuming a limited variety of phytochemicals, in agricultural systems these phytochemical are chemically altered as they enter the food system as whole raw foods and come out of the food systems as recipes. This is discussed further in the food system section of the dissertation.

Managing the acidity/alkalinity (pH) level of food was accomplished by some subsistence farmers with the application of plant acid or lye from plant ashes breaking down soluble toxic compounds through hydrolysis (Johns, 1996). However, this dissertation's results suggest that the healthiest pH acid/base level for agricultural populations may differ from the healthiest pH range for hunter-gatherer populations. The average population urine pH is quite different between Kawymeno hunter-gatherers and Kichwa agriculturalists.

Use of solvents, salting, spices and chemical preservatives in indigenous agricultural food systems prevents the increase of toxic substances via oxidation, which would degrade the food chemical content through age and exposure (Johns, 1990, 1999). The ability to store preserved foods prevents starvation in times of shortage, especially when higher quality food is not available. However, when early farmers use natural methods of food processing, processed foods eventually become ingrained cultural habits and finally a staple food, thus the nutrient and pharmaceutical content of their overall diet has been degraded. Replacing fresh, raw unadulterated foods in hunter-gatherer diets with even minimally naturally processed food is a step away from the dietary evolutionary norm and rather than aid in the prevention of chronic disease may rather assist in the degenerative process.

However, even after extensive manual or industrial processing, such as cooking, peeling, soaking, burying in clay or fermenting or even a combination of these methods not all plant toxins can be removed, so even in sophisticated modern food processing there is a persistence of toxicity (Bjeldanes, 1983).

Furthermore, food processing is a double-edged sword, as some of these same processing methods can actually degrade nutrient content, increase toxicity of certain existing toxins, and actually create new toxins and anti-nutrients that did not exist before in the food (Dufour, 1989; Goodrich, 1989; Johns, 1988; Kataria, 1988; Lancaster, 1982). For instance while roasting or boiling of food has been the norm through most of humanities existence, frying food degrades the nutritional value of food by introducing harmful trans-fatty acids and a disproportionately high amount of omega-6 fatty acids (Johns, 1996).

Illustrative of the value of thinking in terms of food systems rather than individual foods is the different effect on humans many plant phytochemicals have when they are consumed together versus separately (Etkins, 2006). When plant phytochemicals are consumed along with certain other foods, these associated foods may chemically and mechanically interact to buffer toxicological impact. For instance, when foods containing high levels of harmful cyanogenic glycosaids are eaten in conjunction with foods containing high levels of palm oil, the result is a reduction in the bioavailability of these toxic glycosaids (Iyayi, 1986).

CHAPTER 3

PLANT-HUMAN CO-EVOLUTION

Pharmacological effects of plant foods on the human body

Little attention has been paid to the pharmacological potential of diet. Until recently, foods were thought of as chemically inert and thus not relevant to the course of disease. This dissertation suggests that dietary intake of natural pharmaceutical compounds found in all plants, including those used as food, may play as large a role as nutrients in human health and disease. These plant chemicals are called phytochemicals and also referred to in this dissertation as plant defense pharmaceuticals.

Surprisingly few studies consider the health impact of the recent drastic reduction of natural plant defense chemical content in the modern global food system, which has eliminated essential components of food because they do not appear to be nutrients. Far from being inert, these non-nutritional natural plant defense chemicals actively interact in a myriad of ways with human physiological processes and make up ten percent of the dry weight of many plants (Abelson, 1990).

This is a dissertation study of food systems and the principal thesis is that there is something specifically related to a hunter-gathering diet that reduces disease in humans beyond the nutritional aspects suggested by most authors of articles on ancestral diets. Where this dissertation thesis diverges from other work on hunter-gatherers is the consideration of diet as a means of preventing disease

through its pharmacological and medicinal properties. One central thesis is that throughout human evolution diet has always been medicinal and pharmaceutical in nature. However, the advent of agriculture food systems, even thousands of years ago, reduced the preventative medicinal benefits of food found in the human dietary norm, hunter-gathering. Thus, historically agriculturalists have had to create human-made medical systems to compensate for the loss of the natural pharmaceutical protection received while hunter-gatherers. Dissertation study groups provide a case study to examine this difference of health across food systems. Dissertation study Kawymeno Waorani hunter-gatherers, while eating a lot of rain forest plants, use almost no medicinal plants and suffer from very few chronic or infectious diseases. According to study surveys and interviews, the Waorani indicate they do not need medicinal plants, or a Waorani health practitioner or mid-wife because they do not get sick. On the other hand, the agrarian Santa Teresita Kichwa – neighbors of the Kawymeno Waorani – have created a medical system to combat the considerable population chronic and infectious disease load, including hundreds of medicinal plant remedies. This demonstrates the effect that the type of agricultural diet that was common prior to a modern food system may be having on health and health-seeking behavior. Other confounding variables that also effect health are examined in this study. For this dissertation study, it is not important whether Kawymeno Waorani are an approximation of pre-historic hunter-gatherers or not, what matters is that all their food comes from a hunter-gathering food system that relies on a pristine rainforest ecosystem and food chain rather than from agriculture.

This dissertation suggests that if some vestige of the natural pharmaceutical protection in which humanity evolved is not maintained, even our modern high tech medical system may not be able to compensate enough to prevent the accelerating decline in health occurring in modern human society in the 21st century.

Why do plants produce defensive chemicals? So why do plants have all these pharmaceuticals that interact with human physiology? This dissertation argues that the chemical warfare carried out by plants on other organisms is a major underpinning of dietary-based human disease patterns. To understand this pharmaceutical phenomenon, it is necessary to first understand how all plants survive on this planet. Plants can neither run away, nor hide nor physically attack their enemies to escape danger. However, plants are far from helpless vegetation waiting for the next predator to eat them. The way plants fight for survival is largely through the creation of an arsenal of chemicals with which plants wage constant chemical warfare against their enemies and competitors (Howe, 1988). Plants up-regulate and down-regulate these bio-chemical pathways in response to the need to repel, attack and occasionally attract bacteria, viruses, fungus, insects, animals and other plants (Harborne, 1993).

The presence of infectious microbial pathogens, predators and environmental hazards all stimulate change in genetic expression that modifies chemical structure and also alters the quantity of particular phytochemicals produced. There are thousands of different variants of particular chemical bases upon which plant defense chemicals are built. The phytochemical concentration in

plants ranges anywhere from negligible to toxic levels for humans and is influenced by many factors discussed below. To summarize and elaborate, factors affecting type and concentration of plant defense phytochemicals found in food include:

1) The constant presence of harmful microorganisms, such as bacterial, fungal and viral threats (a constant chemical presence is required against microbes) (Bjorkman, 1991; Dyer, 2001; D'Ovidio, 2004).
2) Dense growth and encroachment of nearby competing plants.
3) The presence of predators such as soil parasites, insects, herbivores and humans all of which stimulate up and down cycling of the concentration of plant defense chemicals (Bjorkman, 1991). (Non-microbe predator and competitors may stimulate a more intermittent defense chemical presence based on need rather than microbe defense).
4) There are also environmental factors that affect phytochemical level increases and decreases including aridity and humidity of the environment, exposure to ultra-violet light, temperature changes, seasonal cycles, soil chemical composition, drought, individual plant age and even pruning and plant injury from human gardeners.
5) Finally, symbiotic relationships with other organisms also affect plant defense chemical levels seasonally, such as phytochemicals that attract pollinating insects or phytochemicals that induce the ripening of fruit for animal consumption, (Romeo, 1996; Harborne, 1993).

Plants have particularly large chemical arsenals to defend against microorganisms, which represent the most diverse and constant threat to plant survival. Microorganisms include bacteria, fungi, viruses, and microscopic parasites. All plants have antimicrobial pharmaceutical properties and all humans have receptors particularly designed to absorb these plant antimicrobial defense pharmaceuticals (Harborne, 1993). It is argued that this chemical compatibility is not coincidental, but part of the complex plant-human co-evolution that provides a check and balance system to prevent widespread systemic rise in microbial disease in an ecosystem. Plants have the ability to change genetic expression rapidly to produce novel antimicrobial pharmaceutical defenses that keep up with pathogen microbe ability to mutate in an eternal chemical arms race, plant versus microbes. Microbe drug resistance as a result of mutations was dealt with through plant production of a constant stream of evolving antimicrobial plant pharmaceuticals (Bjorkman, 1991; Dyer, 2001; D'Ovidio, 2004). The creation of novel antimicrobials by plants is accomplished in a minute fraction of the time it takes the human pharmaceutical industry to produce novel antimicrobial pharmaceuticals.

Consonant even with the bioscientific paradigm, there is now evidence for cellular and metabolic interactions between plant food constituents and human biomarkers for improved health (Wrick, 1994). Either excess or dearth of specific phytochemical constituents of food have recognized roles and presumed action in wellbeing (Etkin & Johns, 1998). The plant, microbe, human co-evolutionary relationship is of major interest to this dissertation study.

Natural phytochemicals may function as double-edged swords, having beneficial pharmacological qualities in humans, as well as toxic ones. Plants and humans have pharmacologically co-evolved together over millions of years, confronting common enemies – such as bacteria, viruses and fungi – to such an extent that most human enzymes that metabolize modern pharmaceutical products appear to have been developed specifically by the human body to process plant defense antibody toxins (Beier, 1990; Shuster, 1964). Most modern drugs work largely because they fit into pre-designed chemical niches that originally evolved in human bodies specifically to process particular plant chemicals (Freeland, 1974). The presence of a multitude of plant phytochemical antibody receptors in all human bodies indicates that dietary intake of plant foods may have long served a medicinal role in human populations. Natural plant pharmaceutical processing enzymes are located on the endoplasmic reticula and are active primarily in the liver and kidney and to a lesser degree in the intestinal mucosa, lungs, thyroid, skin, and testes (Mandel, 1972; Parke, 1968; Shuster, 1964; Williams, 1959). Human enzyme systems break down both foreign plant phytochemical pharmaceuticals and internal steroid hormones (Shuster, 1964). This is apparent in the development of oxidative pathways (e.g. Cytochrome P-450 systems) in the liver and other tissues that have evolved to detoxify the plethora of plant phytochemicals encountered in plant foods (Brattsten, 1979).

This dissertation argues that humans relied on pharmaceutical properties from their environment, particularly the rich variety of plant defense chemicals already present in their food, to compensate for the relative lack of flexibility the

human body has in producing defense pharmaceuticals in their own immune defense systems. Biologically effective doses of plant phytochemicals are often found to be orders of magnitude lower than most human-made pharmaceuticals, thus these natural pharmaceuticals are much more concentrated and effective in smaller doses than their human-made counterparts (Gordon, 2005). Human bodies have a limited ability pharmaceutically to respond rapidly to novel microbial threats whereas plants have the ability to adjust their chemical repertoire to combat mutating microbes and changing predators and competitors sometimes within hours.

One potential benefit of this plant–human co-evolution for humans is that plants can develop new antimicrobials against novel, constantly evolving microbial threats much more rapidly and efficiently than human bodies are capable of doing (Phelan, 1992). Plant pharmaceuticals exist in food and humans react to these phytochemicals physiologically. This dissertation study suggests the next step in thinking; dietary plant pharmaceuticals are useful, and furthermore, necessary to human health.

Dietary phytochemicals' effect on body microbe residents. Microbes living in human hosts depend on host dietary intake for nutrients for growth and reproduction, and are affected by ingested nutrients (Ewald, 1994). Every human body is host to millions of co-inhabiting microorganisms that may spend their entire lifecycle in the body. Researchers with an evolutionary perspective have noted that dietary intake modifies these co-evolving microbes that make their homes in all human bodies (Williams, 1991). Microbes form a distinct mini-

ecosystem within a single human body, which often supports human body biological functioning (Jackson, 1991). Thus, while human dietary intake provides materials for maintaining the human body tissue, the microbial populations inside their human hosts also utilize this food. For instance, although dietary bio-available iron intake is essential to prevent anemia, certain pathogens found within human body ecosystems also use the same iron to greatly increase reproduction and spread into deadly infections (Ewald, 1980).

Beyond nutrient consumption, these co-inhabiting microbes also respond to and are modified physiologically by plant antimicrobial defense compounds and other dietary plant defense pharmaceuticals they encounter in the host human body. This dissertation argues that the antimicrobial, anti-inflammatory and immune enhancing nature of many dietary plant pharmaceuticals in the food system may regulate all microbes in human hosts including microbes that assist normal human biological functioning.

Dietary intake of natural plant pharmaceuticals may reduce vulnerability to chronic and infectious disease through numerous etiologies. A few of these include:

1. Prevention of excessive growth of endemic microbes through dietary intake of antimicrobial phytochemicals, thus reducing chronic disease and endemic infections;
2. Through improved immunity given by immune enhancing phytochemicals (the Kawymeno Waorani have the highest IgE antibody level recorded in a particular human culture);

3. Through direct plant toxin attack such as on parasitic infections;
4. Through reduction of inflammation through the high antioxidant phytochemicals levels found in wild plant food, and;
5. Through oxidation of parasite membranes as has been described by Etkin (2003).

These examples of the medicinal effects of plant defense chemicals are illustrative of the complicated biochemical warfare strategies of the plant kingdom that produces a wide range of pharmaceutical techniques and actions against organic threats.

Microbes naturally existing in the human body, such as staphylococcus or streptococcus bacteria, may be regulated by plant-based dietary pharmaceutical intake. The germ theory suggests that in times of physiological vulnerability, such as serious wounds and burns, naturally occurring internal bacteria, such as staphylococcus aureus, usually concentrate and spread into an infection at wound sites. This germ scenario is considered normal by biomedical science. However, this medical perspective comes from a potentially distorted view biased by living in a large-scale agrarian society. Germ infection generated by co-existing bacteria in human hosts may be an anomaly, not the human evolutionary norm. While massive staphylococcus infection uprisings in serious wounds resulting from the body's own naturally occurring lifelong microbial inhabitants may be the norm in agrarian societies, such infections may have rarely occurred in humans from hunter-gatherer food systems. The pharmaceutical regulation by dietary intake of plant defense antimicrobials, immune enhancers and other dietary plant

phytochemicals may have kept bacterial residents in human hosts housebroken throughout human evolutionary history.

The remarkable lack of observable inflammation, or any infectious symptoms on large untreated, open, third degree burns or untreated complete perforations of legs by spear stabbing and other wounds of dissertation study Kawymeno Waorani hunter-gatherers add evidence suggesting the existence of active preventative antimicrobial activity, which this dissertation suggests comes from dietary intake of known plant antimicrobials. For example, dietary antimicrobials routinely ingested in Kawymeno hunter-gatherer diets such as curare hunting poison (*Curarea tecunarum*) are curative when applied externally to infections in wounds (Davis, 1983). Kawymeno Waorani are now exposed to outside diseases, even anti-biotic resistant, nosocomial staphylococcus aureus infections common in hospitals. So, isolation and absence of staphylococcus strains found in modern societies is no longer an explanation.

Natural pharmaceuticals work better within their environmental context. Phytochemical pharmacological disease protection among Kawymeno Waorani hunter-gatherers does not appear to extend to pathogens that are external to the local ecosystem and food chain such as falciparum malaria, hepatitis and tuberculosis. Dissertation results suggest that the antimicrobial properties of wild plant food, coming from the same food chain and ecosystem hunter-gatherers live in, provides protection against endemic microbial, parasitic, animal and plant threats. However, the Waorani and other formerly isolated hunter-gatherer groups seem particularly vulnerable to viral and bacterial infections brought in by outside

cultures. Hepatitis is responsible for the single Waorani death in Kawymeno in 15 years. Measles and polio infections killed groups of Waorani during first contact with outsiders in the 1970s and 1980s, until they were vaccinated (Yost, 1981). It is argued that plant defense phytochemicals are produced to defend against threats that exist within the ecosystem and food chain. Natural selection does not usually permit survival of organisms that expend precious energy unnecessarily– such as by creating natural plant pharmaceuticals randomly to defend against all possible pathogens, worse yet pathogens that have never before existed in the ecosystem. Thus, not only humans, but also the plants and the whole ecosystem these hunter-gatherers live in, are vulnerable to new diseases introduced from outside the ecosystem, in part due to lack of phytochemical pharmacological protection, which requires precedent.

Hunter-gatherer groups have long been observed to have few diseases and in generally to be in outstanding health. Black has suggested hunter-gatherer groups remained largely disease-free by virtue of their small and isolated populations, which could not support virulent microbial diseases such as measles and polio (Black, 1975). However, this common potential critique is a moot point, since the type of infectious diseases that are absent in the Kawymeno Waorani are not the type of virulent measles and polio type infectious diseases to which Black was referring. Other factors beyond isolation and group size are at play since the Kawymeno Waorani hunter-gatherers are not isolated from outside disease, yet are still largely free of disease. This dissertation suggests that the food system pharmaceuticals may be a more relevant factor than isolation per se, although

disturbance of an isolated pristine ecosystem will affect dietary intake of plant phytochemicals coming from the traditional ecosystem and food chain.

Archeological evidence: absence of many infectious diseases in Paleolithic humans. Interestingly, archeological evidence lends support to the dissertation hypothesis that staphylococcus infections in serious wounds may not be the human norm historically, as the germ theory of modern biomedical medicine would suggest. Drilling into living human skulls (trephination), without any attempt at hygienic measures was commonly practiced among former Inca inhabitants of Ecuador and Peru without any archeological evidence of infection in the skulls (Stewart, 1957; Weber and Wahl, 2006). Trephination brain surgery without an attempt at hygiene to control infection was widely practiced by ancient human societies and dates back to Neolithic times (Ackerknecht, 1947; Brothwell, 1981; Crump, 1901; Oakley, 1959; Sankhyan and Weber, 2001). Without strict sterile conditions brain surgery will rapidly kill humans in modern food systems. Older members of the Kawymeno Waorani mention practicing tooth extraction after killing the tooth nerve with a blunt instrument, with no attempt at hygienic measures and yet had no infectious consequences resulting from the primitive operation. Beyond staphylococcus, this dissertation suggests the rate of many non-pathogenic infections was less common in humans in pre-agricultural societies.

Phytochemical pharmacological effect on microbial-based chronic diseases. The complete absence of chronic diseases such as hypertension, coronary heart disease, insulin resistance, eye disease, and neurological disorders

(including migraines, epilepsy, depression) in the Kawymeno Waorani may also be related to dietary plant pharmaceutical regulation of the microbial populations naturally inhabiting the human body that usually cause inflammation and deterioration of body tissue. This lack of chronic disease in the Kawymeno Waorani hunter-gatherers stands in sharp contrast to the high level of chronic disorders present in the nearby Santa Teresita Kichwa subsistence agriculture population.

Beyond microbials: plant defense chemicals and parasitic infections. A different etiology may be involved in the lack of parasitic infestations documented by this dissertation study in Kawymeno Waorani hunter-gatherers, such as leishmaniasis and helminth worm parasites, both of which are endemic and ubiquitous to this Amazonian region. Absence of Waorani parasitic infestations may be related to the direct toxic effects of the dietary intake of anti-parasitic plant pharmaceutical compounds on parasites rather than the regulatory effect hypothesized for microbial infections. Again in sharp contrast, routine infestations of helminth worms and the occurrence of leishmaniasis are part of the disease history of most Santa Teresita Kichwa farmers. The chapter on helminth worm parasite infections explores these phenomena in more detail.

Plant defense chemicals against herbivores such as humans. In addition to microbes and parasites, plants also wage a chemical war against more complex herbivores life forms that also prey on plants such as insects and mammals. Plants have developed chemicals to combat all of these herbivores. Thus, plants are not the placid accommodating source of nutrients for humans we assume they are;

plants also wage a chemical war against humans to survive. Some plant defense chemicals such as tannins and indigestible substances like lignins make the plant less attractive to eat, while inorganic silic obstructs herbivore digestion. Many other plant defense toxins antagonize specific animal and human biochemical pathways, and with the exception of organisms that have evolved particular defenses to neutralize them, these toxins are poisonous (Bras, 1957; Jackson, 1990). Humans consume plants that poison other animals and vice versa, for example chocolate and avocados are poisonous to Amazon parrots. Normally the extensive variety of bacterial flora in the human stomach is capable of degrading a wide variety of plant defense toxins, but plants have evolved chemical tricks to bypass intestinal bacterial protection systems in humans (Freeland, 1974). Plants store anti-herbivore defense chemicals in a form that is not toxic to the plant (glycosides) and these toxins are only chemically activated and turned into toxic glycosidases via intestinal bacteria when already in the human body (Freeland, 1974). However, there are many other plant toxins that these intestinal bacteria cannot degrade, which are handled separately by the human enzyme metabolism (Freeland, 1974). In the end, human detoxification capacity for plant phytochemicals is limited and providing a variety of foods in the diet is a critical way to reduce toxicity caused by overconsumption of particular plants (Freeland, 1974) a problem in agrarian diets that tend to be monotonous and rely on regularly consumed staple foods, such as wheat.

Plant versus plant chemical warfare. Plants use their defense chemicals against competitors, particularly other plant species, which compete for resources

such as sunlight, soil nutrients and space. Chemical warfare strategies against competing plants include altering the amount of chlorophyll and photosynthesis potential in a competitor plant (Harborne, 1993). Other chemical methods used to successfully compete with other plants for space include infusing the soil with substances that interfere with the seed germination and/or growth of neighboring plant competitors (Etkin, 2006). This is done through the release of chemical gas from the roots, the live leaves and even decomposing leaves of the plant.

Phytochemicals designed to elicit collaboration. The toxic effect of plant compounds in otherwise nutritious food is only one better-known aspect of this dietary double-edge sword. This dissertation suggests that throughout evolutionary history humans have (for the most part unconsciously) regularly consumed dietary plant compounds that have served preventative health functions such as effective pharmaceutical treatment against microbial parasite-based disease. The first aspect of the double-edge sword is that the same phytochemicals that can be toxic in high and/or long-term doses can also be medicinal in reduced and staggered amounts.

However, there is really almost an additional third edge to the sword. There are groups of plant chemicals that are used strictly in symbiotic rather than predator-prey relationships. These symbiotic plant chemicals serve functions such as signal chemicals to attract insect bearers of their pollen. The symbiotic part of plant-human co-evolution is an important focus of this dissertation. This dissertation will refer to phytochemicals that serve a symbiotic rather than a defense purpose as “plant symbiosis chemicals”. Plant symbiosis chemicals

relevant to humans include those in fruit that attract animals (such as humans) to eat the plant's fruit. This dissertation argues that fruit, beyond providing some nutritional sustenance, are also intentionally designed to provide medicinal benefit. The animal returns the favor by helping immobile plants deposit the seeds from the consumed fruit in a new area, along with a plant fertilizer, namely animal excrement (Hammerschmidt, 1996).

The paradox of vegetable phytochemicals. The great variation in types and concentrations of phytochemicals between plant parts suggests that mammals can avoid toxic effects by eating plant parts that do not contain large amounts of these chemicals. For instance rats presented with a series of food each containing a different concentration of selenium consistently eat the least toxic food (Frank and Porter, 1936). Animals that consciously avoid toxins in foods include deer, rats and voles (Freeland, 1974).

This dissertation suggests the avoidance of non-fruiting; non-flowering vegetable consumption by Kawymeno hunter-gatherers is an example of plant toxin avoidance, in this case avoiding anti-herbivore plant defense chemicals. It is argued that fruits, designed chemically for symbiotic use in relationships with mammals, have less anti-herbivore phytochemical content than non-fruiting and non-flowering parts of plants. This may be because the plant protects leaves, roots, bark and stems from being destroyed and eaten while encouraging consumption of fruit by select animals. These types of vegetation include modern vegetables such as lettuce, broccoli, asparagus, onions, carrots, and rhubarb. The plant defense content of non-fruiting/flowering plant parts, such as agricultural

products called vegetables, are laced with strong chemical defenses to be used against herbivores (including humans). Anti-herbivore phytochemicals are the topic of numerous books and articles and are discussed in chapter 11.

Edible non-fruiting vegetation was available worldwide to all hunter-gather groups but for the most part, humanity has chosen not to eat vegetables through its history, with the exception of a few tubers, as is evident through a look at all hunter-gatherer studies that discuss foods eaten, although the well ingrained agriculturally based idea that vegetables are an essential part of the diet has caused many earlier ancestral researchers to ignore the fact that humans have only recently started eating vegetables although there is now quiet acknowledgement of this (Carrera-Bastros 2010). This is discussed further in the next chapters. The Kawymeno Waorani hunter-gatherer became nauseous when offered vegetables in this study and with the exception of tubers they do not consume non-fruiting/flowering parts of plants as food. Even tubers, such as manioc, may have been introduced relatively recently to the Waorani (Yost, 1981). The Kawymeno Waorani's impressive ability to detect subtleties in the taste and smell of foods, such as bitterness, and their large vocabulary to describe these subtleties is discussed in an upcoming chapter in relation to detecting dietary plant phytochemicals, which provide the principal flavor to foods prior to the advent of processing foods early in farming history starting with spices, which hide original taste. The Santa Teresita Kichwa agriculturalists on the other hand depend on domesticated vegetables for survival.

Thus, the case is made that vegetable consumption, while providing many nutrients, have negative effects on human health due to significant anti-herbivore phytochemical content. On the other hand fruits have nutritional benefits but without some of the potential side effects of toxic phytochemicals found in non-fruiting vegetables. Despite the vegetarian movements assumption that vegetables are "natural" parts of the human diet, the reality is most non-fruiting vegetables are actually not natural foods in two senses. First, humans rarely ate non-fruiting vegetables throughout their evolutionary history and second, most vegetables are recent products of biotechnology, hybrids derived from wild plants.

The physiological role of phytochemicals in the human body. The food on the table, which all families in modern large-scale food systems eat everyday, is still loaded with pharmaceutical properties. Well-known plant "drugs" such as coffee or tobacco are not exceptional plant cases with unusual phytochemical "drug" compounds. All plants, including those used for foods, contain plant "drugs", this is the rule and foods are not an exception. These metabolically active plant compounds cause a spectrum of physiological changes in humans. A potent example is the extent to which plants can regulate human behavior and perception (Jackson, 1991; Johns, 1995). Hallucinogenic and mind-altering plants such as opium poppies, marijuana, and Amazonian Aya-huasca plant combinations are the better-known examples. Actually, many common table foods may contain subtler or smaller concentrations of behavior-altering compounds that show their effect over time.

Twenty-five percent or more of the prescription drugs in the USA contain natural products extracted from plants (Farnsworth, 1985). Of the 120 active medicinal compounds currently isolated from plants and widely used in modern medicine today, 75% show a positive correlation between modern therapeutic use and the traditional use of plants in indigenous cultures (Elisabetsky, 1991; Laird, 2002).

There are four major groups of secondary plant chemicals that have pharmaceutical properties: alkaloids, phenolics, sulfur-containing compounds and tereniods. Some human chemical receptors in the human body appear to be designed solely for interaction with particular plant chemicals, an indication of the long-term co-evolutionary relationship between plants and humans (Harborne, 1993). Natural plant origin pharmacological agents fulfill roles in the human body as laxatives, tranquilizers, beta-blockers, anti-biotics, anti-virals, anti-coagulants, anti-inflammatory agents, hypertensive's, analgesics, cancer inhibitors, anti-oxidants, vasodilators, vasoconstrictors, insulin regulators and decongestants (Carper, 1997; Leung, 1980). When ingested some of these phytochemicals act very differently on the physiology of the humans than their original physiological function while still in the plant and in some cases these phytochemicals are largely inert waiting until they interact with chemicals in the human body (Harborne, 1993).

Plant defense pharmaceuticals, particularly antimicrobials, are a large group of plant phytochemicals, of which there are five principle classes. Many of these plant defense chemicals are members of two major classes of

phytochemicals, namely the alkaloids, and phenolics. Other plant defense chemicals come from the classes of phytochemicals known as glycosiods, uncommon proteins and unusual free amino acids. Plants need to divert considerable energy to produce these plant defense phytochemicals, and will not divert energy from other basic survival needs until a particular threat is sensed chemically and triggers a specific increase in phytochemical defense production (Oehme, 1978). In many cases, the plant toxins are located at the surface of the plant or peripheral tissue, often to ward off microorganisms, insects or herbivores. For example, the highest concentrations of solanum glucalkoids toxins in potatoes (solanum tuberosum) are found in the peels (Oehme, 1978). But toxins can be found in the center of plant foods; high concentrations of cyanogenic glycoside toxins are found in the seeds but not the flesh of peaches, pears, apples and apricots (Cheeke, 1989) presumably to avoid harming the human or other animal but providing protection for the seeds after their animal stomach transport has left them to grow in a new area.

Triggering natural plant pharmaceuticals in agricultural crops Artificial pesticides, herbicides, insecticides, elimination of competing plants by plowing and weeding, biotechnology and breeding have greatly altered but not eliminated the stimulants found in the wild that precipitate the great variety of plant defense pharmaceuticals. This suggests plant defense chemicals produced in agriculture are less diverse and useful medicinally than wild plants but ironically may have a higher concentration of fewer plant defense pharmaceuticals. Unlike nutrients, plant defense pharmaceuticals are only produced when required. Agricultural

plants still have plant defense toxins, just a more monotonous and concentrated amount compared to wild plants.

It is argued that the use of agriculture itself is a step into the direction of random ingestion of natural pharmaceuticals that were previously coordinated through co-evolutionary processes in natural food chains and ecosystems of our hunter-gatherer ancestors. All foods eaten by populations in modern agricultural food systems are a trade-off, giving harmful and healthy plant defense chemicals to their consumers in an inseparable package (Cordain, 1999; Etkin, 2006). It is argued that humans have always been forced to eat foods that are sub-optimal health choices because all foods are phytochemical mixtures, containing both preventive health properties and potential toxins. There probably will never be natural foods with only health giving phytochemicals available to humanity. Maximizing beneficial pharmaceutical effects of dietary intake of natural plant defense chemicals, while minimizing side effects and overdoses of excess or harmful phytochemicals, is a property of the type of food system humans create from available resources.

Agricultural science usually does not give much consideration to how their practices stimulate plant defense chemicals in crops. Threats and competition from other organisms as well as climate changes affect the defense chemical content of any given plant as much as actual plant species itself. The amount and types of plant defense chemicals in plant tissues vary considerably across plant species, differs widely in different specimens of the same species plant and finally even varies over time in the same plant depending on what external forces are

stimulating phytochemical production. Thus, one cannot assume that because a given plant species is harvested it will have a uniform chemical package compared to other plants of the same species harvested together. Some toxins are always present in plants but their levels fluctuate. Some plant pharmaceuticals and toxins are induced after a predator attack (such as human pruning) or microbial infection and may either form around the area of the plant's injury or conversely manifest chemically throughout the entire plant (Arnason, 2004). Thus, pesticides used to prevent microbes needed for stimulation may cause an absence of certain medicinal plant antimicrobials in food. Conversely, the presence of harmful plant anti-herbivore toxins may be stimulated by pruning and other agricultural practices. Some of these factors even cause phytochemical variation in different tissue areas of the same plant, at the same time, such as the difference between leaves that are partially eaten by herbivores and leaves that are untouched (Arnason, 2004).

Plant-human chemical relationships. The vast majority of plant-human co-evolutionary related research implicitly espouses a human-centered approach to plant-human evolution. However, a more plant-centered research approach is required to pose fundamental questions such as how and why plants might modify humans for their own survival benefit. Evolutionary medicine has focused research on why natural selection has left the human body vulnerable to disease (Eaton, 1988; Ewald, 1994; Greaves, 2002; Gluckman, 2005; Nesse & Williams, 1994; Nesse, 2006, 2008; Stearns, 2007; Williams & Nesse, 1991). However, it is worth remembering humans may play a subsidiary evolutionary role to plants due

to our short time span on this planet and natural selection that causes human vulnerabilities may be unrelated to human survival but related to survival interests of other species. Profet and Ames in the early 1990s came up with a number of theories linking dietary intake of plant secondary compounds and toxins (plant defense antibiotics) with allergies, fetal human development vulnerability and menstruation (Ames, 1992; Profet, 1988, 1991, 1992). Ames and Profet simply considered plant pharmaceuticals poison and did not associate human physiological reactions to any degree with microbe-human host evolution or the chemical co-evolution of plant-microbe-human. Thus, these studies did not consider the potentially beneficial aspects of plant defense antibody toxins to all evolutionary parties. This dissertation suggests that the optimum way to handle our co-evolving plant partners is to better understand the physiological mechanisms involved and the overall laws of nature in both symbiotic and predator-prey types of plant-human-relationships, particularly as regards disease from third party microbial organisms. The following pages have examples of plant-human evolution that demonstrate some concrete beneficial relationships.

The Hausa people of Nigeria have thirty-one plant species that enhance immunity to drug-resistant strains of malaria (Etkin, 2003). Some of these plants used by the Hausa display oxidant activities, which cause the destruction of immature malarial parasites (Etkin, 2003). The fruiting or harvest times of many Hausa plants useful for drug resistant malaria coincide with the highest malaria risk periods of the year, which suggests a potential co-evolution of humans and plant species that has been mutually beneficial (Etkin, 2003). Another malarial

example is the consumption of fava beans in the Mediterranean, which reach peak consumption rates at times of highest malaria risk and confer a similar resistance to malaria, in this case also by increasing oxidative stress in cells (Etkin, 1997).

Human physiological systems, such as temperature regulation, respond to plant food phytochemicals due to pre-existing evolutionary adaptive chemical partnerships (Gordon, 2005). For example, ingestion of juniper plants (Juniperus monosperma) affects metabolism of animals leading to a higher body temperature (McLister, et al., 2004). Animals consume more junipers in the winter than the summer, a behavioral preference that may be a co-evolutionary adaption to reduce the metabolic cost of thermoregulation during winter months. The Kawymeno Waorani have remarkably low average body temperature, which defies human norms established by biomedical science. Plant phytochemical consumption may lower human body metabolism and body temperature, which may explain the "how" in terms of the physiological mechanism that achieves a lowering of body temperature. The "why" is discussed in the results section in terms of adaptive utility low body temperature might have for the Waorani.

Overdosing on plant pharmaceuticals: the agricultural diet. This dissertation suggests that when both plant pharmaceutical production and humans are taken out of their original ecological role of dietary intake, these formally beneficial phytochemicals may be maladaptive in a new set of environmental circumstances both for humans and plants themselves. Plant phytochemical production can have more beneficial pharmaceutical properties for animals, such as humans, within wild ecosystems and food chains in which humans participate.

Thus, modifying the world's environment through agriculture or environmental destruction can convert former genetically regulated and expressed mutually beneficial plant-human chemical complexities into neutral non-beneficial or even harmful chemical interactions. Unfortunately plant pharmaceuticals have been modified and dumped into modern food production and the human diet without regard for their original co-evolutionary role with animal life.

Even natural alteration of the environment can convert plant foods that normally are chemically and nutritionally beneficial to humans into toxins that kill human beings. Under drought conditions in Africa, BOAA (a neurotoxic glutamate analogue phytochemical) occurring in trace amounts is found in some nutritious edible plants, but perhaps to protect the plant in some manner BOAA levels are increased into toxic proportion in draught condition. With draught-induced change in the environment, the vastly increased toxic effects now outweigh the beneficial nutritional aspects of these African plant foods. These same droughts in Africa frequently lead to human famine, causing extreme nutritional deficiency and physiological vulnerability. The combination of reduced human nutritional fitness and exposure to drought-enhanced BOAA toxic plant chemicals in edible plants normally tolerated, can be overwhelming and decimate populations of humans starting with infants and other more vulnerable members (Castleman, 1990; Jackson, 1991; Oehme, 1978).

Unlike temporary phytochemical level changes induced by temporary natural environmental shifts, such as the example above, the institution of massive agricultural systems probably causes even more profound plant defense chemical

production changes. Although agricultural scientists can detect overt plant poisoning, more subtle long-term toxicity may go unnoticed. Agriculturally induced low-level long term phytochemical toxicity may turn a previously beneficial relationship between wild plants and humans into a double-edge sword, where nutritional and helpful phytochemical benefits are canceled out by the increased toxicity of other distinct phytochemicals. Similarly, appropriately dispensed human made medications can control diseases but taken indiscriminately and in excess, synthetic pharmaceuticals are also poisonous. All this is discussed in more detail further on in the dissertation.

There is a widespread public misunderstanding that "natural organic food" equals safe food, when in fact natural plant phytochemicals indiscriminately consumed can be every bit as toxic, mutagenic and carcinogenic as their man-made chemical cousins (Ames, 1989). Almost every plant in the supermarket already contains natural mutagens and carcinogens (Ames, 1992). In fact, total dietary intake of pesticides in the United States is made-up of 99.9% natural plant defense chemicals and only 0.1% human made pesticides (Ames, 1990). Yet research and public health debate focuses almost exclusively on the effect of man-made pesticides on human health. To be hardy enough to survive in the field, even agriculturally coddled and genetically manipulated plants must have an arsenal of plant defense pharmaceuticals to protect against harmful microbes, competing plants, insects and animals (Swain, 1977; Harborne, 1977). Chemical testing reveals that agriculturally produced food in the supermarket has much higher levels of naturally occurring plant defense toxins, anti-nutrients,

mutagens and carcinogens compared to the relatively insignificant quantity of human-made pesticides (Ames, 1989, 1990, 1992). That means that all standard table foods contain plant defense toxins, anti-nutrients, mutagens and carcinogens, which modern food processing has not removed (Huxtable, 1980; Mohabbat, 1976; Oke, 1977; Shoental, 1968; 1982). Plant defense chemicals may be a more significant threat to human health than synthetic pesticides and other toxic chemicals in our food supply. This dissertation suggests our modern food system may be concentrating, to a toxic level, rather than diluting certain natural plant defense pesticides, herbicides, insecticides and antimicrobials.

Like the pharmacological benefit, the toxic harm of plant defense pharmaceuticals may be largely situation-specific. Whether plant food phytochemicals are in moderate beneficial doses or in higher toxic ranges depends on the combination of a number of factors including: 1) dosage, 2) length of exposure (i.e. lifetime dietary wheat exposure versus intermittent exposure to pumpkin in a Thanksgiving pie), 3) whether the human is in a vulnerable developmental stage (i.e. fetus), 4) individual human genetic predisposition, 5) whether the person is malnourished, 6) detoxification capabilities of a given individual, 7) the mixture of foods ingested at the same time, because phytochemicals chemicals interact with each; enhancing, modifying and degrading the pharmaceutical properties of each other (Etkin, 1996a, 2006; Jackson, 1991) and, 8) concomitant consumption of human-made pharmaceuticals degrades, enhances and alters both dietary natural phytochemical pharmaceuticals

and any addition human-made medication consumed (Etkin, 2006) (i.e. grapefruit juice is known to increase bioavailability of many human-made drugs).

It is suggested that hunter-gatherers, such as the study Kawymeno Waorani, avoid the above-mentioned complicating factors that increase phytochemical toxicity of food in agricultural societies. Discussed later is why the study Santa Teresita Kichwa farmers and agrarians in general chose consume food toxins and the role sense of taste and smell has to play. Kawymeno and other hunter-gatherers throughout history tend to use methods that do not significantly provoke chemical alteration of food from a natural state. Hunter-gatherers eat unprocessed, often raw, foods separately from each other; there are few recipes mixing and combining ingredients; cooking processes such as mixing blending, chopping, frying, microwaving, and freezing are not utilized. Finally, hunter-gatherers did not consume human-made medications, and at least in the case of the Kawymeno Waorani, do not use many plants for medicinal properties.

Natural Pharmaceuticals Found in Animals Foods

The sheer amount of research done on plant defense secondary chemical compounds makes it appear that the only useful and diverse defense chemicals are found in the plant kingdom and none are present in the animal kingdom. However, it is likely that the plant chemical bias of natural supplement product research has exaggerated the magnitude of difference (Etkin, 2006). Indeed, a growing body of literature is providing evidence of the pharmacological potential of animals (Angelov 2004, Apaza 2003, Jahovic 2004, Lev 2003, Lusy 2002). However, for no domesticated or wild species of animal does a systematic

documentation exist on their pharmacological potential (Etkin, 2006). Although this dissertation refers mostly to plant-human co-evolution within the context of food systems this is mostly for simplicity. Animal, fish and insect foods consumed by humans have anti-plant defense chemicals due in part to their own co-evolution with plants and the chemical warfare they have practiced against plants to be able to eat them (Angelov, 2004; Apaza, 2003; Etkin, 2006; Jahovic, 2004; Lev, 2003; Lusby, 2002) In sum, animals also produce their own defense pharmaceutical chemicals and on top of that, inherit concentrated versions of plant defense pharmaceuticals via the food chain, albeit modified by enzymatic processing.

In fact, animal and fish foods may have even more concentrated plant chemicals doses than found in the actual plants. Phytochemicals often accumulate and concentrate as they move up the food chain. For example, marine species of algae, such as epibenthic dinoflagellates, contain phytochemicals that cause a decrease in body temperature (Gordon, 2005). These natural algae-based pharmaceuticals increase in strength as they are transferred up the food chain, concentrating in large amounts in many edible tropical species of fish (Gordon, 2005). Thus, animal, bird and fish foods of the study Kawymeno Waorani have concentrated on natural plant pharmaceuticals passed on through a wild food chain from phytochemicals originally created in plants lower down in the food chain. Domesticated agricultural animals of the Kichwa agrarian food system, as well as modern food systems, are not part of a wild food chain. These domesticated animals, poultry and fish lack the plethora of concentrated

phytochemicals that are moving up the varied and complicated wild food chains embedded in ecosystems with complex chemical interchanges.

Another form in which humans receive food-based pharmaceuticals, such as antimicrobials, is directly from other humans. Human breast-milk has natural antimicrobial and immune enhancing properties. This study found that most Kawymeno Waorani babies consumed breast-milk from several different mothers who took care of them. Thus, Kawymeno Waorani babies have a greater variety of natural human antimicrobial pharmaceutical intake from multiple human breast milk sources differing from than Kichwa farmer or modern Western babies who often receive breast-milk from just the birth mother.

The Line Separating Poisonous and Medicinal Cuts Across the Hearts of Most Foods

In this chapter a base knowledge of the co-evolutionary chemical interaction as relates to food systems and the dissertation results was outlined with examples. It is clear the line separating poisonous and medicinal cuts across the heart of most foods. The type of food system a society has, to a considerable degree, dictates which side of this poison/medicinal line a population diet falls under. The dissertation results that follow show in more detail how verging away from the co-evolutionary normal relationship that hunter-gatherers have had with their wild food chain and ecosystem though 99% of human history pushes agrarian-based humanity across the divide into a dietary danger zone. A switch to agriculture from hunter-gathering simultaneously removes much of the medicinal aspects of diet and at the same time increases the toxic effects of dietary intake. Human health outcomes across subsistence agriculture and hunter-gatherer food systems

in dissertation results chapters that follow demonstrate we have the wrong end of the dietary double-edge sword pointed straight at us as humanity enters the 21st century. Can the largely symbiotic chemical relationship that existed between plants and humans be recreated in an agricultural context? Can modern biomedical treatments protect humans from disease in the same way our plant-human relationship once did?



Figure 4 Kawymeno Waorani Girl

CHAPTER 4

DISSERTATION RESEARCH SITE AND STUDY POPULATION

Research on Hunter-Gatherer Food Systems in the 21st Century

There are essentially very few or no functioning intact hunter-gathering food systems in Africa, Asia or the Polar Regions. So are there any hunter-gatherers left who just hunt and gather to survive? The answer is yes, but probably these groups will not survive intact for more than a decade or two at most. While there are probably no humans unaffected by changes that the modern world has brought, there are still groups that have essentially intact hunter-gather systems with minimal influence from subsistence agriculture and outside food systems. The last frontier for these remaining intact hunter-gatherer food systems is South America and New Guinea. The challenge of this dissertation was to find such a hunter-gatherer group that still survived through hunter-gathering but was comfortable enough to collaborate with outsiders in the collection of primary data on their health system and health status.

It is almost a cliché in the group of researchers studying modern hunter-gatherers to state that modern hunter-gatherers are not a good representation of the life of the pre-historic hunter-gatherer lifestyle that has dominated humanities history. A discussion about what a "real" hunter-gather is took place in the previous chapter. Part of the reason is modern hunter-gatherer researchers have rarely worked with modern hunter-gatherers yet these groups still exist in South America. This distinction between modern indigenous farmers that are still part-time hunter-gatherers and groups that engage only in a hunter-gathering lifestyle

is discussed in detail in the chapter on helminths. Prior to the mid-20th century the hunter-gatherer literature is largely anecdotal and descriptive in nature. There was little interest in doing quantitative health studies on hunter-gatherers or even considering hunter-gatherers as a distinct group from other indigenous groups in general, until the middle part of the 20th century. Thus, most of the quantitative health studies were performed long after extensive acculturation had taken place in many hunter-gatherer groups. Even after the mid-twentieth century there was a selection bias on the part of most researchers to work with modernizing displaced hunter-gather groups rather than wild and free hunter-gathering groups.

Modern hunter-gatherers and biased research. There is another bias, a sampling bias, which also affects and puts into doubt generalizations that can be drawn from research conclusions on acculturating hunter-gatherers in Latin America. I conducted a literature search on the well-respected and inclusive Pub Med health research database of the National Institutes of Health. This paper assessed the overall body of medical research conducted in the past 35 years on Central American as well as many South American indigenous subjects (London, 2008, unpublished). The search yielded 334 citations, 123 from 1998-2008, 126 from 1988-1997 and 85 from 1973-1987. This large body of literature was diverse in nature and dispersed throughout academic disciplines.

The analysis in this paper operated under the assumption that the results of this Pub Med literature search are a proportionately representative, valid sample of all the types of medical research done over the last 35 years with the

indigenous populations of Central America. This assumption makes it possible to draw some conclusions from this database of citations.

My literature search showed that conclusions regarding Latin American medical studies of indigenous populations, (both acculturating indigenous farmers and indigenous hunter-gatherers) are based on the same handful of research sites and indigenous participants in Latin America. This over-representation of the same indigenous populations, first, ignores the majority of the population of those particular cultures as a whole and second, completely ignores all the other separate indigenous ethnic groups. Regardless of the food system, indigenous persons in Latin America in general have characterized in research generalizations based on a small and unrepresentative segment of the indigenous population. While wanting the ease of conducting research in established indigenous research sites in which a trusting relationship has been built up over many years, this convenience leads to research assumptions about indigenous population without enough coverage of population breadth to be generalizable to all indigenous groups. Thus, researchers do not want to take the risk or engage in the time consuming process of seeking out establishing new research sites and populations that are likely to have less Western influence from researchers and others.

Absence of primary data on modern hunter-gatherers. There are hundreds of articles on hunter-gatherers discussing the "ancestral diet", discussed previously, in both peer reviewed and popular literature. Almost all of these articles use secondary data and archeological studies and are not actual investigations of the nutritional content of living hunter-gatherer food systems.

The few modern hunter-gatherer articles on food mainly focus on areas such as ecology and energy expenditure rather than actual dietary content and in many cases are studying former or part-time hunter-gatherers that have been displaced from their original environment and practice some degree of subsistence agriculture or are involved in the modern food system. There are very few primary data collection studies on the specific nutritional content of a modern hunter-gatherer diet and virtually no primary studies of plant defense chemical content of a modern hunter-gather diet. Thus, there are hundreds of articles on the ancestral diet based on a very limited pool of hard data leading to precarious statements based more on theory than any real data. Thus, this dissertation is in new research territory with little precedent. Many of the more modern "hunter-gatherer" studies examine former hunter-gatherers that in many cases many cases have been displaced from their native ecosystem.

There is no such thing as a "true" hunter-gatherer as hunter-gatherer cultures vary as much as modern cultures around the world. The word "hunter-gatherer" or "forager" tends to stereotype and limit the diversity of human culture that hunter-gatherers actually represent. The point in this dissertation is not how much hunter-gatherers are influenced by outside cultures. Further, what matters in this dissertation study is not whether or not the Kawymeno Waorani hunter-gatherers are like "prehistoric hunter-gatherer", a term that spans a wild diversity of cultural differences. What matters in this dissertation is the food system, that is if the Kawymeno Waorani hunter-gatherers get a wide variety of wild of phytochemicals from hunting, gathering and a little semi-cultivation instead of

subsistence agriculture with limited variety and low quantity of phytochemicals coming from domesticated plants and animals. Evidence presented in the next chapter points out that many pre-historic hunter-gatherers actually practiced semi-cultivation. For that matter "pre-historic hunter-gatherers" probably had contact with large agricultural cultures like the Inca of South America in the last 10,000 years as well.

Dissertation Requirements for Study Populations and Sites

This dissertation study required a hunter-gatherer food system that contained pharmacological aspects of the plant dietary intake that represented, as closely as possible in the 21st century, the human evolutionary norm for foods systems for 99% of human history. A primary consideration in the selection of study site and study populations was to control for confounding variables that effect human health that are not related to the phytochemical content of the diet. This study makes the case that a change from hunter-gathering to subsistence agriculture and modification of dietary phytochemical content are enough to account for many health changes.

Essentially a natural experiment was required that could be observed rather than manipulated, such as is found when comparing species living on the different Galapagos Islands in the search for understanding natural selection. We wanted two populations with different food systems that were culturally isolated and separate but co-existing in a pristine environment that has not been altered by modern humans.

Specifically, the dissertation study required a subsistence agriculture system set in the same environment as a hunter-gatherer food system, with no social contact between each other that would influence their respective food systems. Both food systems needed to have minimal or no involvement with the modern food system. While the Santa Teresita Kichwa are agriculturalists, economically and geographically they are cut off and isolated from modern food system in Ecuador and important to this dissertation they get their phytochemicals from domesticated food sources without the processing and chemicals present in modern food systems. The environment desired was an undisturbed food chain similar to the type of food systems hunter-gatherers were embedded in prior to converting to agriculture, because this is a study about a plant - human evolutionary relationship, and the plants and animals in the food chain are as important as the humans in this study.



Figure 4. Primary Rainforest Surrounds Kawymeno for Many Days of Walking

The above mentioned conditions and populations were found in Amazonian Ecuador. The following dissertation represents several years of on-site study of both the health status and food system of Kawymeno Waorani hunter-gatherers and the Santa Teresita Kichwa farmers of Amazonian Ecuador. The dissertation hunter-gatherer primary rain forest, Yasuni National Park, is one of the few places where industrialists have not yet altered the environment. In fact, we were the first foreigners to be invited and be allowed to live in that part of Yasuni National Park with the Kawymeno Waorani deep into the primary rain forest.

Dissertation Study Site. The Kawymeno Waorani food system and food chain rooted in Yasuni National Park, a rain forest in the Amazonian region of South America. Yasuni National Park is widely considered one of the most bio-diverse and pristine areas left on the planet where plant and animal life are largely untouched, an environment which may approximate, as closely as is possible in the 21st century, the environment Amazonian hunter-gatherers may have had their food chain embedded in since prehistoric times. This rain forest the Waorani and Kichwa live in is a closed system into which nutrients and phytochemicals are locked into the vegetative process, the trees and the plants, rather than soil itself, (which is only a few inches deep and depleted) holds the nutrients and biochemicals (Yost, 1981). Thus, any agricultural crops that are planted and depend on the biochemically on rain forest soil are not involved in the wild food chain and ecosystem, which is locked into the plants and not the soil. Further, agriculturalists that only use rainforest soil but not rain forest plants are not bio-

chemically connected to rain forest, and are to a large extent locked out of the nutrient and phytochemical cycle of the rain forest. Agriculture in general but particularly in the Amazon, operates outside the natural ecosystem, which relies on wild plant to wild plant biochemical exchange with no intermediary soil to tap into. Agriculture relies on a human made ecosystem that is removed from the influence from the natural eco-system and the rich variety of phytochemicals.

Yasuni National Park is huge expanse of rainforest of about 15,920 square kilometers, of which 9,820 square kilometers is directly in the park, and 6,100 square kilometers is in the form of a reserve. The original Waorani territory in 1958 was approximately 20,000 square kilometers of tropical moist forest and tropical wet forest allowing about 40 square miles per person (Yost, 1981). Kawymeno is located on the banks of the Yasuni River (called the Kawymeno River by the Waorani) and is a several days in a hand-paddled canoe from the outpost village of Nuevo Rocafuerte. The Yasuni River winds through Yasuni National Park and is a beautiful but dangerous trip due to obstacles and logs hidden underwater. The Yasuni River is a narrow and twisting river whose depth varies daily from a few feet deep to 15 feet deep in the same spot depending on rainfall. The head of the Yasuni River sits right on the border between Peru and Ecuador on the banks of the Napo River, a major river that turns into the Amazon River further downstream. The Santa Teresita Kichwa are located across from this entrance to the Yasuni River and often enter the park.

The Kawymeno Waorani remain the greatest protectors of Yasuni National Park keeping out other indigenous groups that would poach and sell

animals such as the peccary for meat and harvest the large primary forest trees that may have taken thousands of years to reach their present size. However we have observed directly that poaching has increased in Yasuni National Park as outside groups lose their fear of the Waorani. The younger generation of Waorani is not the warriors their parents were. Outside groups fear the Waorani due to confrontations in which Waorani speared Kichwa, foreign missionaries and Latino nationals, and thus Kichwa and others rarely enter Waorani territory without being paid by corporations to illegally cut timber, and harvest rain forest products.

In many sites around the world, hunter-gatherers have been relocated or pushed by advancing Western colonists into regions with a scarcity of natural resources that they might not have chosen to live in otherwise. Many authors who have specialized in studying the Waorani hunter-gatherers agree that Yasuni National Park is not an area where hunter-gatherers were pushed into as modern civilization encroached (Yost, 1981; Rival, 2002; Davis, 1983). Rather, this region represents an environment chosen by the Waorani, a rain forest where they have lived in perhaps even for millennia, because of the abundant natural resources. A study in Yasuni National Park may give a better representation of a previous hunter-gatherer food system and the cultural life surround it than many hunter-gatherer studies, which were done in an environment in which hunter-gatherers had been displaced.

Indigenous History of Amazonian Ecuador

Only 80 years before the Spanish conquest of Ecuador in 1533, Ecuador was finally incorporated into the Inca Empire. The Incas left behind the Kichwa language they imposed, which replaced the original languages of the Ecuadorian highlands. Since the Spanish invasion that followed the Incas, most of the original Amazonian Ecuadorian indigenous groups, who have lived many centuries, if not millennia, in the Amazon, have been killed off or assimilated into a mestizo population or melded into the Kichwa language group (Costales & Costales, 1983; Steward & Metaux, 1948). The study group of Santa Teresita Kichwa indigenous is a part of the lowland Kichwa, who are part of this post-conquest creation and like many Ecuadorian indigenous groups speak the Inca language Kichwa that was pushed on them, similar to the way Spanish is now displacing Kichwa. The West is not the first empire to touch most indigenous groups. The Waorani appear to be an exception to the Inca conquest, as their language has absolutely no words from any other known language group, which is a strong indication of their isolated status as is their unique medicinal plant system. Only the less developed more remote hunter-gatherer groups of the Amazon survived into the modern period including the Waorani, Cofan, Siona-Secoya, Shuar and Aschuar.

There are a number of subgroups of Kichwa in the Ecuadorian Amazon region of which the Santa Teresita Kichwa – the group chosen for the dissertation study – belong to the Yumbo sub-group that inhabit the banks of the Napo River. The Yumbo Kichwa filled the vacuum of the now almost extinct Zaparo group.

The Zaparo culture that existed in or close to the original Waorani territory, numbered 20,000 in the mid-1900s (Kvist, 1987; Stark, 1981), but have died out due to the post-colonial invasion of Westerners including US chewing gum companies tapping Amazonian gum producing trees before synthetic gum was invented.

While the Santa Teresita Kichwa borrowed habits such as the use of blowguns and dart poison (evidently from the same plant used by the Waorani, *Curarea tecunarum*) these habits have disappeared (Krukoff and Smith, 1939). Children shortly before my arrival destroyed the last blowgun left in Santa Teresita. Blowguns had evidently not been widely used for 40 years according to the older community members of Santa Teresita. Missionary groups bear a lot of the responsibility for the spread of the Kichwa language and cultural disruption and assimilation of the now extinct and the vanishing native indigenous groups of Ecuadorian Amazon (Karsten, 1935; Steward & Metaux, 1948). The Waorani were the last remaining completely uncontacted indigenous group in Ecuador until the arrival of missionaries from the Summer Institute of Linguistics a number of decades ago.

Below are descriptions of the three study populations relevant to the dissertation research. While the Protectorate Kichwa are not involved in many comparisons, the Protectorate Waorani are nevertheless key because they help rule out genetic explanations for Kawymeno Waorani health outcome. An understanding of the Protectorate Waorani is necessary to appreciate the lifestyle change and health outcome of a genetically identical but food system wise

different Waorani group. Most emphasis has been placed on the Kawymeno Waorani hunter-gatherers, the center of our study, and less on the comparison group of Santa Teresita Kichwa, with a still briefer mention of the Westernizing Waorani who serve more as a indicator that the unusual health characteristics of the Kawymeno Waorani are principally environmentally and dietary driven rather than genetically driven.



Figure 5. Kawymeno Waorani Tradition Home

The Waorani Nation. Lathrap has suggested that the cultures of the upper Amazon devolved from earlier agricultural societies (Lathrap, 1968, 1970). However, experts on the Waorani culture suggest that the Waorani descend from a pre-stone age culture that has not experienced agriculture (Yost, 1981). The Waorani did not make canoes, which require stone tools, and none of the oral traditions give any suggestion of an agricultural past such as in the cultures

Lathrap studied in Peru. The Waorani culture comes from an era that preceded the Stone Age, as even in the 1970s Waorani did not know how to make stone tools, although they found stone tools in the jungle that they attributed to the creator God "Weengongi" not other humans (Yost, 1981). Stone axes are critical for clearing the jungle for agriculture and for a society with a strong agricultural past to lose the knowledge to make stone axes is unlikely (Yost, 1981).

The Waorani use wood blowguns and darts poisoned with plant phytochemicals to hunt birds and monkeys along with wooden spears with wood tips to hunt the larger animals of the forest such as wild peccary. Shotguns are occasionally used when shells are given to the Waorani. My Waorani assistant, Ima, constantly demonstrated what most Waorani know while we worked identifying food plants in the rain forest, namely the cycle of flowers and fruits of all edible forest plants in the rain forest and the interdependence of animal and plant cycles, as well as the preferred plant foods of forest animals and even the medicinal plants animals use to treat themselves when they have a disease.

Waorani marriage customs are an example of the egalitarian nature of their culture, not only can men have multiple wives, but women can have multiple husbands. We know of one woman with two husbands however the custom is dying out. In Kawymeno there is a tendency towards cross-cousin marriages but many exceptions as well. Another example of the highly egalitarian nature of the Waorani we have observed while hunting with the Kawymeno Waorani is that men and women, including husband and wife teams, hunt together. In fact, I have observed that it is traditional for the man to do the initial spearing to bring down

the animal but for the wife to move in and actually kill the animal with a knife. Households in Kawymeno typically span 4 generations and all members can trace their ancestry back to the brothers Kai and Huani who still hunt with their great-grandchildren.

Today there are approximately 1,400 Waorani in the Eastern Amazon region of Ecuador (Rival, 2002) of which approximately 120 are still practicing a strict hunter-gather diet in Kawymeno. Westernized Waorani are living in sedentary villages near airplane runways, roads and readily accessible rivers in the Oil Protectorate. The Kawymeno Waorani live in the opposite end of the rainforest in the protected Yasuni National Park, near no readily accessible modern transport or habitation. While the Kawymeno Waorani today live right on the Yasuni River, pre-contact Waorani originally favored spots a little further inland relying on smaller feeder streams and avoiding larger rivers where enemies could find them more easily (Yost, 1981, 1984). Both the Kawymeno and Westernizing Waorani groups are from the same ethnic group and speak Wao, a language isolate with no connection to any other language in the world (Peek, 1973). Genetically all Waorani groups are almost identical, possessing common unique genetic traits not found elsewhere in the world (Watkins, 1992). There have been only a few cases of Waorani marriage outside the Waorani group to Kichwa Indians. In the case of the Kawymeno Waorani, marriage to outsiders is forbidden and there have been no marriages outside the Waorani clan. There have been no recent confirmed sightings in a number of years of a group of Waorani called the Tagaeri, who broke away from the protectorate a number of years ago

and were living in the rain forest out of contact with the rest of the world. The fate of the Tagaeri is uncertain.

The Kawymeno Waorani practice a traditional hunter-gatherer lifestyle distinct from the acculturation, subsistence agriculture and daily contact with outsiders, typical of Waorani groups in the Protectorate oil fields. For instance, Kawymeno Waorani still maintain cultural practices such as burying their dead in ceramic jars with goods for the trip to the next world, more similar to burials found in archeological sites, rather than modern indigenous communities.

Oil Corporations and the Kawymeno Waorani Hunter-Gatherers.

The Kawymeno Waorani have gone from a pre-stone age hunter-gathering past where the only tools were wooden spears and blowguns and the like, to sudden confrontation with a modern civilization in recent decades. A few years ago, Petrobras, a Brazilian oil company conducted seismic drilling in Yasuni National Park around Kawymeno discovered major oil reserves. The well known ITT oil reserves have been the subject of intense worldwide international controversy and are a major threat to Kawymeno, which lies a scarce 25 minutes canoe ride away. The international community has put up money for the Ecuadorian government to temporarily stop drilling in Yasuni National Park, but this money must be continued to be paid on a year to year basis.

Early Studies of the Waorani

A Harvard researcher who studied the Waorani hunter-gather group in the early 1980s stated “The biomedical data indicate that the Waorani were relatively free from disease at the time of contact. Indeed, they may represent as close a

facsimile of the pre-contact condition as will ever be available for study" (Davis, 1983).

The Waorani had first contact with the outside world late in 20th century and had no previous outside contact due to a reputation for violence toward outsiders, including all other indigenous groups and an inaccessible habitat in the depths of the rain forest (Yost, 1981). The Waorani were a rare exception to the typical story of Amazonian contact with invading outsiders. Serological testing for antibodies for disease demonstrated that the Waorani were isolated from outsiders, including neighboring indigenous groups. Neighboring indigenous groups in contact with Westerners invaders often served as intermediaries of disease transmission that passed second-hand to more remote uncontacted groups, whom often had never even seen the invaders (Kaplan, 1979). Thus, the Waorani first received the devastating diseases originally brought by colonists from Europe in a recent era when vaccines were available (Larrick, 1979). Right from first contact with these diseases the Waorani had access to vaccines and medical programs and thus were not decimated by introduced infections like so many other indigenous groups in past history (Davis & Yost, 1983).

The evangelical religious group called Summer Institute of Linguistics (SIL) gathered and moved most of the Waorani out of their original rain forest homeland in the 1970s and 1980s, and hired an anthropologist named James Yost to assist the Waorani to adjust to life outside the environment to which their diet, health and culture were intimately tied. James Yost invited researchers from Harvard and NIH and collaborated with them in producing a series of important

articles on the Waorani involving health, diet, lifestyle, immunity from disease and ethnobotany (Kaplan, et al., 1979; Kaplan, et al., 1980; Larrick, et al., 1979; Larrick, et al., 1983; Larrick, et al., 1985; Buckley, et al., 1985; Davis &Yost, 1983; Davis & Yost, 1983B; Yost, 1981; Yost, 1981a). These fascinating studies have proved very useful in providing a base of reference for this dissertation study.

Westernizing Waorani in the Protectorate. This relocation of the Waorani by the SIL damaged the Waorani culture and food system, which was dependent on the rain forest environment they had inhabited, and left them living on new land called a "Protectorate" that soon became a site for oil drilling. Some groups, such as the Kawymeno Waorani, retreated from the oncoming destruction of the oil corporation drilling. Authors of studies on the Waorani in the 1970s and early 1980s also made it clear the Waorani they visited in SIL missionary villages were becoming "subsistence agriculturalists", game was no longer plentiful and hunting involved a 4-5 hours trip from the village (Larrick, 1979; Kaplan, 1979). The Protectorate is now divided into blocks leased to various foreign oil corporations for drilling. The Waorani communities now living in the Oil Protectorate region have entered the modern food system and begun to enter the global culture, albeit on the lowest possible rung of the socio-economic ladder. While Waorani living in the oil protectorate still sporadically practice hunting and gathering they are now dependent on the oil companies for their food and survival.

Our visits to Oil Protectorate Waorani communities in 2010 found a group using subsistence agriculture and relying on the oil company for many food items. Our conversations with these Waorani revealed many of the Protectorate Waorani have never even visited Kawymeno due to its remote location and not witnessed Kawymeno's present-day traditional hunter-gathering lifestyle. Wild game and wild plants, still used in Kawymeno, have been depleted or were no longer present in the oil protectorate. Obesity, diabetes and other chronic diseases were commonplace. There are a number of foreign researchers working now with Protectorate Waorani but few articles on the state of their health. Talks with public health officials confirm the protectorate Waorani health status, which resembles the health of Native Americans on reservations in the USA in terms of dietary related diseases such as obesity, diabetes and other chronic diseases and the Westernizing Waorani. In addition the Protectorate Waorani had many infectious diseases not found in the Kawymeno Waorani such as Staphylococcus infections.

In one key respect, genetic similarity, the protectorate Waorani would have made a desirable study comparison group to the Kawymeno Waorani. However, there are indications that genetic constitution does not explain the lack of disease between the Kawymeno Waorani. The deterioration of the Westernizing Waorani's health, including the appearance of chronic and infectious diseases the Kawymeno Waorani do not have, within the space of a few decades out of the rain forest, suggest the Waorani have no special genetic protection from disease that can be separated from environmental factors.

While the Santa Teresita Kichwa are genetically different than all Waorani, their health outcome is similar to the Protectorate Waorani because of their common agricultural, domesticated phytochemical based food system. Both Protectorate Waorani and Santa Teresita Kichwa groups health differs from the Kawymeno Waorani because of the vast phytochemical difference across food systems documented in this dissertation, resulting in a health outcome difference that comes from transitioning from a wild food system to a farming food system.

This dissertation makes the case that among humans, food system related health outcome is similar disregardless of genetic make-up because the plant-human physiological ties are much stronger than human genetic differences. Even comparing animal health outcome to human health outcome, let alone humans to humans, plant-human physiological ties are stronger than genetic differences across mammal species, as plants have shaped have genetic evolution beyond even the million years of human existence, a physiological influence pre-dating hominoids and even primates. Plant-human physiology is linked back beyond humans, to ancestral organisms humans developed from, a plant-animal co-evolutionary collaboration that began when the plant and animal kingdom came into existence."

Therefore the environment and a hunter-gatherer food system are a more likely influence than genetics on the remarkable health status of the Kawymeno Waorani.

Finding a Suitable Comparison Population. For the purposes of this dissertation study, the Kichwa are a more suitable comparison population than the

Protectorate Waorani primarily because the modern food system has not had the impact on these Kichwa yet in the way the oil companies have forced the modern food system on the Protectorate Waorani. This is a study about food itself, wild versus agricultural food systems and without the confounding factors of processing and chemicals of the modern food system. Nor is this study about modern life versus hunter-gatherer life or controlling for genetics. It is more important to control environmental factors in this study than genetic, Protectorate territory is not virgin rain forest and thus, not a suitable for controlling for environmental factors. Tiwino, Bataburo and other parts of the Protectorate where most of the acculturated Waorani live is secondary rainforest or open fields, a different environment than pristine rain forest eco-system the Santa Teresita Kichwa and Kawymeno Waorani share. Furthermore, contamination from numerous oil spills into the environment affects the health of the Protectorate Waorani, which does not affect either the Santa Teresita Kichwa or the Kawymeno Waorani.

In this investigation, organic subsistence farming itself is being critiqued. While aspects of the modern food system are no doubt harmful to human health, this is a different topic. The study needed a clear look at just the foods and the difference in phytochemicals eaten across food systems with as few confounding factors present in a modern diets as possible. By using a subsistence farming population as a comparison population to a hunter-gathering system, rather than a population engaged in the modern food system, many confounding factors in diet

and environment are controlled as discussed in the chapter on helminths, the food system chapters and the health outcome chapters in detail.

This dissertation makes the case that whether the food is organic or not is secondary to the divide between wild and farmed foods. The Kichwa, as isolated subsistence farmers, still eat whole, unprocessed, organic foods. Farmed foods, organic or not, have an absence of wild varied phytochemicals, which this dissertation makes the case, is basic to human health while the organic issue is important but still secondary. The Kichwa farm and live in the same environment as the Waorani. The Kichwa, while having health problems, do not have the nutritionally related chronic diseases that are a hallmark of being in the modern food system. Thus, this study is able to separate and compare the actual foods eaten in a farming lifestyle with wild foods, without all the processing, chemicals and lifestyle issues that confuse the picture in modern agriculture and in fact almost all dietary studies conducted by researchers.

For this dissertation study, avoiding the many confounding factors of modern life that impact health is of paramount importance to isolate phytochemical factors that influence health. Organic farming has little in common with wild foods although the food industry and many nutritionists make it seem that way. Organic is a vague word that means less artificial but does not imply the food is wild. This dissertation is concerned about food itself and argues that although the Santa Teresita Kichwa have an organic farming systems this does not protect their health from chronic disease.

Confounding variables include controlling for the difference between subsistence farming and modern food. The comparison is between hunter-gathering and organic farming. These variables are reduced by using a subsistence farming group rather a group involved in the modern food system include: (1) Food Additive variables: both "natural" such as spices and salt and artificial such as preservatives, colorants, taste enhancers etc. (2) Agricultural technique variables: pesticides, herbicides, fungicides, fertilizers etc. (3) Preservation and cooking methods variables: Frying, microwaving, freezing and chemical, preservation while being shipped in from around the world etc. (4) Difference in lifestyle variables: Medical prescription drugs, street drugs, obesity, lack of exercise, stress etc. (5) Environmental Difference variables: exposure to environmental factors coming from all over the globe, the norm in a mobile modern world, such as exposure to multiple eco-systems, different pathogens, different contaminants and toxins. Again this dissertation is making the case that organic farming is not an answer to the world's health problems although no doubt a great improvement over the modern food system that issue is left for other studies. While this is an assumption, the main focus of this study is on phytochemicals not the organic-ness of food as organic foods have the same phytochemical absences as large scale agriculture.

The Kichwa Nation. The Santa Teresita Kichwa are a larger, more permanent population than the Kawymeno Waorani. There were 312 Kichwa living in Santa Teresita and 121 people living in Kawymeno in 2011. Santa Teresita is communal land where only that particular group of Kichwa is legally

allowed to live. The household structure consists of an extended family living together in several nearby structures with gardens close by and relatives a few minutes' walk away. Almost all marriages are within the community of Santa Teresita itself. There is surprisingly little socialization between the Santa Teresita Kichwa and neighboring Kichwa communities partly due to their geographical isolation.

The Kichwa in Santa Teresita differ greatly in diet and lifestyle from Kichwa in places most foreigners come in contact with, such as Kichwa from Tena region of Amazonian Ecuador. Santa Teresita is a part of the Yumbo Kichwa on the Napo River whereas the Kichwa inhabiting Tena are the Quijo, a sub-group of Kichwa with different customs. For instance the Santa Teresita Kichwa do not practice ceremonies using the hallucinogenic plant combination called "Aya-huasca". Aya-huasca ceremonies are frequently associated by foreigners as being part of all Amazonian Kichwa cultures.

The Santa Teresita Kichwa practice subsistence farming. There are weekly "mingas" or community work parties, which are similar to mingas in many Kichwa communities, where part or all of the community does communal gardening and other work. Most Kichwa food comes from domestic animals and plants, not from the rain forest they live in, thus their connection to the rain forest food chain is largely, but not completely severed. I use the word "subsistence farmer" to describe the Santa Teresita Kichwa who rely on domestic plants and animals for most of their dietary intake of nutrients and phytochemicals, although the Kichwa augment their diet through occasional hunting and some fishing. Due

to excessive commercial hunting, the wild game has moved into the center of the park and is not available to the Kichwa. The Kichwa use very little wild food, but do use an extensive and varied amount of wild medicinal plant remedies. The Kichwa are plagued by numerous chronic and infectious diseases the Waorani do not have.

Kawymeno Waorani and Santa Teresita Kichwa: Isolated Neighbors. Both Santa Teresita Kichwa and Kawymeno Waorani groups co-inhabit the same rainforest region and there is some conflict between these two groups over rainforest resources. The Kichwa live on the fringes of the Yasuni National Park, but even this Kichwa area is a vast unexplored rainforest wilderness extending into Peru. However, the Kichwa rarely enter the vast Waorani territory, according to the Kichwa we interviewed, due to fear of the Waorani. The Waorani have killed many Kichwa in the past century when Kichwa were sent in by corporations and landowners to harvest from the rain forest; tapping gum trees, clearing land, cutting lumber and other money making ventures.

The Kawymeno Waorani and Santa Teresita Kichwa have no social contact, which is important for the study as they maintain completely separate food systems. The Waorani as a whole have in fact maintained a relatively large homeland for their population size, largely because of the fear and respect even modern oil corporations have had for the Waorani groups that stayed out of the protectorate. On the other hand the Kichwa on the Napo River have often been marginalized into small village communities.

In the summers of 2008, 2009 and over much of 2010, my wife and I began our work living with the isolated Kawymeno Waorani hunter-gatherer sub-group in the Yasuni rainforest. We camped in the rain forest day in day out with the Waorani for months at a time with no contact with the outside world, since getting out to the nearest town was a weeklong process through rainforests and rivers. We also lived with the Kichwa, alternating with the Waorani site to capture any common seasonal factors more effectively. The dissertation work is described in the following chapters.

CHAPTER 5

STUDY HYPOTHESES AND METHODOLOGY

There is reason to question whether we have even found the major categories in food that maintain health let alone all the individual chemical elements that maintain human health. Are nutrients the only physiologically active components of the human diet? Consider the following**:**

Few studies consider the health impact of the recent drastic reduction and modification of plant defense phytochemical content in the modern global food system and human diet. Far from being inert these plant chemicals found in food actively interact in a multitude of ways with human physiological processes and make up ten percent of the dry weight of many plants (Abelson, 1990). Plants and humans have pharmacologically co-evolved together over millions of years confronting common enemies; such as bacteria, viruses and fungi. There are plant receptors throughout the human body to process these plant phytochemicals. This is apparent in the development of oxidative pathways (e.g. Cytochrome P-450 systems) in the liver and other tissues (Gordon, 2005). Even many human made synthetic medications work only because they fit into pre-designed chemical niches designed to process dietary plant pharmaceuticals found in food. Having these numerous plant chemical receptors in the human body indicates a long plant – human pharmaceutical relationship in the evolutionary development of humans. What is known is that pharmacological components of the human diet exist in all foods and have been modified by agriculture away from the evolutionary norm of

the hunter-gatherer diet. What is unknown are if these dietary plant phytochemical are essential or not to humans and beneficial or not to humans.

Study Hypotheses

These hypotheses are stated briefly as a simplification to be elaborated on in the next chapters. In a study as complicated as this one study hypotheses involve a complicated interweaving of arguments, which is presented in full in the food system chapters.

- Hunter-gathering food systems are not only nutritionally but also pharmaceutically beneficial and prevent disease through high dietary intake of varied plant defense chemicals (phytochemicals).

- Reduction of phytochemical intake to below levels typical in human evolutionary history due to the introduction of agriculture may leave humans vulnerable to diseases that were prevented through a hunter-gathering diet.

- The line between food and medicine is artificial; foods are both nutrients and medications at the same time.

- The flip side of the toxic effects of phytochemicals in food is their pharmacological potential to prevent disease. This line separating poison and cure runs through the heart of many foods.

- Phytochemical antimicrobials and immune altering substances in food alter the millions of organisms that make-up the microbial ecosystem inhabiting all human bodies. This alteration greatly affects human health. The great difference in antimicrobial and immune stimulating phytochemical content between hunter-gatherers and farmer diets is one factor in health differences across these food systems.

- Plant defense phytochemicals produced in agricultural plants are not equivalent to the chemicals produced in plants from the wild ecosystems hunter-gatherers live in. Agricultural food systems produce a diet of a very limited variety of phytochemicals consumed over and

over again on a daily basis over the entire human life span. This monotonous unrelenting phytochemical intake causes long-term toxic reactions leading to chronic diseases in agricultural societies.

- Unlike agricultural humans, hunter-gathering humans and their food exist within the same eco-system with the same microbial threats. Longer-term evolutionary relationships between plants, microbes and humans within an eco-system may produce phytochemicals that are more likely to have health benefits for humans within that ecosystem than for humans from another eco-system.

These points are elaborated on in the food system chapter.

Participant Observation

General study methodologies employed are detailed below. Specifics on some methods are discussed in more detail before pertinent sections. I established residence in both the Kawymeno Waorani and the Santa Teresita Kichwa communities as well as a temporary presence in the Westernizing Waorani in the Oil Protectorate. I made new acquaintances, took part in community activities, and worked to establish rapport and gain understanding of the dynamics of the respective food systems. I systematically recorded day-to-day interactions, observations and informal conversations by taking field notes on a daily basis to help me identify domains of life that need to be explored in greater detail. Data gathered through participant observation enriched and directed the focus of quantitative data gathering. By putting the food system and health outcome into socio-cultural context I extended the internal and external validity of the study and thus assured I selected and measured the quantitative factors that were relevant to dissertation objectives.

Sample Populations. My project is based on a sample of Waorani foragers, which consisted of 74% of the sampling frame of the entire community of 121 people in Kawymeno. The sample of the Kichwa subsistence farmers from the community of Santa Teresita was 19% of the entire community of 312 people. Since many people in the study sampling frame of Kichwa farmers and Waorani hunter-gatherers were minors below 18 years of age and thus ineligible for participation, the number of total adult study participants was a much higher proportion than minors. Both communities live next to each other in, or along the border of Yasuni National Park in Amazonian Ecuador near the Peruvian border. There is little contact between the two groups due to the violent history between the groups as the Kichwa were employed by corporations entering Waorani territory for almost two centuries and there is some disagreement regarding territory that both use. Both Waorani and Kichwa cultures are non-monetary living outside the Ecuadorian economy. The hunter-gathering Kawymeno Waorani are more mobile and live along the Yasuni river and practice no agriculture other than temporary cassava gardens and consume no grains, sugar, salt, spices, cooking oil, Westernized processed food or alcohol (outside of yearly kin gatherings) and diet is mainly fruit and meat. The Santa Teresita Kichwa also live in the same remote rainforest but along the Napo River, they rely on cassava and subsistence farming with minimal access to Western food production and their diet is mainly domestic vegetables, fruit and animal products. The selection of this group with a non-Western diet is intentional by study design to make a straight comparison between hunter-gathering and agriculture without possible

confounding factors of modern food and modern life. The oil companies discourage any type of study that may reflect unfavorably on their oil production and their treatment of the Waorani. Many Waorani work for the oil company for very limited wages (e.g. rather than being given a job Waorani have to share a job and salary with other Waorani) with apparent intention often more to control the Waorani population than to give real jobs that helped oil production. The purpose of including the Westernizing Waorani is to see if genetic characteristics of Waorani biology are partly responsible for their unusual immunity to disease. Further, more detailed characteristics of the three study populations are described in the dissertation chapter entitled "study site and populations" while details of the food systems are found in the "food system" chapter.

General Methods. First, an idea of Kawymeno Waorani hunter-gatherer and Santa Teresita Kichwa farming food systems was obtained via principally ethnographic qualitative methods (participant observation) to develop a macro-picture. Second, links between dietary and health factors across food systems were examined using primarily quantitative methods to understand the systemic food system and health outcome similarities and differences across hunter-gatherers and farmers, and identify significant specific variables linking diet and health in the two food systems.

The same methods including medical equipment, laboratories and survey instruments were used to capture data across both groups. All data that identified participants, such as the participant's name, was removed from study files and replaced with coding system.

Both Kawymeno and Santa Teresita are difficult worksites. The research site is a three day canoe trip from the nearest outpost with transport out only available every few weeks, very primitive living conditions, no medical care possible in emergencies and no method of communication with the outside world. One needed to camp in the Amazon rainforest for months in an environment that is harsh for outsiders, with many biting insects, in an area with one of the world's highest rates of fatality from poisonous snakebite and no access to food other than what the indigenous groups are eating.

My wife and I were the first foreigners the Kawymeno Waorani have permitted to stay with them. This dissertation study required a special methodology to deal with hunter-gatherers who have a wider cultural difference from the investigator than all agricultural groups of indigenous this investigator has worked with. This type of experience can only be acquired after many years of work with indigenous groups in isolated locals. I have fifteen years actually living and working with indigenous groups in many remote sites in Africa, Central America and South America for extended periods of time. The special methodology section on "giving back to indigenous communities one does research with" explains part of this specialized methodology.

Multiple methodologies were required to capture enough data on two complete food systems and two sets of health outcomes to get the database needed for the study results. These methods are detailed below. First in brief form the specific data collection methodologies are listed. These methods are elaborated on

later as the complicated nature of the details of these study methods are better discussed in context with the results.

- Medical/physical exams: (vision, blood pressure, anthropometric measurements)

- Medical histories

- Lab test data on feces, urine, involving over 100 different factors (including presence of helminth in stools) many of which will be the subject of future publications.

- Obtaining and analyzing available public health data surveys available to the public

- Health surveys and focus groups

- Dietary surveys and focus groups

- Complete Food system documentation – photographs and identification of all commonly eaten food species, and extensive information for each species (such as frequency of consumption). One year of participant observation of daily life divided between both groups.

The data collection methodology section is divided into two sections: Food Systems and Diet. 2) Health Outcomes.

Research Assistance to Carry out Methods for both Health and Food System sections. My Waorani study assistant Ima has a almost encyclopedic and photographic memory for food plants and spent many months in the rain forest

with me cutting through undergrowth to identify food plants and animals and their parts. My four other Waorani students, who I talked to on a daily basis, whose names are Oyowa, Omeway, Kemo and Winame double-checked to confirm Ima's plant identification. They helped me with many aspects of the study above.

Kichwa Assistants who performed the same role as my Waorani assistants and included Yasuni National Park native Kichwa guides, Belezario and Juan Carlos, residents of Santa Teresita and Nuevo Rocafuerte respectively. They helped find and organize Santa Teresita Kichwa groups, collect data and samples from households and provide assistance with the large task of tracking down and identifying species in the Kichwa food system, albeit an easier task than the Waorani food system, since foods were domesticated and farmed nearby the settlement.

Numerous ethnobotany specialists assisted me with the identification and scientific names of food system species including Amazonian ethnobotany specialist Dr. Chris Canaday, Biologist at the Omaere Ethnobotanical Park in Puyo, Ecuador, as well as two of my student research assistants at Arizona State University, Jennifer Pinney and Kara Gill who worked with the Vascular Plant Herbarium at Arizona State University.

Methods Used in Food Surveys, Focus Groups, Participant Observation and Plant Identification. Multiple methods were used to capture the entire food system of both the Waorani and Kichwa, which was by far the most difficult and time-consuming task of the dissertation study.

1) ***Individual food surveys*** were conducted to identify individual foods eaten and collect pertinent information, such as seasonality, frequency, for both Waorani and Kichwa food systems. A standard instrument (see appendices) was used to collect data on each food species eaten was developed.

2) ***Small focus groups*** of 10 people that had already been individually interviewed were conducted to provide consensus for each food survey study question on the actual instrument. Since the opinion of one person is not as reliable as combining group and individual observations about diet both were conducted. The same instrument in the appendices was used. My Waorani students assisted me with these focus groups and my Kichwa assistants helped me with the respective Kichwa groups.

3) Data based on ***participant observation*** over one year was gathered about the most commonly eaten foods, including dietary intake. Methods of hunting, fishing, gathering, and preparation of foods that affect the plant defense chemical content of the food systems were gathered. One year of participant observation on a long-term daily basis confirmed and added to the depth, reliability and validity of the focus group and individual interview information on dietary intake.

4) ***Plant and animal food identification in natural environment:*** Many months were spent combing through the rain forest physically tracking down foods, to document, identify, photograph and catalogue each food species eaten and a photographic file of the food systems of more than 2000 photos was

assembled. Many of the fruit species are not in common use in a modern food system so careful identification was necessary.

The list of all recorded plant and animal species consumed and respective scientific names from both the Kawymeno Waorani and Santa Teresita Kichwa foods systems is found in the food systems chapter and summarizes a portion of what was a large effort in data collection and analysis. Only plants consumed at least a few times a month by the whole population are included. The list of fruit occasionally consumed would add another thirty-two fruits to the study fruit list of the Waorani, already a food system with 70 recorded fruit food species. Beyond this list of plant and animal species consumed by the Kichwa and the Waorani are hundreds of pages of data on all these plants, of which a small amount is analyzed and summarized in the results section of the dissertation, the rest awaiting future study and are beyond the scope of this dissertation. Most species were identified and were labeled with scientific names for future more expensive projects such identifying individual categories of phytochemicals present of the food system.

Justification of Novel Analytic Methods used to Analyze Food System Data. Gathering and analyzing data on a hunter-gatherer food system presented many challenges not faced by nutritionists working with agricultural and modern food systems. A quick short-term snapshot approach is used in most traditional modern dietary studies such as food frequency questionnaires, food weighing, and recalling food eaten. These data collection devices allow for relatively easy analysis and are attractive because these instruments provide a simplified,

standardized, widely accepted method that can readily be compared to other dietary studies. However these traditional mainstays of the nutrition scientific community are impractical when studying hunter-gather diets, and particularly phytochemical intake, for several reasons.

1) The Waorani do not eat meals at set times of the day and in addition the number of meals varies day to day. Rather the Waorani eat when they are hungry and food is available. Traditional nutritional survey instruments are based on measurement at mealtimes, but recording a hunter-gatherer diet would require an investigator to follow a Waorani through the jungle all day measuring the significant quantity of berries and other food that never make it back to the house. Thus traditional nutritional surveys are not practical, and the Waorani would be unlikely to cooperate or even recall what berries and foods they ate every few minutes of the day. Even at the cooking fire the Waorani reach in a grab a chunk of meat making measurement difficult but we have managed to roughly weigh meat consumption.

2) The Waorani diet varies greatly seasonally, weekly and daily. Agricultural diets are characterized by their monotony and predictability. Thus, even an instrument that measures a week of dietary intake, a time-span often recorded in many traditional nutritional studies, would not be able to capture a "normal" dietary intake of a population whose food intake varies so much over the days, weeks, months and year.

3) Capturing pharmaceutical content of a food system is not the same as capturing nutritional content. Using a nutrition instrument to capture

phytochemical pharmaceutical dietary content is inappropriate. Variety and frequency are more important factors than quantity of phytochemicals consumed. Phytochemical content of even the same food species varies greatly seasonally and geographically. Even two plants of the identical species and weight may have a wide variation in phytochemical content as plant turn on and off chemical production depending on environmental threats and possibilities for alliance with other species. Thus, gross weight is not as useful an indicator for phytochemicals as for nutrients.

Novel Methodology and Data Analysis Required for Hunter-gatherer populations. Therefore this dissertation study required the invention of a new system of data collection and analysis to capture phytochemical food intake of hunter-gatherers. Although traditional dietary measuring instruments such as food frequency surveys may have functioned with the Kichwa farming lifestyle, to have data that can be compared with the Waorani food systems, a principal study objective, both food systems needed to be measured using the same method used for the hunter-gatherer population, which means avoiding the traditional concept of measuring meals since the Waorani eat when they feel like it and food is available not on a schedule since food is not stored.

Since the study is focused on pharmacological rather than total nutrient quantities of foods, quantity by weight or bulk of a given food is less important than frequency the food species is consumed. A numerical dietary frequency of consumption system was developed and is described below to compare and

contrast all food categories and groupings desired by researchers within and across these two dissertation study food systems.

Dietary intake frequency was obtained for study food species. Frequency was measured over a year rather than a day or week for both Waorani and Kichwa food systems. Since this is a novel system of analysis a more detailed explanation is given below:

The amount of days over the yearly seasons in which foods were available and eaten was obtained for every food. In turn, the average number of days per year a food was consumed was obtained by averaging out a particular food intake frequency over the entire year, including months when the food is not eaten, to take into account the great seasonal fluctuation in consumption of most wild and some domestic foods species.

The individual food frequency of a particular species was measured as the "average number of days a food is consumed over a year". The combined frequency of dietary intake of individual food species that were grouped by selected characteristic(s) into a category of foods is also measured as "average number of days a food category is consumed over the year". Thus numerical frequency figures emerged from the data collection data that was comparable and could be charted. These frequencies were used to measure quantitatively, similarities and differences of dietary intake within and across the hunter-gatherer and subsistence farmer groups. Longer periods of time were used for measurement than meals or days since food intake for the Waorani hunter-gatherers fluctuates day to day and season to season. Kichwa food intake was also

measured using more long-term measurements. Foods that were eaten less than once a month on the average over the year were not included leaving out many fruit foods of the Waorani.

Below is an example calculation. First, an example category: Let's say there are nine foods that are categorized by the Kichwa as "being both a food species and also used as a medicinal plant**"**. Each of these nine foods has been averaged over the year to get a figure of the average amount of days per month the food is eaten by one of the populations which is 93.5 days per year for the category of food species that fall under that classification.

The days per year (93.5) is divided by 9 (the total number of foods in the category) to get an average of the number of days per year, the food category entitled ***"****Both medicinal plants and foods"* is consumed, which is 10.3 days per month. The formula looks like this:

Total dietary frequency per food category/ (divided) by variety of species = the overall average frequency of all combined foods in the category.

93.5 total frequency in days per year/9 species = 10.3 days per year average per food species in the category

Beyond the total category frequency, the overall *average* frequency of all combined foods in the category gives more additional information such as whether the total category frequency is large, because there are a few foods but very frequently eaten which would yield a larger average frequency of all foods combined number. On the other hand if the total frequency is large because there

are many foods eaten but less frequently which would yield a smaller average frequency of all foods combined number.

I can compare and contrast any given category in a quantitative manner with other food system categories within and across hunter-gatherer and subsistence agriculture food systems in the study. If there are foods which have a much higher frequency than most of the other foods in the category, extreme outliers that may be distorting these average category numbers, it is evident by looking at the frequency of individual foods before these food species are combined in a category. There are only a few foods that are much more frequently eaten in both food systems and are well known and documented in the study so this is easy to take into account.

Drawbacks to this Novel Analysis System. These frequency numbers give the relative dietary importance and impact of food categories in comparison with each other both within and across the dissertation Waorani and Kichwa food systems. The disadvantage of any new research tool such as this one is direct comparisons with traditional dietary studies that have used different methodologies in more difficult. However, since there are few or no studies have looked at phytochemical content of true hunter-gatherer food systems this is less of an issue than if the study compared nutritional factors. Seasonal changes on each and every food were included in the calculations as the number of days eaten is usually the same as the season the food is available.

These study food frequency numbers have two other limitations. 1) these frequency numbers are not age or sex sensitive because of the cultural differences

and the collective nature of the answers are given due to Waorani hunter-gather understanding food consumption, which differs from agriculturalists. However, all extreme age and sex differences were picked up in that data collection and can be analyzed using stratified categories. The only major difference in terms of frequency, not quantity which this study does not measure, are age related differences in the consumption of eggs and several domestic fruits in the Kichwa system. In these cases results were calculated separately in the data collection because this is the one time the difference was so large between adults and children as the Kichwa considers these important for child development. 2) as mentioned study frequency numbers do not take into account quantity thus, certain foods that are eaten in great quantity but only over a short period of time would not show up as different from foods consumed with the same frequency but in lower quantity. However, through participant observation and food focus groups and individual surveys of both food systems over the year, the half dozen foods that are intensely consumed over a short period of time are known, so this is not a major issue.

Food System Analysis on Taste and Smell of Foods

Focus groups were used for various purposes beyond the understanding and comparing the larger picture of the entire food system. In one type of focus group with the Waorani, physical food samples such as fruit from their food system, and unfamiliar domesticated fruits from outside their food system, were given to a focus group of Waorani to smell, taste and eat. The Waorani were posed questions about the taste and smell of the foods to help develop a

vocabulary list in the Waorani language of Waorani tastes and smells to help understand dietary selection and satiation as explained in food system chapter. The same was not done with the Kichwa group. While a comparison across food systems cannot be made the findings were so unusual that they are included in the dissertation and analyzed separately in the results section.

Health Outcomes: Data Collection and Analysis

Physical exams, individual and family health history, lab tests and public health data. Data on health differences between Kawymeno Waorani hunter-gatherers and Santa Teresita Kichwa subsistence farmers was gathered through a physical exam, lab tests and medical history of both populations. Besides a formal health exam and history, the study continued to monitor and record all health events over a year through participant observation (discussed below). The same medical equipment, laboratories and health surveys was used for both populations. Most results were age and sex stratified to make age and sex appropriate comparisons rather than limiting results to generalized overall population data, which can be misleading when dealing with health outcomes.

(1) ***A Physical Exam:*** (See recording instrument in appendices). The physical exam includes checking general physical health for (1) nutritional status such as signs of anemia and malnutrition, (2) signs of infectious disease such as staphylococcus skin infection, leishmaniasis, fungal infections, (3) as well as signs of chronic diseases such as arthritis, allergy, asthma, diabetes, neurological deficits, hernias, (4) general body vital signs and capabilities such as blood pressure, body temperature, and a vision exam. In addition anthropometric

measurements were taken (specifically age, sex, weight, height, triceps skin fold, arm circumference) to determine Body Mass Index (BMI) and Mid-Arm Muscle Circumference (MUAMC) and other measures.

(2) ***Individual and family health history*** (see health data collection instruments in appendices) Individual and family health histories were gathered from participants including information on: (1) age, sex, birth date, pregnancies and child birth, birth spacing, children's health/age/sex, family mortality/morbidity (age and cause of death and disability), (2) history of disease - snakebite, TB, malaria, dengue, heart disease, cancer, hepatitis, nutritional disease, chronic/infectious disease, diabetes symptoms, fungal infections, accidents (particularly infection and outcome of wounds), (3) hygiene and sanitary practices, drinking water (4) any medical or hospital visits - use of health practitioner shaman/midwife/western doctor, (5) plant defense chemical intake (particularly hunting and fishing poisons), intake and frequency of use of pharmaceutically active natural rain forest or human made substances classified as medicines, (6) health beliefs – mainly difference in treatments which in this case means a hunter-gatherer society that rarely gets ill and uses few treatments compared to an agricultural society with many treatments and health beliefs surrounding them and (7) daily activity and amount of exercise. I also continued to monitor and record all health events while conducting participant observation during the year and in the case of the Waorani, data included daily informal focus groups with my Waorani class (discussed below). The same health history instrument and questions were used for both populations.

(3) ***Lab Tests:*** Urine and stool samples were collected for bioanalysis from both Kawymeno Waorani and Santa Teresita Kichwa. Waorani stool and urine specimens were obtained when the Kawymeno Waorani were brought into town and housed only a few blocks from the lab by the Ecuadorian government oil company during oil drilling negotiations in 2010. Kichwa urine and stool specimens were transported by high-speed motorboat to the lab. Stool samples were placed into sterile stool lab containers using sterile spoons, and then packed in chemical ice and there was never more than a two-hour delay in reaching the lab for either Waorani or Kichwa specimens. The investigator personally supervised the complete stool collection process of all Waorani and Kichwa samples, starting from obtaining the sample in the field, to labeling sterile specimen containers and finally transporting it to the laboratory.

Laboratory analysis was done on stool samples from sixteen adult Waorani hunter-gatherers, (eight males and eight females). We also had a laboratory analysis done on stool samples from 63 Kichwa subsistence farmers, (thirty-three males and thirty females).

All feces samples were labeled with the age and sex of the participant, and were checked for the following: color, appearance, consistency, mucus, digestive fats, digestive yeast, digestive starches, bacterial digestive flora, blood in feces, spores, piocites, polimorfonucleares, helminth worms, amoeba, giardia and other parasites, gram negative and gram positive bacteria, E. Coli, shigella, campylobacter, citrobactor, adenoviruses and rotaviruses.

Urine samples were taken from sixty-three Kichwa farmers and sixteen Waorani hunter-gatherers. All urine samples had age and name of participant and were checked for density, PH, protein, glucose, cetona, hemoglobin, bilirubin, urobilinogen, nitrites, leucocites, piocites, erithrocites, bacteria, fungi, mucus, crystals, cylinders, (bacilos) gram negative bacteria, and (coccos) gram positive bacteria.

The investigation collected one round of stool and urine samples from all those participating. A single stool sample identifies about 75% of the parasitic infections that would be have been detected over time with the use of three different stool samples on the same subject (Cartwright, 1999). Thus, a single stool sample is reasonable evidence of determination of helminth infestation history. (An exception would be the Enterobius species, a non-pathogenic helminth species, which due to their life cycle are not usually even found in stools, but may appear in a stool sample if they are clinging to perianal folds)

(4) ***Public Health Data***: Excellent relationships with the Ministry of Education, Ministry of Health and Waorani umbrella group have greatly enhanced the quantity and quality of public health data obtained.

In the case of the Waorani, we were fortunate enough to get data on sex, age, birthdates, birth mothers and vaccine history of the entire Kawymeno population going back fifteen years. A Ministry of Education teacher who alone oversaw the Kawymeno Waorani during this time period kept all this information. He is also the present education supervisor for the Waorani region and has always been of great help with the dissertation research.

While no comparable health history information could be obtained on the Santa Teresita Kichwa the Ministry of Health and Franklin Tello Hospital in Nuevo Rocafuerte has provided this study with general population health statistics for the local region of Kichwa communities in which Santa Teresita lies. This Ministry of Health Public Health data from the Franklin Tello Hospital will not be used for this dissertation work directly, but served to confirm that the major health problems of the local region of Kichwa communities, in which Santa Teresita lies, are similar to our findings in Santa Teresita. This health data will be used in future studies beyond the dissertation.

Past Waorani/Kichwa Studies Used for Comparison. Some health examinations, medical histories and food system observations were done on the previous generation of Waorani in the late 1970s and early 1980s by Harvard and NIH teams, shortly after the Waorani had been relocated to the protectorate (Kaplan, et al. 1979; Kaplan, et al., 1980; Larrick, et al., 1979; Larrick, et. al. 1983; Larrick, et. al., 1985; Buckley, et. al. 1985; Davis & Yost, 1983; Davis & Yost, 1983B; Yost, 1981; Yost, 1981a). Although not done with the Kawymeno Waorani these Harvard and NIH studies serve as valuable comparisons and provide general baseline information to put dissertation data in context temporally. The NIH and Harvard quantitative and qualitative data is included in several chapters.

Probably, the only published peer reviewed journal article on either the Kawymeno Waorani or Santa Teresita Kichwa was done by Michael Kron on both groups when he spent two days gathering blood samples and measuring IgE

antibody levels in 1995 (Kron, 1995). Kron only stayed a few hours with each group while the hospital was conducting vaccinations. The proximity of these Waorani and Kichwa study groups to each other, and assistance from the Franklyn Tello Hospital made Kron pick the same Waorani and Kichwa groups used in the dissertation study. Both Kawymeno Waorani and Santa Teresita and their immediate neighboring Kichwa groups had their IgE levels taken and compared to Westernizing Waorani in the Protectorate. Kron's study provided valuable information to support study statements regarding food systems and immunity.

Sampling Techniques for Health Outcome Data. The sample size provided enough participants from both Waorani and Kichwa groups to do age and sex stratified data analysis and inferential statistics to test the study statements. The whole existing Waorani forager sampling frame totals 125 members. 74% of the Kawymeno Waorani population sampling frame participated in the study. Most of the Waorani population that did not participate were children under study age limits. Almost universal participation of the Kawymeno Waorani adults in the study frame reduced bias (including self-selection bias based on willingness to participate) and simplified statistical analysis especially as there was a similar sampling situation with the Kichwa (below). In some cases not all measurements were obtained for Kawymeno Waorani participants.

However, urine and stool collection sampling were a little different due to logistical necessities of having participants close to lab facilities. A smaller

percentage of the sampling frame participated. There may have been some self-selection bias of urine and stool sample participants since they chose to come to the town of Coca and selection was therefore not random.

The whole existing Santa Teresita farmer sampling frame, while larger than the Waorani, is still relatively small 312 persons. As with the Waorani, almost no Kichwa families declined to participate, although in the case of a couple of houses the family was not home when we visited and were not included if they did not return in a day or two. All present household members participated, since it is very difficult to leave the Santa Teresita community due to its geographical isolation few participants were absent from the households, (the community is surrounded by the Napo River on one side and an immense span of virgin rainforest on the other side). When the study reached population limits required for comparison, data collection stopped. All households encountered were interviewed, although the southern region of Santa Teresita was more heavily represented since data collection started there. However, there were no known special differences between families a little further up or down river and there was minimal opportunity for self-selection bias based on willingness to participate. All Kichwa participants received a medical check-up and if there were health issues, the dissertation study funds provided medical treatment and referral to our collaborating partners in Franklyn Tello Hospital in Nuevo Rocafuerte.

The only dissertation data collected on the Protectorate Westernizing Waorani population was descriptive through participant observation and conversations with medical personnel serving the Protectorate Waorani

community. The purpose of the protectorate visits and interviews was limited to addressing the possibilities of genetic explanations for health outcomes rather than as another complete study population. Oil company resistance to research in general made further study more challenging in the protectorate communities.

Statistical Analysis

All statistical analysis was done using Microsoft Excel. Since most of the health data is parametric biostatistics and standard deviations were a low, average from the mean for each population, t-tests were chosen to be used for statistical testing. The mean, median, variance and standard deviation, and standard error were calculated. The t-tests comparing means were done across populations for all health outcomes for both the Kawymeno Waorani and Santa Teresita Kichwa groups, at each age and sex level of data stratification. The t-tests generated p-values and effect sizes to determine if the differences in results were likely to be chance occurrences or real differences and statistically significant. Chi–square tests were done on certain tables to determine p-values, namely the probability that results were chance occurrences such as with the monthly fertility tables of the Waorani.

All the statistical analyses health outcome quantitative comparisons can be found in Appendix H of the dissertation. All food system comparison figures are only total numbers of groups, thus they are descriptive in nature rather than quantitative and have no statistical analysis.

Results Chapters

The dissertation results in the next chapters are organized in two forms (1) a narrative descriptive form and (2) a more quantitative form via charts, tables and diagrams with explanations. The Kichwa are mentioned less during the narrative portion of the study because people are familiar with agricultural systems such as the Kichwa use so repetition of common knowledge is not necessary. However, the Kichwa occupy equal space in the dissertation in the sections on food system and health outcomes. The quantitative data collection effort was the same for both Kichwa and Waorani groups. This dissertation, for length purposes, does not focus on indigenous cultural differences not related to the food system. Thus, in the case of narrative data and description of the culture and food system, more emphasis on data collection through participant observation was made with the Waorani because hunter-gathering food systems are the focus of this dissertation. There is no description of the Kawymeno Waorani food system or culture available while the culture of Kichwa farmers has been described in hundreds of articles, peer reviewed and lay likewise so no introduction is required. The hunter-gatherer food system description is more novel and one point of the dissertation is describing its particulars since without this context quantitative data has less meaning. Much of the data gathered in the dissertation process awaits future publication, as emphasis in this dissertation was put on including data addressing dissertation hypothesis and statements.

CHAPTER 6

GIVING BACK TO THE COMMUNITIES DURING THE INVESTIGATION IMPROVES METHODOLOGY AND RELATIONSHIPS

Waorani Health Promoter Training

For anthropologists in the field doing current research with indigenous cultures, the question is no longer can we preserve the culture or protect them from modernization by non-interference, but rather how can we help the indigenous cultures adapt to the severe changes that are occurring due to acculturation, both at a cultural and individual level. Scientific detachment at the expense of human suffering has damaged researcher relationships to indigenous groups to the extent that many indigenous cultures resent the intrusion of researchers who come wanting information, but often offer little in return that the indigenous value.

During the research process with Waorani, efforts were made to ensure something of value was immediately given back to the communities who aided this study and permitted us to stay with them. We were the first outsiders the Kawymeno Waorani had allowed to stay in their community and wanted to set a good precedent.

Many researchers try to give back to the community after the study, such as presenting the study results to the community. I would argue presenting study results to the indigenous community is insufficient because (1) not too many

studies come up with knowledge that is of real applied benefit to the communities they study and (2) offering advice to indigenous groups can lower the indigenous confidence in themselves to solve their own problems, and (3) the information or advice we give them might be wrong.

Donating material and financial aid is another form of giving. However, donations to the Waorani can promote Waorani dependency on the outside world and reduces ability of the Waorani to cope with outsiders. Those who give are put in a position of power, while those who can only receive often feel in a position of powerlessness.



Figure 6. Waorani Health Promoter Practicing Anti-venom Injections

During the first two visits to the Waorani in 2008 and 2009 an assessment of community needs was done to see what might be appropriate for us to offer to the community. The following criteria were taken into account when making this

decision (1) offering the Waorani something they valued and wished to be assisted with, rather than offering what we believed the Waorani needed. (2) offering something that promoted successful interactions with the outside world, especially since this group was located near the ITT oil wells in the Yasuni National Park, and Waorani permission was required to start drilling near their village (3) offering something in which benefits greatly outweighed any possible problems (4) offering something my wife and I were capable of doing and completing and finally (5) offering something that would benefit the whole Waorani community not just selected individuals in the community.

In 2010 an agreement was reached with the Waorani. It was decided to donate time and medical resources to provide training for Waorani health promoters and build potential foundations for initiating a community health program.

I already had experience training indigenous health promoters, in this case for the Guatemalan government for several years. Also while on the Faculty of Medicine at Harvard Medical School I founded and ran a mental health clinic dedicated to developing culturally appropriate mental health treatments for indigenous populations in Guatemala. However researchers do not have to possess specialized experience to do many types of teaching and training, and the training objectives can be very simple. Training is also only one alternative way researchers can give back to participants in their study beyond post-study feedback and material gifts.

Another reason health promoter training was chosen was because the Waorani vocalized the need for protection against diseases coming from increasing contact with the world outside their isolated community, such as tuberculosis, falciparum malaria and hepatitis as well as certain local threats such as venomous snakebite. Daily training provided personal interaction and we hoped would increase Waorani ability and confidence to communicate successfully with outsiders. By having a successful experience working with foreigners we argued there will be an increased competence and confidence on the part of the Waorani in the future in dealing with outsiders including the government, oil companies, religious groups and non-profit organizations. This is another benefit of health promoter training and clinics. Finally, health promoter training benefits the entire community by providing for some of the universal basic health care needs, needs that as our study showed, increased greatly in other Waorani communities as they came into contact with outsiders. This Waorani group had almost no access to Western health care yet increased access to diseases from Westerners. Also, introduced dietary changes are having a major negative effect on the Waorani health in other communities as they give up traditional hunting and gathering. The Kawymeno Waorani are still in good health because of their hunter-gatherer diet in spite of diseases introduced from the outside.

Actual Training Highlights. We trained four Waorani community members: one woman, and three men, who varied from 24-40 years old for six months. The community selected all four trainees, and training took place most

mornings for many months unless hunting, gathering and other survival needs took precedence.



Figure 7. Kawymeno Waorani Health Promoters Finishing Course

The aim was to encourage them to continue their present diet and lifestyle and provide complimentary health skills not competing ones. The first activity was finding out what health problems the Waorani did have and what health problems the Waorani did not have. Time was put in to understanding their health practices before starting to design the health-training curriculum. This Waorani group is a unique hunter-gathering group that does not yet have most of the health problems other indigenous groups and even Westerners do. That was one of the reasons we were working there.

An early project was a nursery garden of wild Waorani food plants to help emphasize the value of their present diet. We hoped this would provide a learning tool to help young Waorani appreciate and make an informed decision as to the

advantages as well as challenges of maintaining a traditional hunter-gathering diet as basic agriculture not to mention modern food are introduced. An effort was made to explain the advantages and disadvantages of the modern food system.

Finding appropriate and fun teaching methods is essential. Lecturing to hunter-gatherers is inappropriate. The method of experiential learning was employed such as role-playing games where Waorani trainees pretended to be sick and were mock-treated by others. They were taught to administer snake anti-venom, made oral rehydration fluid, sutured wounds and other first aide, practice reading a thermometer, identifying physical symptoms of disease through examination, actually treating diseases like malaria etc. We visited people that were sick in the community. My wife worked with the little children teaching activities such as tooth brushing, hand washing through songs and games. A full description of training activities is beyond the scope of this dissertation.

There were many impromptu training occasions such as when one of the health promoters got bitten by a very poisonous snake (*Bothrops atrox* or Fer-de-Lance) which were extremely common in this region, and I had the opportunity to demonstrate a technique we had taught and injected anti-venom into him several times to control the reaction to the poison. In another instance, when a Waorani warrior split open his forehead, I had to stitch it up. We practiced stitching on animal skins from animals they hunted.

Sustainability is key aspect to health training. Continued opportunity to learn and acquire health-promoting skills is essential. We made contact with an indigenous health promoter training organization operating for many years in

Amazonian Ecuador called Sandi Yura. Sandi Yura agreed to include the Waorani promoters in continued annual regional health promoter training workshops for Amazonian indigenous groups after we left.

Health Promoter Training as Research **Methodology** Health promoter training is a two way street. It provided an opportunity to talk about health and diet with the Waorani hunter-gatherers on a daily basis for months, which helped to target some of the data collection later, which consisted of medical examinations, lab tests, anthropometric measurements, dietary surveys, food system surveys and participant observation, and mapping the dietary intake of both food systems. In this informal exchange, we had daily conversations, not unlike focus groups, about study topics such as health and diet and gathered data and accomplished in months what might otherwise have taken years. We developed mutual respect and bonds of friendships with the Waorani and gained initial community acceptance, again in months instead of years. For example, one of my Waorani assistants eventually named his son after me, and we have maintained contact even when we were back in the United States when he emerges from the rain forest.

We could answer Waorani questions daily about our research to avoid misunderstandings. The Waorani knew what the study was about and why we were interested in certain research questions. Thus, our research was better understood and this created an environment in which they felt comfortable asking questions about the research whenever they wanted to.

In conclusion, I hope researchers will continue the trend of becoming involved and giving back something of immediate value to the indigenous community in which they do research. All researchers have skills they can offer, and a specialized skill (such health promoter training experience) is not required to give back to the community. However, whatever the researcher chooses to give back to the community has to be thought out carefully to make sure it is appropriate, including answering some of the questions addressed above in the section. I suggest that succeeding at this giving back to the community activity is not as important as the process of doing the activity and showing you care and want to contribute. I argue that a major benefit of training (versus other methods the researcher can use to give back to the communities they conduct research in) is increased self-confidence and inter-cultural competence of the participants in dealing with outsiders. Conducting studies comparing the effect of training versus other methods of giving back to the indigenous communities, which participate in our research, will help establish advantages and disadvantages of each method in terms of benefiting the community.

CHAPTER 7

FOOD SYSTEMS I: A COMPARISON OF HUNTER-GATHERER VERSUS SUBSISTANCE FARMING FOOD SYSTEMS

> "And tribal people are the best guardians of the natural world. Where they have been allowed to continue living on their lands, forest cover and biodiversity can be much higher than in other kinds of protected areas. Many tribal people know something that many of us have forgotten: that we are not separate from nature." (Survival International)

This dissertation provides evidence that both a misbalance in phytochemical intake, through a lack of, or excess phytochemicals causes disease in agrarian humans that – while accelerated in a modern food system – started from the dawn of substance agriculture. This chapter compares the actual differences in terms of dietary intake that take place when a hunter-gatherer becomes an agrarian through living neighboring examples.

The Kawymeno Waorani hunter-gatherer food system has a much broader phytochemically-rich plant food base than the Santa Teresita Kichwa food system. It is an asset, which makes all the difference in the dramatic contrast in health status across food systems, as the next chapter on health outcomes details.

Documenting two complete food systems is a challenging task. This chapter provides highlights of both Kawymeno Waorani hunter-gathering and Santa Teresita Kichwa subsistence agriculture food systems, and compares and contrasts

characteristics that may impact health, especially the phytochemical content of the diet. This chapter is descriptive in nature and a serves as a database providing dietary intake information that is used to explain some of the very unusual and striking health differences observed between study hunter-gatherers and farmers. This dissertation study looks at the big picture of food systems by first analyzing the smallest details of every animal and plant food eaten, then by comparing and contrasting food species details in the charts presented in this chapter, to eventually provide a clearer description on a broader scale. This comparing and contrasting of food systems is supplemented with ethnographic material from a year of participant observation to provide context and meaning to the more numerically-oriented data. This chapter focuses on the results of the data collection comparing both food systems and is a results chapter. Since a literature review has already been provided, extensive citations are not used if the subject has already been covered in the previous chapters.

Study Group Food Systems: Hunter-Gathering versus Agrarian

Based on an exhaustive literature review, I found no comparative study across hunter-gatherers and farmers that parallels this dissertation study's focus on dietary intake of phytochemicals. This study uses some novel methodology first because I worked with hunter-gatherers and second because I worked with phytochemicals. Unlike the nutrient component studies that make up much of the hunter-gatherer literature, the focus on phytochemicals requires more emphasis on frequency of dietary intake, and less emphasis on bulk weight of foods ingested. Unlike nutrients, minute quantities of a myriad of individual phytochemicals

found in all foods can have major physiological effects; therefore, analysis by the pound of phytochemicals is not appropriate. Rather, frequency of plant phytochemicals intake is used in this study to measure the long-term effect dietary phytochemicals may have in the prevention of diseases. As anyone who has tried to interview a hunter-gather knows, opinion surveys such as the Food Frequency Questionnaire, and other staples of the nutrition field, are impractical when working with non-agricultural populations. Weighing food is equally impractical in hunter-gatherer study populations that have no set mealtime, eat much of their phytochemical intake while collecting food in the rain forest, or if the food is to be cooked, eat directly from a fireplace rather than a plate. Further discussion justifying and explaining the actual methods that produced the food system charts and other results in this chapter are provided in the methods chapter of the dissertation.

Dietary Shock: A Hunter-Gatherer Meets an Agrarian

"We handed Aneanto, the Kawymeno hunter-gather leader, a bowl of meat and rice we had cooked for our dinner. Aneanto said, "The Father (Catholic Priest) introduced me to eating rice. I felt my stomach could not grind the rice. It was hard inside the stomach. The Father told me it was good for me, that I keep eating rice. I was afraid of eating rice. These were the first days I tried to eat rice. The Father said I had to eat the rice and nothing will happen. But the rice was hard inside my stomach. The Father said rice would help me grind the meat I ate. Now, I still don't like

rice. That is why I don't want to eat it" (Field Journal Entry, Douglas London. August 20, 2008)

The conversation quoted above that I had with a Kawymeno Waorani hunter-gather friend demonstrates the dietary shock of a hunter-gatherer being initiated into agriculture. Grains are not part of the normal Kawymeno Waorani diet, and indeed not even part of the hominoid diet for most of pre-human existence. Anaento, like other Kawymeno Waorani hunter-gatherers I have talked to, found the experience of eating grains uncomfortable and unpleasant. Most of my Kawymeno Waorani hunter-gatherer friends have resisted attempts by the religious groups that were trying to convert them not only religiously, but also dietetically from hunter-gatherers to agriculturalists. The Kawymeno Waorani are the last remaining known part of the Waorani population where religious missions and Western dietary influence have yet to have caused significant changes in 2010. Dietary conversion is causing the destruction of the food system the whole Waorani nation depended on for their well-being and health, and eliminates a dietary legacy humanity could learn from. Almost all accounts of early contact between previously uncontacted hunter-gatherer groups and missionaries suggest that dietary conversion has been a part of every modern, former hunter-gather group's fate, which contributed to a rapid increase in infectious and chronic disease in these populations. This dissertation presents the case that a hunter-gatherer entering an agricultural system is giving up a dietary intake that naturally prevented many diseases pharmacologically, because their former diet was

medicinal in nature. While the Protectorate Waorani now only occasionally hunt and gather and have started to enter the modern food system, the Kawymeno Waorani continue to have a traditional hunter-gathering lifestyle. The entry of novel infections, that decimated most hunter-gatherer populations when first contacted by Westerners, is not an indication that a hunter-gatherer diet provides no protection against endemic diseases. It is merely that humans in general do not have immunological protection against threats they have never encountered. Hunter-gatherer groups entering into an agricultural-based diet go through a form of dietary shock as the new dietary intake is far removed from the hominoid norm of countless millennia. The Waorani may actually have a lot to teach us about diet and health, and this dissertation is a vehicle to pass the hunter-gatherer message along. The reality is that while religious and secular organizations have a lot of information to pass to the countless hunter-gatherer and indigenous groups they convert, the hunter-gatherers have a lot of valuable knowledge necessary for humanity's survival in the 21st century. Unfortunately, conversion rarely seems to be a two-way street as hunter-gather food systems are seen as being primitive and the land, ecosystem and food chain they once used to eat from is taken away. In the case of the Waorani, most now live in oil fields rather than rain forest, while the religious and secular groups that moved them out of the rain forests take pride in having "civilized" the Waorani.

Transition from Hunter-Gatherer to Farmer: Summary of Food System Table and Discussion

This section of the dissertation takes a look at the before and after results of food system transition from hunter-gatherer to farmer that all our ancestors made by comparing an actual living hunter-gatherer's dietary intake with that of a neighboring subsistence agriculturalists' diet. This is accomplished through a series of charts, tables, photos and ethnographic material. In this chapter, the differences between the two food systems are described both in writing and through the use of charts of quantitative data that selectively summarize in a graphic form 1,000s of pages of data gathered during this dissertation study. Details of the differences and similarities between the actual populations in the two study groups are found in the previous chapter describing the populations. This chapter focuses on the food system of these people. While health outcomes are referred to in this food system chapter, the results from the medical exams, health histories, dietary surveys and health surveys are described in detail in the following chapter.

The broad scope of the data collected, combined with a detailed investigation of all regularly consumed foods, allow the entire hunter-gathering food system to be contrasted with the entire subsistence agriculture food system to the extent that comparative generalities can begin to be made regarding these food systems as a whole functioning entity.

Note: In the following tables "Native" foods means the food plant grows wild in the region, although in some cases these same native plants may also be utilized in a garden. On the other hand, "introduced" plant foods are plants that never

grew wild in the region but were brought in by humans from outside for use as food sources.

Also important to note is that when this dissertation refers to eating "plants" in the case of the Kawymeno Waorani this means eating fruit as the Waorani eat virtually no non-fruiting parts of plants. In the case of the Santa Teresita Kichwa, non-fruiting parts of plants make-up part of their dietary intake of plant species, so eating "plants" means eating both fruiting and non-fruiting (vegetable) parts of plants. Both fruits and vegetative parts of plants are rich in phytochemicals, but this dissertation makes the case later that the types and categories of phytochemicals present generally differs between fruit and non-fruiting parts of plants, in a way that impacts the health of consumers who eat part of the plants.

Table 1. Summary of Food Systems: Hunter-gatherers vs. Subsistence Farmers

	Kawymeno Waorani	Santa Teresita Kichwa	Comparison
Food system	Hunter-gatherer	Subsistence agriculture	Different
Variety of animal and plant food species	130 total 42 animals 88 plants	65 total 20 animals 37 plants 8 store-bought plants	Different
Food chain origin	Rain forest	Garden	Different

	Kawymeno Waorani	Santa Teresita Kichwa	Comparison
Semi-cultivated Waorani and fully domesticated Kichwa food species	No animals 6 plants (2 regularly used) and 3 wild regional species	4 animals 33 plants	Different
Wild/native food species	122 80 plants 42 animals	20 4 plants 16 animals & 6 preventative medicinal plants	Different
Variety of plant food species	88	37	Different
Seasonal plant food species	77	12	Different
Major food categories in order of quantity consumed	Wild Animals, Wild Fruit, Tubers	Tubers, Farmed vegetables, Farmed fruits, Animals (wild and domestic)	Different
Store-bought food	None	Occasionally bought: 4	Different

	Kawymeno Waorani	Santa Teresita Kichwa	Comparison
		vegetables, 4 grains, 3 dairy foods, 2 cooking oils, 3 flavoring/spices	
Manioc root intake	One of several principal foods	Staple Food	Some Similarity
Mammal/fish/bird/ reptile intake	Staple foods (42 species)	Addition to meals (20 species)	Different
Fruit food species	80 75 wild 5 introduced	24 22 domesticated 2 wild	Different
Vegetable food species	No vegetables other than 3 starchy tubers	8 farmed vegetables 4 store-bought vegetables	Different
Grain food species	1 wild grain	4 farmed grains 4 store-bought grains	Different
Overlapping plant food species	See comparison column	See comparison column	Nine
Phytochemical – based hunting and fishing poison	Very high (4 plant species used daily)	Minimal	Different

	Kawymeno Waorani	Santa Teresita Kichwa	Comparison
intake			
Use of medicinal plants	Few dozen	Hundreds	Different

Summary of Food Systems: Hunter-gatherer 1

Identification of Dissertation Study Food Species and Discussion of Tables on all Scientific/Common Names and Characteristics of Plant and Animal Food

The four tables below are the complete food species listing of both the Kawymeno Waorani hunter-gatherers and Santa Teresita Kichwa subsistence agriculturalists and provide a foundation for this dissertation study and a database for future researchers interested in the specific types and categories of rain forest plants and animals that make up an Amazonian hunter-gatherer diet, as well as an isolated Amazonian rain forest subsistence agriculture diet. The original database on each food species from Kawymeno and Santa Teresita, from which these segments are drawn, is extensive with dozens of categories of information regarding each food species that exceed the needs of this dissertation and will serve for future research papers. Only the most pertinent information from the food system database is presented in the form of charts in this chapter.

The first four tables in this chapter below list all the foods consumed regularly by both the Kawymeno Waorani hunter-gatherers and the Santa Teresita Kichwa farmers. Through the use of over 3,000 photos and consulting with ethnobotanical experts, most Kawymeno Waorani and Santa Teresita Kichwa

foods were identified and could be assigned scientific names. The process of putting together these four simple tables took over a year. Positively identifying and assigning a scientific name to every food system species in two different food systems represented a major challenge, yet was only the first step toward putting the data collected into context so it could be categorized and analyzed. Many months were spent trekking through the rain forest tracking down food plants for photographing and identifying with my Waorani assistant, Ima. A similar photographing and identifying exercise was carried out with Santa Teresita Kichwa plant foods that involved more time in gardens and in the rain forest near the community with my Kichwa study assistant, Juan Carlos. Animal foods were similarly identified across both groups. I also went gathering, gardening, hunting, and fishing with the Waorani and Kichwa to obtain as many of these food species as possible and to prepare and eat the food with these indigenous groups so that I could experience the food system personally.

Ethnobotanical experts were consulted for positive identification of species, particularly those at the Omaere Foundation in Puyo, who specialize in ethnobotany of indigenous groups in Ecuador. Two experts who assisted greatly are Chris Canaday, a biologist and botanist who specializes in indigenous plant use in Ecuador, and his wife Teresa, an expert in the use of indigenous plants for healing.

Where possible, the tables on food system species list the Waorani or Kichwa common name, the scientific name, and any known existing Spanish or English common name. Some of the study plant food species are not known to the

public and restricted to a vanishing primary rain forest ecosystem, thus outsiders have no common name for a plant they have never seen. The food species tables also indicate if the food species is native or imported to the region, and in the case of the plant foods, which part of the plant is ingested and if the fruiting season is seasonal or not. A small number of plant food species could not be identified by botanical experts consulted and may be species with which no experts are familiar. There is also considerable variation in appearance within a single species of plant in different sections of the Amazon rain forest. This may make identification difficult in certain cases. To our knowledge, due to its remoteness, the region surrounding Kawymeno, where this study took place has not received a botanical overview, (although oil companies have hired scientists to conduct in-house biodiversity studies in various parts of the Yasuni National Park). The assignment of a few food species' scientific names will have to await post-doctoral work.

Table 2. Kawymeno Waorani, Scientific and Common Names and Characteristics of Plants

Waorani Plant Name *Scientific Name*	Comments, Other Names (English, *Spanish*)	Native/ Introduced	Fruit Eaten/ Seasonal
TUBERS AND GRAINS			
Acage *Ipoemoea batata*	(sweet potato, *camote)*	Introduced	No/ No
Capamo *Pachyrhizus angulatus*	(sweet potato, *camote*)	Native	No/ No
Kewe (plant) Kene *Pachira aquatica / Manihot esculenta*	(manioc, cassava / *yuca, mandioca*)	Introduced	No/ No
Koromo *Arachis sp.*	(*mani de monte*), put in chicha beverage	Native	No/ No
HUNTING AND FISHING POISONS (not counted separately in food system figures)			
Conpago/Compag	Fishing poison	Introduced	No/

Waorani Plant Name *Scientific Name*	Comments, Other Names (English, *Spanish*)	Native/ Introduced	Fruit Eaten/ Seasonal
o *Lonchocarpus Nicou - Var Languidus*	(*barbasco*)		No
Konii/Conii/Cogu i (Shuar = *masumas*) *Clibadium sp. (but not asperum)*	Fish poison, fruit used, not listed previously in literature on Waorani	Native	No/ Yes
Meniko *Lonchocarpus nicou - var. Urca*	Most common fish poison by Waorani	Native	No/ No
Onta *Curarea tecnarum*	Curare hunting poison	Native	No/ No
PLANT FOOD SPECIES			
Aquino/Aquimo *Musa sp. (Musaceae)*	Type of (banana, *platano*)	Introduced	Yes/ No

Waorani Plant Name *Scientific Name*	Comments, Other Names (English, *Spanish*)	Native/ Introduced	Fruit Eaten/ Seasonal
Awencatomo *Tapura amazonica*		Native	Yes/ Yes
Awenkawe *Cordia alliodora (Boraginaceae)*		Native	Yes/ Yes
Awenkatowe *Stephanopodium peruvianum/ Eugenia muricata*		Native	Yes/ Yes
Bagamowe *Abuta grandiflora*	Roots used medicinally	Native	Yes/ Yes
Bataca *Perebea guianensis*		Native	Yes/ Yes
Bereyowemo *Saurauia prainiana, Coccoloba densifrons*		Native	Yes/ Yes

Waorani Plant Name *Scientific Name*	Comments, Other Names (English, *Spanish*)	Native/ Introduced	Fruit Eaten/ Seasonal
Bikaremo *Ceiba sp*		Native	Yes/ Yes
Bobeka/Bobewe *Ceiba pentandra*	Cotton used for blowguns	Native	Yes/ Yes
Bogimonkamo *Mayna odorata*		Native	Yes/ Yes
Boguinka/Bogincа *Herrania nitida*	*cacao chiquito*	Native	Yes/ Yes
Boyomo/Contaka *Pentagonia spathicalyx*	2 sub-species in different environments. Medicinal use.	Native	Yes/ Yes
Cagiwenca *Cayaponia ophthalmica, Cayaponia Ruizii*		Native	Yes/ Yes
Dabayo *Bactris concinna*	Used medicinally, also wood used for improvised spears	Native	Yes/ No

Waorani Plant Name *Scientific Name*	Comments, Other Names (English, *Spanish*)	Native/ Introduced	Fruit Eaten/ Seasonal
Daboka/Daboca *Solanum pectinatum; S. sessiflorum*	(native chamomile, manzanilla) Used as shampoo to make hair dark and shiny. Two types: one with spines, one without spines.	Introduced	Yes/ No
Dabomo (cultivated) *Solanum sp. (Solanaceae)*	(chamomile, *manzanilla)*	Introduced	Yes/ Yes
Dabomo (wild) *Solanum sp. (Solanaceae)*	*(manzanilla de monte)*	Native	Yes/ Yes
Dagenka/Tewe *Bactris gasipaes*	Wood used to make spears for killing humans not hunting (*chonta)*	Native	Yes/ Yes
Deyeyowe	Tree used to make	Native	Yes/

Waorani Plant Name *Scientific Name*	Comments, Other Names (English, *Spanish*)	Native/ Introduced	Fruit Eaten/ Seasonal
Pourouma tomentosa sub. Tomentosa	brown dye		Yes
Imeñeweno/ Emeyemo (Kichwa Sani) *Undetermined*	Chicha won't ferment after eating this fruit if saliva is used in preparation (*camucamu*)	Native	Yes/ Yes
Emeyewe *Undetermined*	Two species: riverside and dry land variations	Native	Yes/ Yes
Ewemao *Inga sp. (Fabaceae)*		Native	Yes/ Yes
Gatobo *Undetermined*		Native	Yes/ Yes
Gaibamo *Chelyocarpus sp.*	Blowgun darts made from branches	Native	Yes/ Yes

Waorani Plant Name *Scientific Name*	Comments, Other Names (English, *Spanish*)	Native/ Introduced	Fruit Eaten/ Seasonal
Gemeno variation Petemo (small fruit version) *Jessenia bataua var.*		Native	Yes/ Yes
Giimo *Capsicum chinensis*	A spicy fruit. Used medicinally	Native	Yes/ Yes
Gogayowe *Pourouma guianensis subsp. Guianensis*		Native	Yes/ Yes
Gontokao *Inga sp*		Native	Yes/ Yes
Han *Inga edulis*		Native	Yes/ Yes
Hica *Bactris sp. (Palmae)*		Native	Yes/ Yes

Waorani Plant Name *Scientific Name*	Comments, Other Names (English, *Spanish*)	Native/ Introduced	Fruit Eaten/ Seasonal
Iwa Ao *Inga sp.* *(Fabaceae)*		Native	Yes/ Yes
Kagiwan *Inga sp.* *(Fabaceae)*		Native	Yes/ Yes
Kemogohive *Inga sp.* *(Fabaceae)*		Native	Yes/ Yes
Kontaka/Contaka/ Boyomo *Pentagonia spathicalyx, Rheedia spruceana*		Native	Yes/ Yes
Kopemowenka *Theobroma cacao l.*	Bark used to carry heavy things, branches used for fish net frames (*cacoa de monte,*	Native	Yes/ Yes

Waorani Plant Name *Scientific Name*	Comments, Other Names (English, *Spanish*)	Native/ Introduced	Fruit Eaten/ Seasonal
	cacao amarilla)		
Kowentobe/ Cowentobecagui *Arecaceae sp*		Native	Yes/ Yes
Mangimeo *Cecropia sciadophylla*		Native	Yes/ Yes
Menegowenka *Pouteria torta subspecies tuberculata*	*jaimito de monte*	Native	Yes/ Yes
Migika/Paigenka/ Paiganka *Psidium guajava l.*	Similar to manzanilla	Native	Yes/ Yes
Mimontao *Inga auristellae*		Native	Yes/ Yes
Minentowemo/ Guinentoweta *Arecaceae sp*		Native	Yes/ Yes
Minka	Waorani say it is	Native	Yes/

Waorani Plant Name *Scientific Name*	Comments, Other Names (English, *Spanish*)	Native/ Introduced	Fruit Eaten/ Seasonal
Undetermined	native & similar to Iryanthera juruensis		Yes
Ñoipewe/Nopewe *Helicostylis tomentosa*	From 50+ meter tree	Native	Yes/ Yes
Nanpamo *Musa acuminata*	[type of] banana, *banana*	Introduced	Yes/ No
Nontoka *Mauritia flexuosa variation*	Used medicinally	Native	Yes/ Yes
Nontowe *Mauritia flexuosa*	(palm nut, *morete*)	Native	Yes/ Yes
Obogenka *Astrocaryum chambira*	Twine used to make hammocks, ropes, and bags lasts 5-6 years	Native	Yes/ Yes
Okatowe *Aniba hostmanniana*		Native	Yes/ Yes
Omakabo	Leaves used for	Native	Yes/

Waorani Plant Name *Scientific Name*	Comments, Other Names (English, *Spanish*)	Native/ Introduced	Fruit Eaten/ Seasonal
Arecaceae sp.	roof (coconut, *coco*)		Yes
Omancomo *Coussarea brevicaulis*		Native	Yes/ Yes
Omencai *Begonia sp.*	Means "poisonous fruit" in Wao but eaten	Native	Yes/ Yes
Omentakabo *Peritassa laevigata*		Native	Yes/ Yes
Omoya/Omoye *Matisa malacocalyx*	Bark used medicinally	Native	Yes/ Yes
Ontaka *Garcinia macrophylla*		Native	Yes/ Yes
Ontowemo *Undetermined*		Native	Yes/ Yes
Opogenkawe	Coconut	Native	Yes/

Waorani Plant Name *Scientific Name*	Comments, Other Names (English, *Spanish*)	Native/ Introduced	Fruit Eaten/ Seasonal
Astrocaryum chambira			Yes
Opoka *Micropholis venulosa*	Fruiting season every 2 years, (Kichwa name *leche wayo)*	Native	Yes/ Yes
Opowenka *Astrocaryum chambira*	Type of golfball size coconut (coconut, *coco*)	Native	Yes/ Yes
Pabaw *Inga sp.* *(Fabaceae)*		Native	Yes/ Yes
Pantomohemo/ Pantomo *Undetermined*		Native	Yes/ Yes
Penenta (banana) *Musa paradisiaca*	(plantain, *platano*)	Introduced	Yes/ No
Petowe/Petomo *Jessenia bataua*	(*hungurawa*)	Native	Yes/ Yes
Tentemowe/	Used medicinally,	Native	Yes/

Waorani Plant Name *Scientific Name*	Comments, Other Names (English, *Spanish*)	Native/ Introduced	Fruit Eaten/ Seasonal
Teentecagui/Teen temo *Renealmia sp.*	believed to repel snakes		Yes
Tepawe/Tepa *Iriartea deltoidea*	Wood used for blowgun more now than traditional Cayewebewe	Native	Yes/ Yes
Tepenka *Theobroma subincanum*	(*cacao amarillo*)	Native	Yes/ Yes
Titemowe *Undetermined*	50 meter high tree	Native	Yes/ Yes
Tobenaka *Grias neuberthii*	(*cacao verde*) grows right off trunk not branch	Native	Yes/ Yes
Wecaiwe (Shuar *shakashkaya*) *Iryan thera cf. paraensis*	Used medicinally	Native	Yes/ Yes

Waorani Plant Name *Scientific Name*	Comments, Other Names (English, *Spanish*)	Native/ Introduced	Fruit Eaten/ Seasonal
Wegamoñi/ Wegamowe *Mansoa alliacea*	Peccary eat garlic flavor pit, flavors peccary meat. Wao eat fruit	Native	Yes/ Yes
Wenemengo *Inga sp. (Fabaceae)*		Native	Yes/ Yes
Wengamo *Undetermined*	50 meter high tree. If peccary eat seeds, their meat smells bad	Native	Yes/ Yes
Wengawe *Undetermined*		Native	Yes/ Yes
Wento *Urera baccifera*	Fruit stings but certain parts of fruit eaten often, used in childbirth	Native	Yes/ Yes
Wepemonka *Lacmellea lactescens or*		Native	Yes/ Yes

Waorani Plant Name *Scientific Name*	Comments, Other Names (English, *Spanish*)	Native/ Introduced	Fruit Eaten/ Seasonal
oblongata			
Werekeho *Inga sp. (Fabaceae)*		Native	Yes/ Yes
Wingimonkawe *Iryanthera juruensis*	Used medicinally; also, peccary break branches to rub on wounds	Native	Yes/ Yes
Wingitage/ Mingikawe *Protium polybotryum*		Introduced	Yes/ Yes
Wiramonka *Undetermined*	Large berry	Native	Yes/ Yes
Yepenemoncawe *Casearis fasciculatua; Casearia prunifolia*	Sap used as glue	Native	Yes/ Yes
Yowewe Ikitika		Native	Yes/

Waorani Plant Name *Scientific Name*	Comments, Other Names (English, *Spanish*)	Native/ Introduced	Fruit Eaten/ Seasonal
Pourouma cecropiifolia			Yes

Table 3. Kawymeno Waorani Non-Plant Names, Common Names and Scientific Names

COMMON NAME/ WAORANI NAME	**SCIENTIFIC NAME**
Mammals	
White-Lipped Peccary/Ure	Tayassu Pecari
Woolley Monkey/Gata	Lagothrix lagotricha
Collared Peccary/Amo	Pecari Tajacu
White-Bellied Spider Monkey/Deye	Ateles belzebeth
Dusky Titi Monkey/Coto and Yellow-Handed Titi Monkey/Iwa	Callicebus discolor, Callicebus lucifer
Equatorial & Monk Saki Monkey/Gogaroka	Pithecia aequatorialis, Pithecia monachus
Red Howler Monkey/Kojinko	Alouatta seniculus

COMMON NAME/ WAORANI NAME	SCIENTIFIC NAME
Squirrel Monkey/Gekire	Saimiri sciureus
White-Fronted and Brown Capuchin Monkey/ Bogi	Cebus albifrons, Cebus apella
Armadillo/Gomata	Dasypus novemcinctus
Giant Armadillo/Goma	Priodonte maximus
Guanta/Panone	Cuniculus paca
Guatin/Buyego	Myoprocta praatti
Guatusa/Pene	Dasyprocta fuliginosa
Squirrel (larger species)/Nene	Sciurus sp.
Tapir/Tite	Tapirus terrestris
Birds	
Pavo Colorado/Kowatay	Penelope jacquacu
Amazon Parrot (3 species)/Tobe	Various Amazona sp. (Psittacidae)
Blue & Yellow Macaw, Scarlet Macaw/Minta	Ara ararauna, Ara macao
Tucan/Yawe	Ramphastos tucanus
Pava negra/Kowe	Pipile pipile
Reptiles	
Yellow Spotted River Turtle/Pake (meat and eggs)	Podocnemis unifillis
Arrau River Turtle/Pake (meat and	Podocnemis expansa

COMMON NAME/ WAORANI NAME	SCIENTIFIC NAME
eggs)	
Yellow Footed Tortoise/Titeke	Geochelone denticulata
Fish	
Pacu/Neñe Kakata	Piaractus brachypomus, Colossoma macropomum
Undetermined/Kemonka	Undetermined
Barbudo/Nagemo	Pimelodus sp.
Sardina/Kame	Heterocharax sp.
Piraña, Piranha/Gare	Serrasalminae sp.
Palometa/Kakata	Mylossoma sp.
Boca chico/Keremene	Prochilo dusnigricans
Carachama/Oba	Piaractus sp., Liposarcus pardalis
Vieja/Baitere	Aequidens tetramerus
Pikalon/Ongoñe	Undetermined
Black Catfish/Goka (Omare)	Pimelodidae sp.
Catfish/Nawa (Omare)	Pimelodidae sp.
Painted Catfish/Kampaname (Omare)	Pseudoplatystoma sp.
Insects - Ants	
Arieras Ant/Bore	Undetermined Atta genus
Lemon Ant/Owekawe	Myrmelachista schumanni

Table 4. Santa Teresita Kichwa, Scientific and Common Names and Characteristics of Plants

Plant Name: Kichwa *Scientific Name*	Common Name (English, *Spanish)*	Parts Eaten Comments	Fruit Eaten	Native/ Introduced	Seasonal
Grains and Vegetables					
Ajijimbre *Curcuma longa (Zinziberaceae)*	*ajijimbre*	Vegetable (root) Root medicinal	No	Introduced	No
Cumalo, Comal *Ipomoea batatas*	sweet potato, *camote*	Root Leaf medicinal	No	Introduced	No
Inchi *Arachis hypognea*	peanut (domestic), *mani domestico*	Grain	No	Introduced	No
Papas: Chaqui *Solanum tubcrosum (subspecies)*	potato, *papa*	Vegetable (root)	No	Introduced	No

Plant Name: Kichwa *Scientific Name*	Common Name (English, *Spanish)*	Parts Eaten Comments	Fruit Eaten	Native/ Introduced	Seasonal
Papas: Guagua *Solanum tubcrosum (subspecies)*	potato, *papa*	Vegetable (root)	No	Introduced	No
Papas: San *Solanum tubcrosum (subspecies)*	potato, *papa*	Vegetable (root)	No	Introduced	No
Papas: Yarina *Solanum tubcrosum (subspecies)*	potato, *papa*	Vegetable (root)	No	Introduced	No
Pepino *Cucumis sativus*	cucumber, *pepino*	Fruit	No	Introduced	No
Piton *Grias neubertii*	*piton*	Grain/seed Seed medicinal	No	Native	Yes
Sacha Culantro *Eryngium*	wild cilantro, *culantro de*	Vegetable (leaf)	No	Introduced	No

Plant Name: Kichwa *Scientific Name*	Common Name (English, *Spanish)*	Parts Eaten Comments	Fruit Eaten	Native/ Introduced	Seasonal
foetidum	*selva*				
Sacha Henchi *Arachus sp. (wild)*	wild peanut, *mani de monte*	Grain/seed	No	Native	No
Sara, Choklo (Immature) *Zea mays*	white corn, *maiz*	Grain	No	Introduced	No
Uchu Arara, Chunchuly, Kiru *Capsicum sp.*	peppers, *aji, chile*	Vegetable	No	Introduced	No
Yuca/Mandioca *Manihot esculenta*	manioc, cassava / *yuca, mandioca*	Vegetable - staple food (root)	No	Introduced	No
Fruits					
Achoccas *Cyclanthera pedata*	*achojcha*	Fruit	Yes	Introduced	No
Aguacate	avacado,	Fruit	Yes	Introduced	Yes

Plant Name: Kichwa *Scientific Name*	Common Name (English, *Spanish)*	Parts Eaten Comments	Fruit Eaten	Native/ Introduced	Seasonal
Persea americana	*aguacate*				
Auio *Chrysophyllum cainito*	starfruit, *caimito*	Fruit	Yes	Introduced	Yes
Chiquilla (Chihuilla) *Ananas sativus (Ananas comosus)*	pineapple, *piña*	Fruit	Yes	Introduced	No
Chonta *Bactris gasipaes (syn. Ciliata for species)*	peach palm, *chonta*	Fruit New leaf medicinal	Yes	Native	Yes
Guineo *Musa sp. various*	banana, *guineo*	Fruit	Yes	Introduced	No
Jatun Pacay (Big) Chilla Pacay (Small)	*Guaba Grande, Guaba*	Fruit Branches medicinal	Yes	Introduced	Yes

Plant Name: Kichwa *Scientific Name*	Common Name (English, *Spanish)*	Parts Eaten Comments	Fruit Eaten	Native/ Introduced	Seasonal
Inga sp. (Various varieties)	*Pequeno*				
Lima *Citrus aurantifolia*	lime, *lima*	Fruit	Yes	Introduced	No
Limon *Citrus Limon*	lemon, *limon*	Fruit and leaves Fruit juice medicinal	Yes	Introduced	No
Mandarina *Citrus reticulata*	mandarin, *mandarina*	Fruit	Yes	Introduced	No
Manduro *Bixa orellana*	Annato, *achiote*	Fruit	Yes	Introduced	No
Mango *Mangifera indica*	mango, *mango*	Fruit	Yes	Introduced	Yes
Melones *Cucumis sp.*	melon, *melón*	Fruit	Yes	Introduced	No

Plant Name: Kichwa *Scientific Name*	Common Name (English, *Spanish)*	Parts Eaten Comments	Fruit Eaten	Native/ Introduced	Seasonal
Naranja *Citrus vulgaris*	orange, *naranja*	Fruit and leaves	Yes	Introduced	No
Paparagua/Fruitipan *Artocarpus incisa, artocarpus altilus*	breadfruit, *árbol del pan, frutipan*	Fruit Leaves and sap medicinal	No	Introduced	No
Papaya *Carica papaya*	papaya, *papaya*	Fruit Leaves medicinal	Yes	Introduced	No
Patas Muyo *Theobroma sp.*	white cacoa, *cacao blanco*	Fruit	Yes	Introduced	No
Sacha Cocona *Solanum sp. (Solanaceae)*	wild naranjilla, *naranjilla silvestre*	Fruit	Yes	Native	Yes
Sandia *Citrullus lanatus*	watermelon, *sandia*	Fruit	Yes	Introduced	No
Sapallo	squash,	Fruit	No	Introduced	No

Plant Name: Kichwa *Scientific Name*	Common Name (English, *Spanish)*	Parts Eaten Comments	Fruit Eaten	Native/ Introduced	Seasonal
Cucurbita maxima	pumpkin / *calabaza, zapallo*	Seed medicinal			
Tomate *Solanum lycopersicumvar* .	tomato, *tomate*	Fruit	No	Introduced	No
Toronja *Hybrid - Citrus paradisi*	grapefruit, *toronja*	Fruit	Yes	Introduced	No
Zapote *Quaraibea cordata*	*zapote*	Fruit	Yes	Introduced	Yes
Regularly Consumed Medicinal Plants (counted separately in food system figures)					
Auca Jambi/All Jambi *Lonchocarpus nicou var Urcu*	*barbasco fuerte* (type of fish poison)	Poison (roots and trunk)	No	Introduced	No

Plant Name: Kichwa *Scientific Name*	Common Name (English, *Spanish)*	Parts Eaten Comments	Fruit Eaten	Native/ Introduced	Seasonal
Chuchuhuasca *Maytenus chuchuhuasha*	*chuchuhuasca*	Medicinal (leaf)	No	Native	No
Chucriyuyu *Kalanchoe pinnata*	*paicheponga*	Medicinal - succulent (branch)	No	Introduced	No
Clavohuasca *Tynnanthus sp.*	white clove, *clavo huasca*	Medicinal (leaf)	No	Native	No
Garavato Casha *Uncaria tomentosa*	cat's claw, *uña de gato*	Medicinal (bark /trunk)	No	Native	No
Hila Wiki *Ficus sp. (Costaricana)*	fig tree, *higueron*	Medicinal (sap)	No	Native	No
Sandi Yura (tree)/ Sandi Wiki (sap) *Brosimum*	cow tree, *arbol de sandi*	Medicinal (sap)	No	Native	No

Plant Name: Kichwa *Scientific Name*	Common Name (English, *Spanish)*	Parts Eaten Comments	Fruit Eaten	Native/ Introduced	Seasonal
lactescens					
Yahuar Huiqui *Croton lechleri*	dragon's blood, *sangre de drago*	Medicinal (sap)	No	Native	No
Storebought					
	beans (various)	Grain	No	Store-bought	No
	garlic	Root	No	Store-bought	No
	lentils	Grain	No	Store-bought	No
	onions	Root	No	Store-bought	No
Colocasia esculenta	*papa china(potato)*	Root	No	Store-bought	No
	rice	Grain	No	Store-bought	No
	tomatoes	Fruit	Yes	Store-bought	No

Plant Name: Kichwa *Scientific Name*	Common Name (English, *Spanish)*	Parts Eaten Comments	Fruit Eaten	Native/ Introduced	Seasonal
	wheat	Grain	No	Store-bought	No

Table 5. Santa Teresita Kichwa Non-Plant Food Names and their Common and Scientific Names

COMMON NAME/ KICHWA NAME	SCIENTIFIC NAME
MAMMALS	
Guanta	Cuniculus paca
Guatusa	Dasyprocta fuliginosa
Guatin	Myoprocta praatti
Squirrel (larger and smaller species)	Sciurus sp.
Armadillo	Dasypus novemcinctus
REPTILES	
Yellow Spotted River Turtle (meat and eggs)	Podocnemis unifillis

COMMON NAME/ KICHWA NAME	SCIENTIFIC NAME
Yellow-Footed Tortoise (meat)	Geochelone denticulata
FISH	
Barbudo	Pimelodus sp.
Sardina	Heterocharax sp.
Pirana	Serrasalminae sp.
Palometa	Mylossoma sp.
Boca chico	Prochilo dusnigricans
Carachama	Piaractus sp., Liposarcus pardalis
Vieja	Aequidens tetramerus
INSECT	
Arieras Ants/ Ukui	Undetermined Atta genus
FUNGI	
Cachi cayamba, Monda caiamba, Shigra caiamba	Undetermined
DOMESTIC ANIMALS	
Domestic pigs	
Domestic cattle (meat and milk)	
Domestic ducks (meat and eggs)	
Domestic chickens (meat and eggs)	
STORE BOUGHT FOODS	

COMMON NAME/ KICHWA NAME	SCIENTIFIC NAME
Tomatoes	
Potatoes	
Rice	
Beans	
Lentils	
Milk	
Garlic	
Onions	
Salt	
Sugar	
Wheat: Pasta	
Wheat: Bread	
Dairy products: yogurt	
Dairy products: cheese	
Cooking oil - Vegetable	
Animal-based cooking fat (lard)	
Store condiments: Sabora	
Store condiments: Magi	
Store condiments: Alino	

Table 6. Kawymeno Waorani and Santa Teresita Kichwa Food Species Categories, Seasonality, Native Plant Status and Fruits Eaten

Kawymeno Waorani				
Plant Food Species	Overall	Seasonal	Native	Fruit
Tubers and Grains	4	0	0	n/a
Hunting and Fishing Poisons	4	1	3	1
Plant Food Species	80	75	75	80
Total	88	76	78	81
Non-plant Food Species	Overall	Seasonal	Native	Fruit
Mammals	16		16	
Birds	8		8	
Reptiles	3		3	
Fish	13		13	
Insects (Ants)	2		2	
Total	42	0	42	0
Santa Teresita Kichwa				
Plant Food Species	Overall	Seasonal	Native	Fruit
Grains and Vegetables	13	1	2	
Fruits	24	6	2	24
Regularly Consumed Medicinal Plants	8	0	6	
Store-bought	7	0	0	
Total	52	7	10	24

Santa Teresita Kichwa				
Non-plant Food Species	Overall	Seasonal	Native	Fruit
Mammal	5		5	
Reptiles	2		2	
Fish	7		7	
Insect	1		1	
Fungi	1		1	
Domestic animals	4		0	
Store-bought foods	19		0	
Total	39	0	16	0

Dissertation Inclusion Criteria and Vocabulary

Dissertation criteria for inclusion or exclusion of food species in the study. The decision was made to exclude from the dissertation study any plant food species that could not be documented by the investigation as being eaten at least once a week during the fruiting season or, if not a seasonal food plant, could not be documented as being used at least every two weeks throughout the year by the whole population. For instance, since some frequently consumed seasonal plants only have a fruiting season every few years they were not included in the food identification tables.

Indigenous vocabulary used to describe dissertation study plant food species. Another issue in comparing this study with previous research on the Waorani is some common names for plants vary across Waorani communities.

The same holds true for Kichwa plant names across Kichwa communities due to their remote locations. Thus, a couple of Waorani plant names on the food species identification tables may not correspond exactly to Waorani plant names used in other articles and books. Kawymeno in particular is so isolated from the Waorani nation, it has separate names for at least a few plants, while within the Protectorate the Waorani have more commonality in food species names.

The Kawymeno Waorani categorize plants partly on physical characteristics, but also based on particular uses for the plant such as for food and medicine, and spiritual beliefs associated with each plant. Western scientists categorize and break down plant species characteristics based on an abstract relationship with the plants. The Kawymeno Waorani categorization has value for survival and structuring their food system culturally, while Western categories have value for intellectual scientific study. The Kawymeno Waorani have their own classification system for plants which a little demonstration of Kawymeno Waorani vocabulary will demonstrate: *Tepaire* (all plants), *Awemo* (large trees), *Aweire* (small plants), *Penecore* (native food plants planted near the home), *Omeñecaire* (roots), *Pikewa* (primary forest plants), *Winenkore/Wiñewa* (secondary rain forest plants), *Awe* (plants with no sap, however there's no word for plants that do have sap). The "*–owe*" suffix indicates the fruit while "*-eme*" indicates the tree or plant itself. The plant name suffixes employed in the dissertation were selected based on the choice of words most commonly employed in the vocabulary of the people interviewed.

The number of Waorani plant food species is probably larger than indicated on the food species tables. One reason is there are frequently strikingly different looking plants that have the same Waorani name. For instance, we found a number of varieties of a native coconut species with different leaves, tree shapes and fruit sizes. Although there is only one coconut species on the food system list, there are significant differences in subspecies and variants of the original coconut species. What is a new species and what is a variety of the same species is a decision for Western botanists, and beyond the scope of this study, which is on food systems rather than botanical nomenclature.

However, it is quite likely these subspecies' phytochemical content may be as different as their appearance. Thus, there is even more phytochemical diversity in the Waorani dietary intake than the food species tables can illustrate.

Comparisons of the Waorani Food System across Time and Against Other Hunter-Gatherers Twenty-seven years of changes in the Waorani food system

. A comparison across three decades of food system change indicates the Kawymeno Waorani are still eating as wide a variety of wild plant foods as pre-contact Waorani did when an ethnobotanical survey of the plants used by the Waorani was conducted in 1983, only a few years after their first sustained peaceful contact with outsiders (Davis and Yost, 1983). Davis and Yost listed the wild food plants in the Waorani food system as numbering 44 and estimated capturing at least 80% of the plants the Waorani used for all purposes. In comparison, this dissertation captured 75 commonly used wild food plant species, which indicates the diversity of the wild Waorani food system remains intact in

Kawymeno. Davis and Yost probably captured a smaller amount of Waorani wild food plant species because their survey was brief, spanning a few weeks, while the dissertation survey lasted a year. In sum, the variety of wild plant foods ingested regularly in Kawymeno is as large, or larger than, the variety of Waorani wild plant foods eaten near the time of first peaceful sustained contact. This indicates the Kawymeno Waorani are still eating as wide a variety of wild plant foods as pre-contact Waorani did.

Minimal Store Bought Food Used by the Santa Teresita Kichwa Subsistence Farmers.

The Santa Teresita Kichwa are a group that has not yet entered the modern food system, and still represent a largely subsistence agricultural diet with a few store-bought additions of mostly whole foods such as vegetables, grains and one-ingredient food items. The plethora of chemicals and processing that has invaded the modern food system are still largely absent in the Santa Teresita Kichwa diet. Along with their own farmed and native food species, the Santa Teresita Kichwa use 18 mostly unprocessed store bought items; 4 grains, 4 vegetables, 3 dairy products, 2 cooking oils, 3 soup cubes, salt and sugar. There are few artificial ingredients and little processing in Santa Teresita Kichwa store-bought food, including an absence of: flavors, colorants, preservatives (and freezing to preserve food), hormones, antibiotics, other than 3 types of soup flavoring and salt. The few Santa Teresita Kichwa store bought foods are mostly one-ingredient items such as grains, vegetables, sugar, and salt. Food processed outside the community is rare in the Santa Teresita Kichwa diet and no packaged, canned, bottled or

mixed ingredient items are purchased regularly, other than the three types of soup flavor enhancers. When the Santa Teresita Kichwa get access to money, they sporadically purchase lard and oil for cooking, as well as bread and pasta. Visits to the store are rare and many Santa Teresita Kichwa families have no money to purchase any store bought ingredients.

In terms of non-nutritive foods, cigarettes are rarely if ever purchased, sodas are purchased only every month or two and some alcoholic beverages are purchased. Coffee is the most frequently purchased and ingested non-nutritive food.

Comparing overall diversity of both study food systems. Diversity is the hallmark of the Kawymeno Waorani diet. Kawymeno Waorani hunter-gatherers consume more total plant and animal food species than the Santa Teresita Kichwa farmers. The Kawymeno Waorani regularly ingest over 130 plant and animal food species. The Santa Teresita Kichwa have only 64 regularly ingested plant and animal food species in their food system and a heavy reliance on a few staple foods. Plants are a direct source of phytochemicals. In food plants alone, the Kawymeno Waorani have a large repertoire of 88 food plant species (80 of them being wild rainforest fruit) that are regularly ingested, compared to the smaller array of 37 Santa Teresita Kichwa plant food system species.

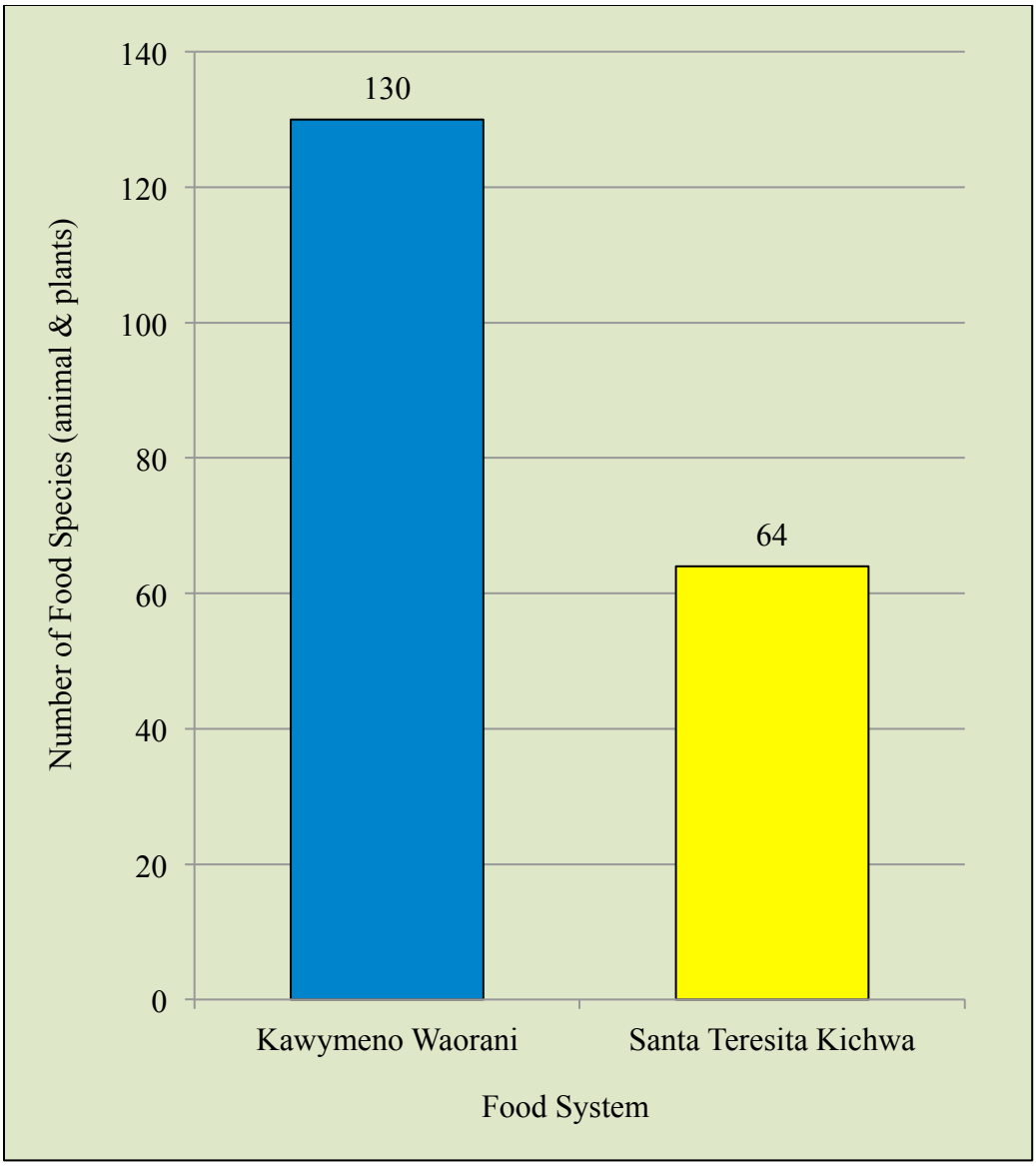


Figure 8. Number of Food Species Consumed per Food System: Kawymeno Waorani vs. Santa Teresita Kichwa. 2010

Same environment, but few overlapping foods: table and discussion. As the below table demonstrates, the Santa Teresita Kichwa farmers, in spite of living in the same ecosystem as the Kawymeno Waorani, have only 9 overlapping foods in common with the Kawymeno Waorani in their entire food system. This is an example of two human cultures in the same environment using completely

different food resources. Both groups have access to most of the same rain forest food resources. There are several reasons why there is so little food overlap. The Santa Teresita Kichwa have depleted the larger wild mammals by hunting and selling them. However, in the case of the still abundant native wild plant foods growing near the Santa Teresita Kichwa, the lack of food overlap appears to be simply due to a preference for gardening over gathering. This dissertation study has measured and found the Kawymeno Waorani hunting and gathering activities actually require less time and labor than farming, so the reduced workload does not account for a preference for gardening as is illustrated in the figure on exercise in the next chapter.

Table 7. All Plants Consumed in Common by Both Study Populations

Scientific Name	Waorani Name	Kichwa Name
Arachis sp.	Koromo	Sacha Henchi
Bactris gasipaes	Dagenka/Tewe	Chonta
Capsicum chinensis	Giimo	Uchu 3 Varieties: Arara, Chunchuly, Kiru
Grias neuberthii	Tobenaka	Piton
Inga sp. (Fabaceae)	(various) Guaba	Jatun Pacay (Big) Chilla Pacay (Small)
Lonchocarpus nicou var. Urcu	Meniko	Auca Jambi/All Jambi

Manihot esculenta	Kewe (plant) Kene	Yuca/Mandioca
Musa sp. (Musaceae)	Banana species	Guineo
Solanum sp. (Solanaceae)	Dabomo (cultivated)	Sacha Cocona

Phytochemical Content in Wild Versus Domesticated Food Species One of the principal differing factors between the Santa Teresita Kichwa agrarian food system and the Kawymeno Waorani hunter-gatherer food system is the source of phytochemicals, which are from wild foods in the case of the Kawymeno Waorani hunter-gatherers, and mostly from domesticated food species in the case of the Santa Teresita Kichwa farmers. The Kawymeno Waorani ingest 117 native rain forest animal and plant food species from the Kawymeno area including 75 wild plants, as well as 3 semi-cultivated species native to the nearby Amazon area, and 7 semi-cultivated food species not native to the region. On the other end of the scale in the Santa Teresita Kichwa food system there are only 20 native, sporadically consumed food species, 16 rain forest animal and 4 plant food species and 6 heavily consumed "preventative" medicinal plants. The Santa Teresita Kichwa have 45 domesticated total food species, including 41 domesticated plant species and 4 domesticated animal species, that are more heavily-consumed than native species and are imports with origins often outside of Ecuador. The Kawymeno Waorani have, across the board, a much larger percent of their diet intake frequency that is wild foods; 117 out of a food system total of 130 species while the Santa Teresita Kichwa have 20 native species out of a food system total of 64 species.

Variety of wild and domesticated plant food species: chart and discussion. In terms of strictly plant food species, the Kawymeno Waorani food system has 75 wild rain forest plant food species, all of which are types of fruit. In addition to the native food species, the Kawymeno Waorani have 3 semi-cultivated species native to the Amazonian region and 7 non-native plant food species of which 3 are fruit trees and 3 are starchy tubers (sweet potatoes and manioc) and there is one wild peanut seed food. The Kawymeno Waorani also have 4 hunting and fishing poisons routinely consumed in food, of which 3 are native and one is wild, but introduced from another region. The curare blowgun dart poison is a wild rain forest vine. Two of the native fish poisons are sometimes taken from the wild and transplanted near the community for daily access. The other native fish poison is imported from Puyo, Ecuador and planted near the community.

The Kawymeno Waorani usually just plant the semi-domesticated food species and leave them to grow in the rain forest so these plants are forced to interact with the local ecosystem and its phytochemical exchange in the same manner as wild plants. To survive, these semi-domesticated plants must produce more defensive phytochemicals to offset rain forest threats. The Kawymeno Waorani do not use any plants that require any real on-going care. Manioc are the closest the Kawymeno Waorani come to agriculture as rain forest trees are cleared where the manioc are planted.

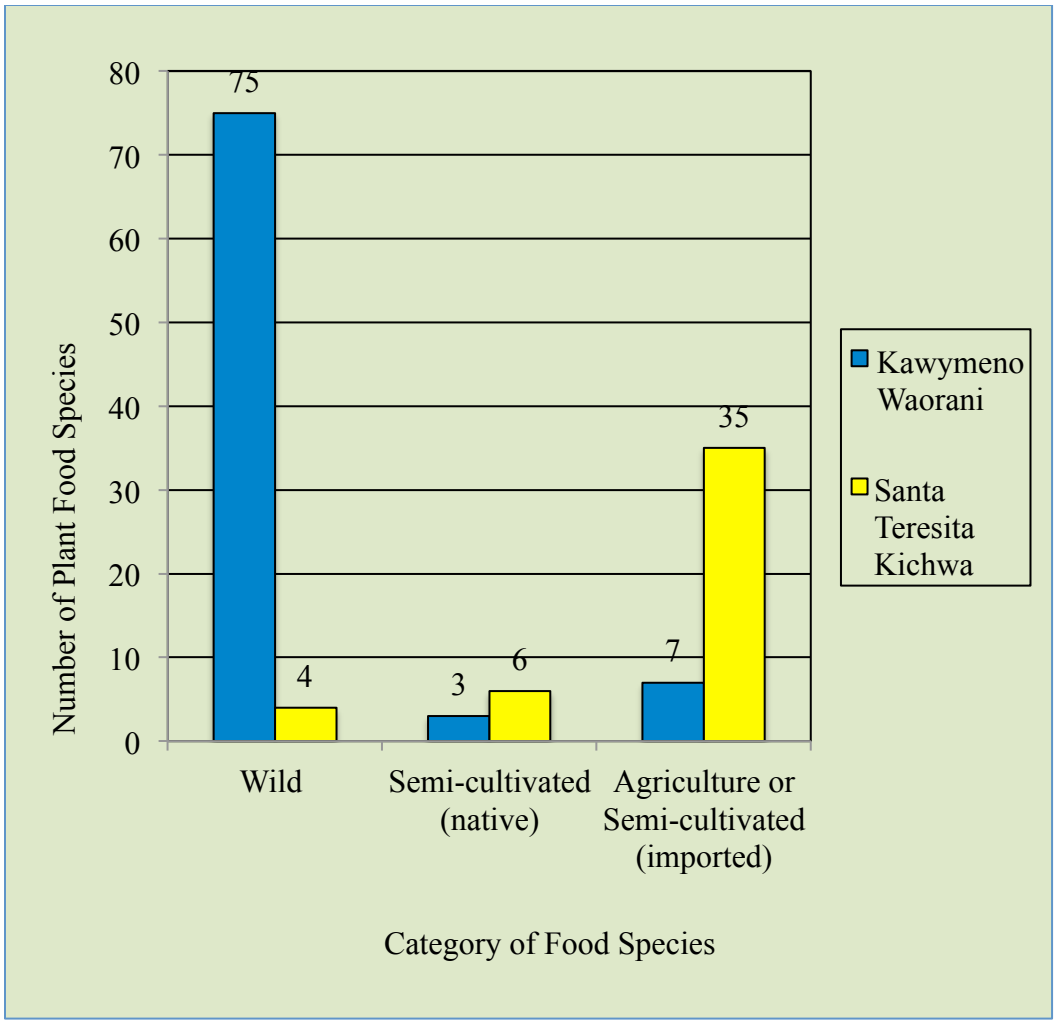


Figure 9. Number of Species of Wild and Cultivated Plant Foods Consumed: Kawymeno Waorani vs. Santa Teresita Kichwa. 2010

The Santa Teresita Kichwa have 35 imported "domesticated" plant foods as well as 8 store-bought plants, 4 store-bought vegetables and 4 store-bought grains. The Santa Teresita Kichwa have very few wild plant foods species; several wild plant fruit trees, 1 wild grain species. Unlike the Kawymeno Waorani semi-cultivated plants, which are left to their own devices, the Santa Teresita Kichwa domesticated plants are actively cared for on a daily basis and separated from the surrounding rain forest eco-system in protected gardens. In addition, while having

almost no wild plant food species the Santa Teresita Kichwa have many wild medicinal species. Six medicinal plants are eaten daily by many residents to cure diseases (see Kichwa plant food species table), so regularly that these medicinal plants qualify as a "food" under this dissertation's definition of a food species. In fact, these medicinal plants are consumed more frequently than many normal foods in the Santa Teresita Kichwa food system.



Figure 10.Author eating lemon ants(*Myrmelachista schumanni*) near Kawymeno

Medicinal characteristics of food: study definition of food. The fact that food is medicine, and medicine is food is an underlying theme of this dissertation. This dissertation defines something ingested as a food species by the regularity of its ingestion, not by abstract human value categories such as "medicinal" or "food". What counts for this dissertation is if the community regularly ingests a plant or

animal species that has significant nutritive and phytochemical properties, not which definition, as “medicine” or “food”, the culture chooses to bestow on the ingested species. Neither nutritional value nor phytochemical value change according to which category humans choose to place ingested species into. Human perceptions may change, but not the biochemical realities.

Whether considered as primarily medicinal or primarily food, in the dissertation study food species have to meet the same frequency criteria outlined in the methods chapter of this dissertation. In contrast to the Santa Teresita Kichwa, the Kawymeno Waorani do not consume any plant for medicinal qualities regularly enough for these medicinal plants to qualify as food in this study. However, daily intake of hunting and fishing poisons in Kawymeno Waorani food are included in the food system. The small Kawymeno Waorani repertoire of medicinal plants are consumed occasionally as needed and most are applied to the skin rather than ingested orally. This dissertation makes the case that the medicinal qualities in smaller preventative doses are already in the wild food plants the Kawymeno Waorani consume, therefore extra strong medicinal plant varieties are rarely needed. These types of dietary pharmaceutical phytochemicals are also found in everyday foods although not necessarily in therapeutic variety or dosage.

Rainforest versus domestic production of phytochemicals. It is well known that wild plants, particularly in rain forest regions, actively use a much wider range of more potent phytochemicals to survive multiple threats in their complex and chemically intertwined ecosystem, in comparison to protected and

largely segregated domesticated farmed food plants. Cultivated plants have much lower concentrations of natural phytochemicals than their wild counterparts (Ames, et al., 1990b). Rain forest plants produce an arsenal of varied phytochemicals all with different mechanisms to deal with threats from insects, microorganisms, parasites, competing plants and larger plant eating animals including humans.

Another set of rain forest plant and animal phytochemicals are used to interact symbiotically with other organisms as plants interdependently fulfill survival needs of multiple organisms in the process of assuring their own propagation and survival. For instance, a species of rain forest tree (*Duroia hirsute)* provides phytochemical and physical protection for a species of Lemon Ant (*Myrmelachista schumanni*). The ant returns the favor by killing off all competing rain forest plants within a radius of several yards around the plant by injecting their leaves with a natural formic acid herbicide. Interestingly, the Kawymeno Waorani also form part of this plant-ant rain forest chemical relationship by eating the Lemon Ant and utilizing this ant's animal defense herbicide as a drug to minimize feelings of pain and hunger. This permits the Kawymeno Waorani to hunt for days without food. I have eaten these ants and observed this ant animal "phytochemical" and its affect on human physiology. This type of ant-plant-human rain forest biochemical dynamic is a dramatic example of the very normal – and typically hidden from human senses – way in which rain forest organisms interact with each other biochemically to produce

plant and animal phytochemicals that are beneficial for human beings, in a way a domestic garden's limited phytochemical interexchange cannot match.



Figure 11. Monkey arm - the author and his wife ate the same food as the Waorani for months at a time

The Santa Teresita Kichwa get most of their phytochemicals from coddled, protected, domesticated plants that need much less diverse chemical arsenals to ward against the few natural threats that have yet to be eliminated or reduced by human farming care. Potential rain forest allies of plants are also cut off through farming segregation. Agricultural technology protects food plants from microorganisms, competing plants, insects and large herbivores by, among others, physically separating and isolating plants from surrounding biochemically-stimulating ecosystem threats, weeding, fencing in, tilling of soil, and large pest removal. The use of synthetic pesticides and herbicides by modern agriculture provides an additional chemical barrier to any biodynamic relationship with the

outside eco-system. The Santa Teresita Kichwa rarely use artificial chemicals on their gardens, partly because several hours a day of attention helps preserve the plants in a way less attention would not, and lack of a functioning economy prevents purchase of Gramaxsone and other agricultural chemicals. Segregation, and in the case of modern agriculture, pesticide poisoning, keeps the agricultural plants away from potential biochemical-stimulating allies, such as the Lemon Ant used in the example above, as well as plant enemies.

Food Preparation Differences Between Hunter-Gatherers and Farmers

> *I watched and assisted Ima and Way in the preparation of the huangana (White-lipped Peccary) today. They cut the huangana into pieces. Way said the head is the best, while Ima liked the ribs. They didn't wash the meat, they put the blood on the meat. They eat almost every part of the huangana except the feet and the "parte que apesta" [colon]. They started a fire with wood inside the house, no chimney to let out the smoke. They boiled the intestines in a container. They burned off the hair then they cooked the meat flipping it every half hour. They said with this type of smoking/cooking the meat lasts a week. They use no other preservatives such as salt.* (Field Journal Entry, Douglas London. February 16, 2010)

The advantages of raw one-ingredient meals versus recipes and cooked food. Humanity is evolutionarily adapted to a diet of one-ingredient meals such as those the Kawymeno Waorani still use. The one-ingredient foods

and one-ingredient medicinals that make up the Kawymeno Waorani food and medicine system were probably the norm throughout human prehistory. This means humans are adapted to unadulterated phytochemicals from single plant sources. The advent of cooking and mixing foods creates substances the human body was not prepared for evolutionarily.

Kawymeno Waorani use one-ingredient recipes not only for most meals, but also in their medicinal plant repertoire. While the Santa Teresita Kichwa have complicated medicinal plant recipes with many ingredients and elaborate preparation, almost all Kawymeno Waorani medicinal remedies are one simple ingredient. My observation is that Kawymeno Waorani medicinal treatments are far more effective than Santa Teresita Kichwa medicinal treatments, even though Kawymeno Waorani use a couple dozen medicinal plants. With an unadulterated single treatment, it is more apparent whether the treatment is successful or not and the decision to continue or search for a better treatment is more straightforward. The lone medicinal plant treatment of the Kawymeno Waorani that involves multiple ingredients (more than a one ingredient from one plant) is one remedy for poisonous snakebite.

The Kawymeno Waorani hunter-gatherers have a much higher intake of food that is raw and unmixed with other foods in comparison to the Santa Teresita Kichwa. Foods are not chemically inert; foods have chemical interactions that when cooked or mixed with each other modify phytochemical compounds. Beyond original raw phytochemical content, hunter-gatherer diets may be healthier in part because hunter-gatherer foods are eaten whole, plain, separated

and in the case of plant foods, as uncooked as possible. Since using a recipe, mixing ingredients and using sauces and additives to flavor foods is the norm in modern cooking, little thought is given to the damage that may occur to both nutritional and phytochemical content in the process. Cooking and mixing foods together, while creating new interesting tastes, alters original phytochemical content.

Cooked versus raw: review of categories and numbers of food species.

Discussion of food preparation chart. In terms of food preparation, the Kawymeno Waorani eat mostly raw fruits that are picked directly from the tree, and often consumed on the spot, without mixing with any other foods. The Kawymeno Waorani, for the most part, do not eat non-fruiting parts of plants with the exception of a few tubers. Animal foods are lightly roasted or boiled and eaten plain. On the other hand, the Santa Teresita Kichwa alter the phytochemical content of the original, raw, freshly picked fruit, vegetables and animal foods by cooking, mixing different foods together in recipes, and adding powerful taste-dominating natural spices that are powerful phytochemicals and alter taste themselves.

Put simply, the Kawymeno Waorani eat most of their plant food raw while the Santa Teresita Kichwa cook much of their plant food. While animal foods are cooked over a fire by both groups, that is where the similarity ends, the Santa Teresita Kichwa add the animal food to a recipe.

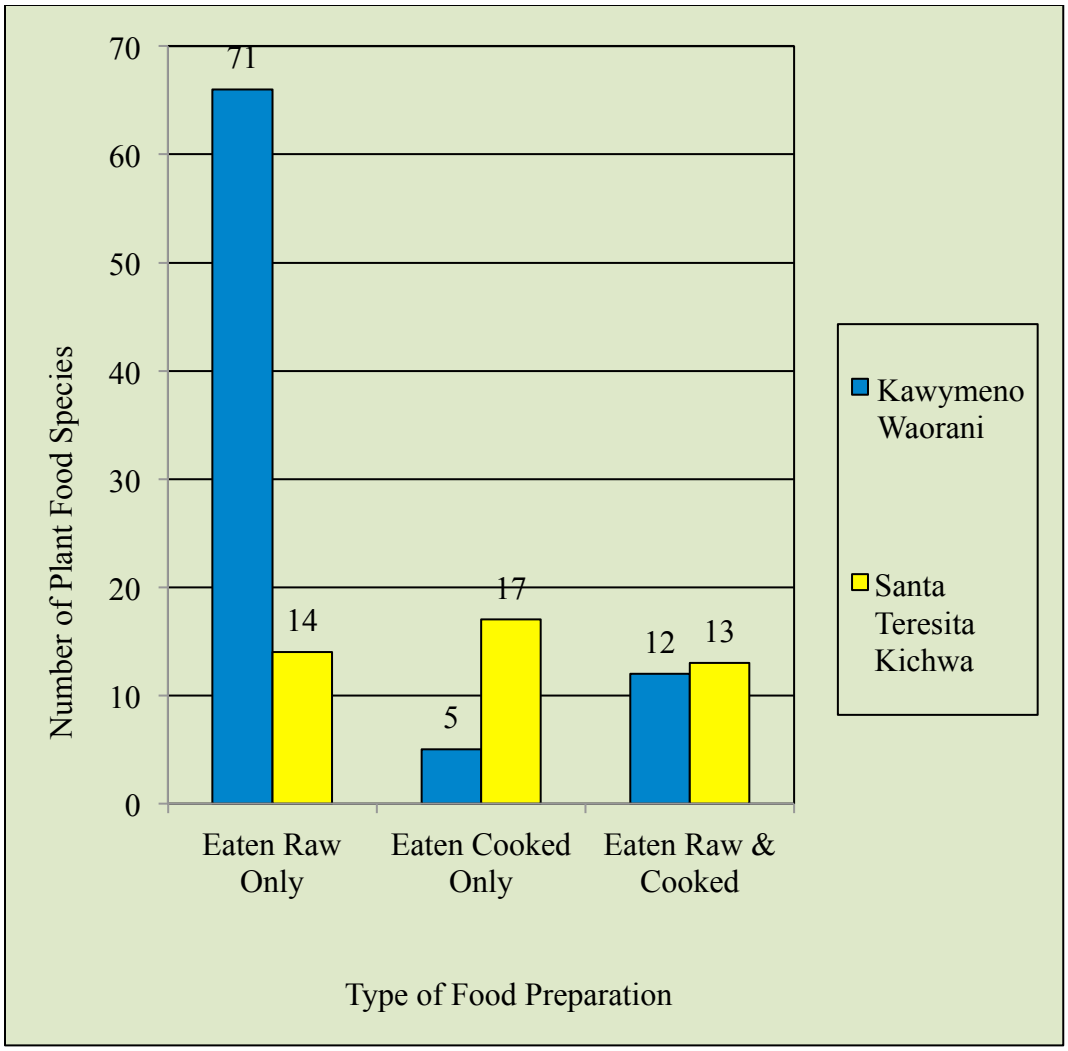


Figure 12. Food Preparation and Number of Species of Plant Food per Community: Kawymeno Waorani vs. Santa Teresita Kichwa. 2010

In the chart above the level of cooking and preparation of foods was divided into three categories across the hunter-gatherers and farmers: never cooked, occasionally cooked and always cooked. The first category is foods that are never cooked. In the Kawymeno Waorani food system, of 88 plant foods 71 are eaten raw, 5 are eaten only cooked and 12 are eaten raw or cooked. The fruits that are cooked by the Kawymeno Waorani are usually boiled as part of chicha

fermentation preparation. The one exception to the boiling of fruits is the little berries of the native cotton plant (*Ceiba pentandra)* that are put in leaves and cooked above a fire. The cotton used to stabilize blowgun darts, and these edible berries both come from the same cotton tree pod. The Kawymeno Waorani consume 80.6 percent of their plant food raw. On the other hand, the Santa Teresita Kichwa eat only 14 plant food species raw out of a total of 44 plant food species and these are mostly domesticated fruits. Thus, 31.8 percent of the Santa Teresita Kichwa plant food species are consumed raw. In the Santa Teresita Kichwa food system 17 plant food species are always cooked and 13 plant food species are usually cooked.



Figure 13. Kichwa Shaman Preparing a Medicinal Remedy

All Santa Teresita Kichwa animal foods, vegetables and store-bought items are cooked. The Kawymeno Waorani use no store-bought items and only a few tubers (manioc is always cooked while the sweet potatoes are sometimes cooked), but cook almost all of their animal-based foods. Even hunter-gatherers do not have powerful enough jaws or dental structure to rip animal flesh apart. Thus, Kawymeno Waorani and Santa Teresita Kichwa must cook most mammals, birds and reptiles to make them edible. Most of the 13 Kichwa fruits and vegetables that can be raw or cooked are usually raw with the exception of the 3 bananas.

Health benefits: Waorani do not mix foods in recipes. The Santa Teresita Kichwa tend to cook all the foods in recipes while the Kawymeno Waorani for the most part just cook the chicha fruit ingredient (morete, chonta, hungurahua, koromo and manioc) in recipes mixed with other foods. There are numerous consistencies in the Kawymeno Waorani food system in terms of preparation. One is that Kawymeno Waorani plant foods and animal foods are rarely mixed either in preparation or in consumption. Most Kawymeno Waorani plant foods are prepared and consumed separately from other plant and animal foods. The exception to this no-mixing rule is the making of these fermented chicha beverages. Kawymeno meat is always cooked by itself and eaten by itself. Kawymeno monkey and birds are also typically boiled separately and eaten alone. In Kawymeno the meat, fowl and fish are always eaten without any other additions such as sauces, spices and salt. Sometimes other foods such as plantains and manioc root are eaten alongside, but never mixed with the meat, bird and fish.

Most wild fruits in the Kawymeno Waorani hunter-gathering food system are also eaten without other foods, often one by one in the rain forest or house.

Effects of structured versus unstructured eating schedules. Just like the wild animals that surround the Kawymeno Waorani in their remote Yasuni rain forest environment, Kawymeno Waorani feeding times are based on opportunity and interest. The Kawymeno Waorani eat when they are hungry and there is food available. This major difference in food preparation between the hunter-gathering and farming study groups is so basic that it is easy to forget. The Kawymeno Waorani have no set meals while the Santa Teresita Kichwa eat at the same time every day. By meals I mean set times of the day in which the community is accustomed to eating food. There are no meal formalities or structures such as breakfast, lunch or dinner or pre-determined hours to eat in Kawymeno. Foods that need to be cooked are brought home, while many raw foods are eaten on the spot in the rain forest. Sometimes the Kawymeno Waorani eat in the morning and then other days they do not eat in the morning. Sometimes there is food at night and sometimes there is no food at night.

The Santa Teresita Kichwa have two large meals a day, once in the morning, a sort of breakfast, and a second meal at 3:00 p.m. or 4:00 p.m. The Santa Teresita Kichwa eat in extended family groups at the house. Since the main work activity is gardening and the community is surrounded by water on one side and rain forest on the other, most family members are usually at hand for meals. At their meals, the Santa Teresita Kichwa consume simultaneously a whole range and mixture of cooked foods.

The Kawymeno Waorani hunter-gatherers are constantly eating single-ingredient unprepared fruit foods throughout the day. Taking small doses of fruit phytochemicals throughout the day may have a different effect than consuming all the fruit phytochemical content simultaneously in two daily sittings as the Santa Teresita Kichwa do. It is not unreasonable to assume better digestion occurs if the human body is not overwhelmed with a large and diverse quantity of food given all at the same time. The Waorani plant snacking may also be a more efficient way to maximize phytochemical impact, and minimize chances of overdosing on these natural pharmaceuticals.

Medicinal Use of Food Species

In the Kawymeno Waorani food system, 10.7 percent of all plant food species also have some medicinal use attributed to them by the community. In the Santa Teresita Kichwa food system 26.9 percent of all plant food species are double classified by the Kichwa as medicinal. The Santa Teresita Kichwa use both native and imported domesticated food plants as medicinals. The Kawymeno Waorani medicinal use of food plants is restricted to wild food plants. Food plants are a small percentage of the thousands of local rain forest plants. However, the percentage of food plants used medicinally is much higher compared to the percentage of all rain forest plants used medicinally. This may be because the Kawymeno Waorani are more familiar, and in contact with food plant species than non-food plant species of the rain forest. It may also be because food plants are more likely to have beneficial medicinal qualities in humans than random plants in the rain forest. This dissertation makes the case that phytochemical

compounds in dietary intake have a greater tendency to be beneficial medicinally than other rain forest plants.

For plants with recognized dual food and medicinal use in both the Waorani and Kichwa group, the fruit of the plant was usually classified as "food" while the other parts of the plant such as the leaves, bark, roots and sap were used medicinally. The exceptions were plants specifically designated as solely medicinal by the Santa Teresita Kichwa, yet consumed regularly enough to be classified as food under the dissertation definition. In these Kichwa designated strictly medicinal plants, non-fruiting parts were used medicinally while the fruit from the plant was not eaten. The Waorani exception to the rule is the Wenta plant (*Urera baccifera),* as parts of the Wento fruit are used medicinally, but not eaten while the rest of the fruit is eaten.

Both groups use animal food parts less frequently for medicinal remedies such that only a few are present in the Kawymeno Waorani food system. The Kawymeno Waorani use peccary colon and Lemon Ants medicinally. Snake "fat" is used by the lowland Kichwa culture in general medicinally, but not in Santa Teresita. The lowland Kichwa also use the stones found in the Covina fish's brain medicinally.

The Kawymeno Waorani have a much lower percentage of food species with medicinal aspects than the Santa Teresita Kichwa mainly because the Kawymeno Waorani use very few medicinal plants to start with as they have very few diseases that require treatment. While this dissertation is focused on food and not medicinal discoveries, dissertation surveys have also observed that beyond

food plant species, the Kawymeno Waorani have very few medicinal plants in general compared to either the Santa Teresita Kichwa, or the westernizing Waorani entering the modern food system in the Protectorate. Davis and Yost (1983A) commented on the surprising lack of medicinal remedies in the Waorani population in the late 1970s and the large and varied amount of plant food species consumed.

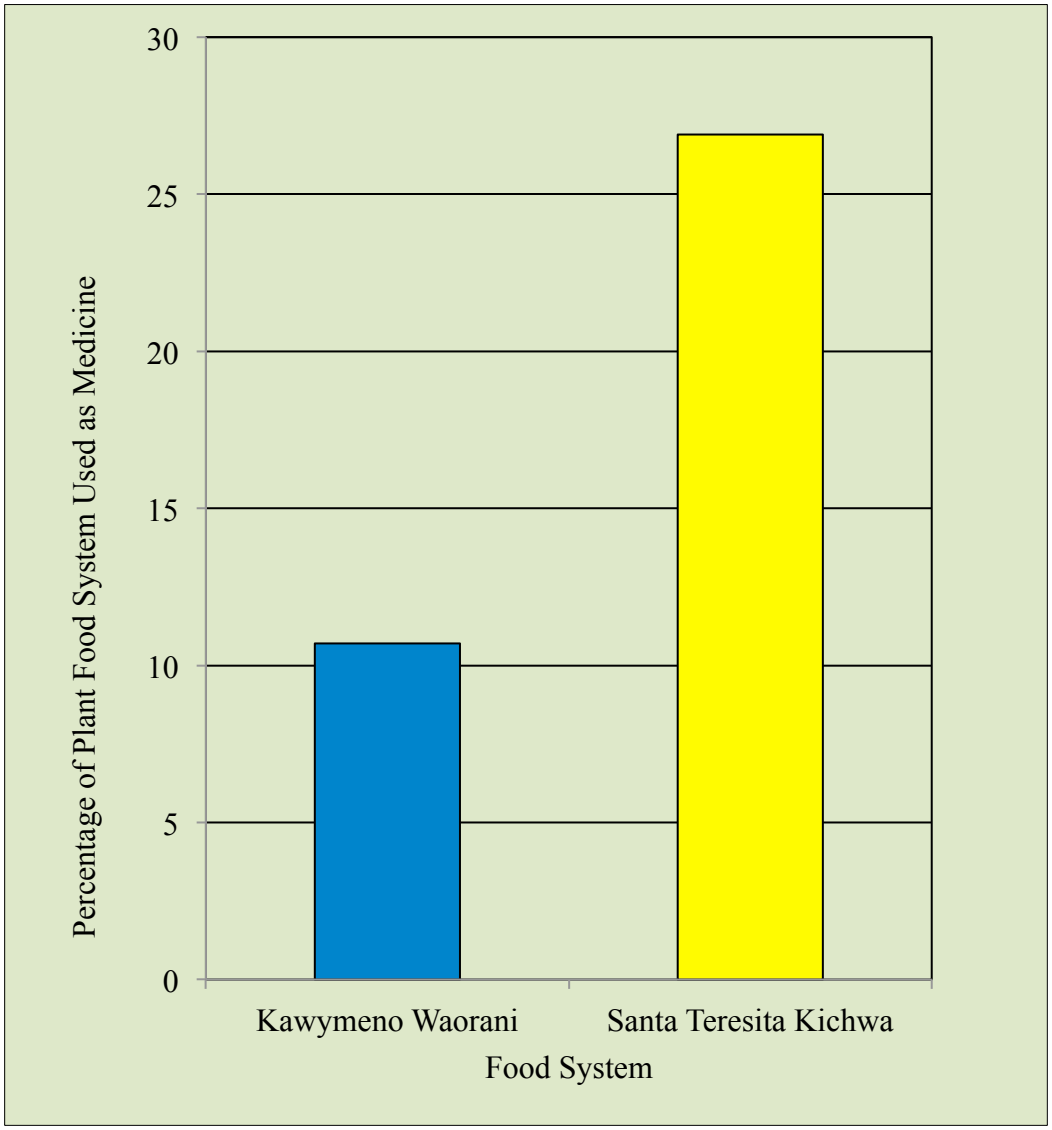


Figure 14. Percentage of Plant Food Species Recognized and Used as Medicine: Kawymeno Waorani vs. Santa Teresita Kichwa Food Systems. 2010

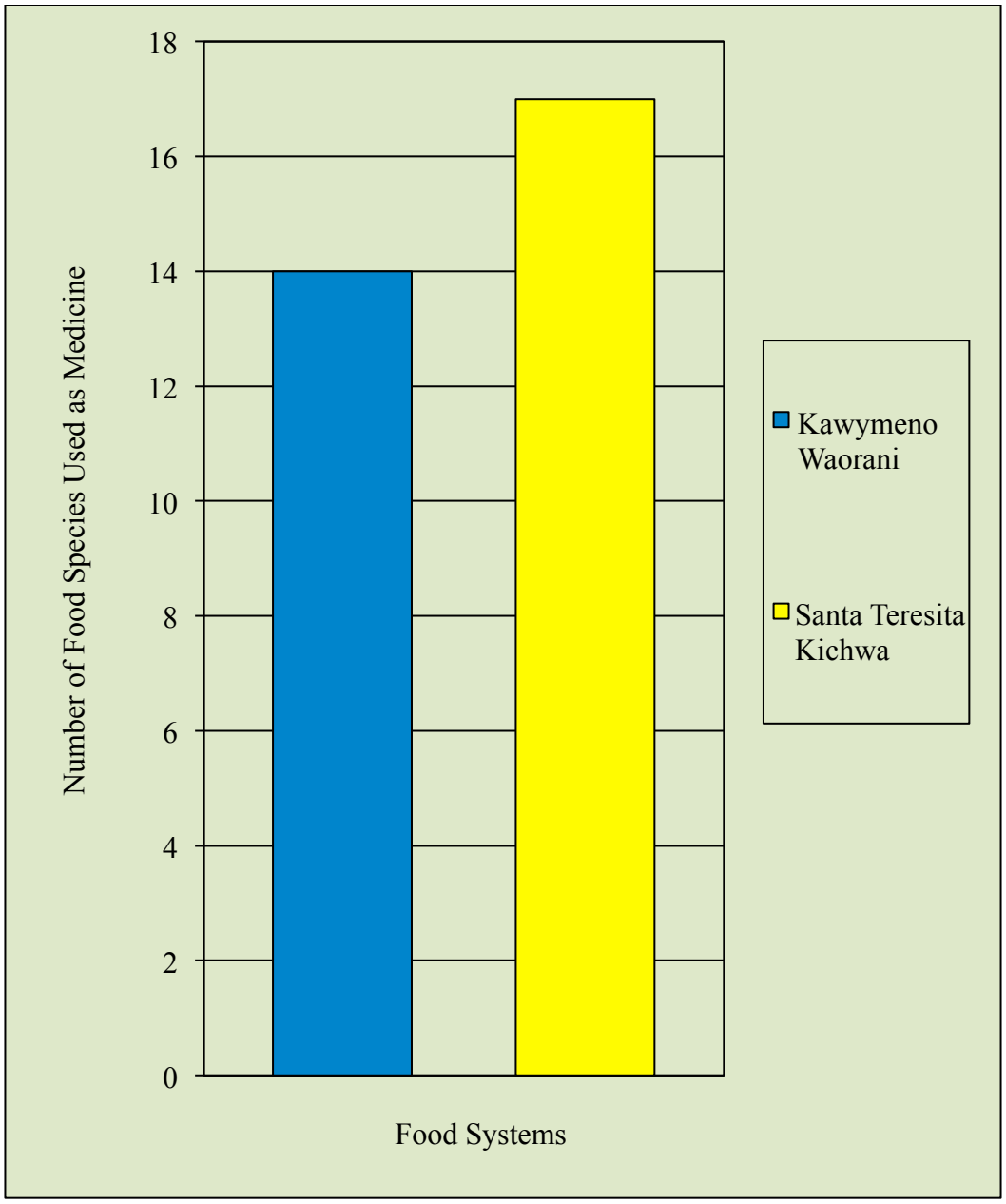


Figure 15. Number of Food Species Recognized and Used as Medicine: Kawymeno Waorani vs. Santa Teresita Kichwa Food Systems. 2010

This dissertation makes the case that the dietary intake of the Kawymeno Waorani is already medicinal in nature and is preventing diseases from reaching

the stage of requiring formal treatment. The Santa Teresita Kichwa preponderant use of both dietary and non-dietary medicinal plant species suggests a diet with lower beneficial medicinal qualities and more diseases than the Kawymeno Waorani that require intervention with curative medicines. As the next chapter shows, the Kawymeno Waorani have very few diseases either chronic or infectious. The entire Kawymeno Waorani diet is medicinal in nature in a way the Santa Teresita Kichwa diet is not due to the variety and quantity of wild rain forest medicinal phytochemicals consumed throughout the day. In sum, hunter-gatherer dietary phytochemical intake prevents diseases and thereby limits the need for formalized medicine, while agricultural diets do not provide adequate phytochemical preventative protection against disease, thus a formal large repertoire of medicinal remedies – such as the medicinal arsenal used by the Santa Teresita Kichwa and the lowland Kichwa – is required to compensate.

The Santa Teresita Kichwa define seven plants included in the dissertation's study food system list as "preventative medicines" rather than food. The dissertation defines food by regular intake, not the belief system surrounding the use of the ingested item. Again, the preponderant deliberate regular use of phytochemicals specifically designated as "medicinal plants" and the greater amount of disease in the Santa Teresita Kichwa community indicates that diet is not preventing disease in Santa Teresita although those diseases may have other causes or non-dietary factors.

This chapter was an overview of the differences between the study hunter-gathering and subsistence farming food systems and diet. The difference

phytochemically between the two food systems is profound. The hunter-gathering diet has a rich variety of wild phytochemicals, while the subsistence agriculture diet has a small variety of domesticated phytochemicals. The hunter-gatherer diet is part of the ecosystem of the rain forest, while farming has effectively cut off the agriculturalists from their surrounding ecosystem. Although both the Kawymeno hunter-gatherers and the Kichwa farmers co-exist in the same rain forest there is almost no dietary overlap and almost no foods in common. Food preparation differs greatly between the two groups, with the Waorani making very little alteration to the natural phytochemical content of their food. The Kichwa farmers alter the natural phytochemical content through preparation. The summary table lays out point by point the particular differences and similarities between the two food systems in detail, while the chapter has focused on some of the more interesting aspects that likely impact human health.

CHAPTER 8

FOOD SYSTEMS II: VEGETABLES - PART OF THE HUMAN EVOLUTIONARY DIET?

Kawymeno Waorani Reaction to Being Offered Vegetables

The following are passages from my field journal during my stay with the Kawymeno Waorani:

> *"Ima, my Waorani assistant who was born in the Protectorate, said to me as we were eating together one night, "Wao do not like vegetables, we only like fruit". The food with onions we had offered as a treat was unpalatable for Ima's family tonight. When we have cooked for curious Waorani they always leave the vegetables to one side. The kids we invited this week for some "dinner" (little Kai and Bainka last night) left the vegetables and ate everything else. When I mentioned the vegetables the boys asked me for some tomato sauce in an effort apparently to drown the flavor of the vegetables but tomato with sugar covered vegetables still proved unpalatable although they tried to eat them."* (Field Journal Entry, April 2010, Douglas London)

The Kawymeno Waorani express disgust when they see vegetables being consumed. Taxa fixed a salad for herself one afternoon. My Waorani assistant's wife, Way, when she saw her eating the salad said to Taxa that "seeing someone eating these plants made her want to vomit". Indeed, Way's son Gaba almost vomited when watching Taxa eat the salad and went to the bathroom. Disgust or

dislike has been our experience whenever we have offered vegetables to people in Kawymeno.

On the occasions we brought in vegetables and the Waorani were curious enough to try them, the Waorani tasted them, expressed disgust and unceremoniously spit all the vegetables out, even when mixed in with their favorite meats and foods. These non-fruiting vegetables included leafy greens such as lettuce, kale, cabbage and spinach; non-starchy roots such as carrots, onion and garlic; and stems such as celery, broccoli, and cauliflower. The Kawymeno Waorani appeared to be sensitive to the phytochemicals in the vegetables, which provide most of the flavor of vegetables. The Waorani have over 29 vocabulary words for the English word "bitter" and have a subtle and exquisite sensor system for plant phytochemicals, which is discussed later in the chapter. The Waorani rely almost exclusively on fruit rather than non-fruiting plant parts for the plant species component of their dietary needs, although there are many non-fruiting vegetation/vegetables available in the rain forest including leaves, stems, bark, roots and other vegetation that probably has adequate nutritional content, but may not be phytochemically appropriate.

Indeed, while reading literature on hunter-gatherers, one vaguely gets the idea that vegetables were part of a hunter-gatherer diet (Leaf and Webber 1987; Eaton et al 2000). It took me a while to realize that this was certainly not the case with the Kawymeno Waorani. Now, when one reads recent scholarly hunter-gatherer literature, authors are beginning to mention hunter-gatherers rarely eat non-fruiting vegetables aside from tubers (Carrera-Bastros, 2011).

Other than fruit, the Kawymeno Waorani ate no other parts of any plant routinely and no vegetables were consumed other than the few tubers mentioned above. Vegetables were probably never part of the Waorani diet, and hunter-gatherers in general throughout history probably have not eaten many vegetables, since most vegetables are mostly a product of agriculture and a recent introduction to the human diet. The vegetarian movement suggests vegetables are natural and part of the way humans used to live. Neither of these statements is true, dietary vegetables are not a natural part of humanity's dietary evolutionary history, nor are vegetables wild plants. Most commonly eaten vegetables and grains today are the product of ancient farming technology available to early subsistence agricultural societies used to modify wild species. Despite impressive developments in agricultural breeding over the last 12 millennia, 17 plant species chosen by early Neolithic farmers make up 90% of the world's food supply in the 21st century (Harlan, 1992).

Kichwa dietary intake of vegetables. The Santa Teresita Kichwa diet has a limited variety of vegetables that are very frequently used, consisting of 9 farmed vegetables, 1 store-bought vegetable. This dissertation observed all members of Santa Teresita Kichwa families expend at least 3 hours 4-5 days of the week caring for their gardens called "chakras", which are no more than 20-100 meters from most households. In addition, there is a fairly universal South American Kichwa custom of "mingas", in which the whole community gets together to help each other work on communal projects - often times communal gardening. The Santa Teresita Kichwa carefully care for these vegetables almost

every day. These gardened vegetables are consumed at every meal and are the base of the Santa Teresita Kichwa dietary intake.

While this separate and individual care of the Santa Teresita Kichwa assures their vegetables and fruit survive away from a rain forest system, this human care also alleviates these agricultural plants from any phytochemical responsibility to defend themselves.

Phytochemicals in Vegetables: Less Variety but More Toxic

Vegetable intake across food systems: chart and discussion. Several factors are probably at play in defining the phytochemical output of Santa Teresita Kichwa vegetables. First, domesticated vegetables, through extended generations of farming, may no longer have the ability to produce the variety of natural phytochemicals needed to survive against multiple threats found in a natural ecosystem. Second, even if some species of domesticated vegetables still have the innate ability to activate more vigorous and varied phytochemical production, Santa Teresita Kichwa human protection reduces any need for the plant to increase the variety phytochemical protection on its own. Third, as discussed above, through segregation from the surrounding ecosystem, these plants are cut off from the environmental stimulation needed to produce a large variety of phytochemicals to start with.

Ironically, the principal threat for the domesticated plants of the Santa Teresita Kichwa, and indeed all agricultural plants, is consumption by humans. This dissertation hypothesizes that domesticated plants use more potent anti-herbivore phytochemical toxins against humans than do wild plants. Ironically,

other non-human threats to agricultural plant survival have been reduced by Santa Teresita Kichwa and other human farmers, leaving gardened plants free to concentrate chemical effort against their main threat, humans, who inevitably destroy and eat the vegetables. While in reality humans protect and preserve whole species of plants through agriculture, a gardened individual plant only senses being picked and torn apart by human beings intent on eating it. Thus, Santa Teresita Kichwa farmed plants may produce toxins to protect themselves against their human benefactors, who represent the individual farmed plant's principal threat in the garden. Wild plants may have less energy to spare for production of anti-herbivore, anti-human phytochemicals with so many more pressing threats and enemies. Of course, any time a domesticated species becomes obviously poisonous with anti-herbivore phytochemicals, these plant food species are eliminated from agriculture, leaving only less toxic domesticated plant versions, which may quietly cause long-term health damage to humans. While many domesticated plants are bred to have a level of anti-herbivore phytochemicals that are not immediately or obviously poisonous, that does not mean that anti-herbivore toxins have been removed from these domesticated plants. Long-term consumption of any low level poison may have serious health consequences regardless of whether it is a natural phytochemical pesticide or a human made pesticide. Ames et al noted that plant foods in American supermarkets had much higher levels of natural phytochemical pesticides than human made synthetic pesticide residues by a magnitude of 10,000 times more

natural phytochemical pesticides to human-produced synthetic pesticides (Ames et al 1990a, Ames et al 1992).

The Kawymeno Waorani food system has no vegetables other than three species of starchy tubers – manioc *Manihot esculenta* and sweet potatoes (*Ipoemoea batata, Pachyrhizus angulatus)* – one wild grain/root, and wild peanuts (*Arachis sp.).* The main vegetable the Kawymeno Waorani consume is manioc, which is fermented specifically and consciously to get rid of the toxic phytochemicals that would otherwise make manioc inedible for humans. With so few vegetables in the Waorani diet, which in any case receive little human contact to stimulate anti-herbivore phytochemicals after they are planted, the Kawymeno Waorani would have low exposure to anti-herbivore phytochemical toxins found in vegetables. Dissertation thinking on the reduced anti-herbivore content of fruit, the mainstay of the Kawymeno Waorani diet, in relation to vegetables is later discussed.

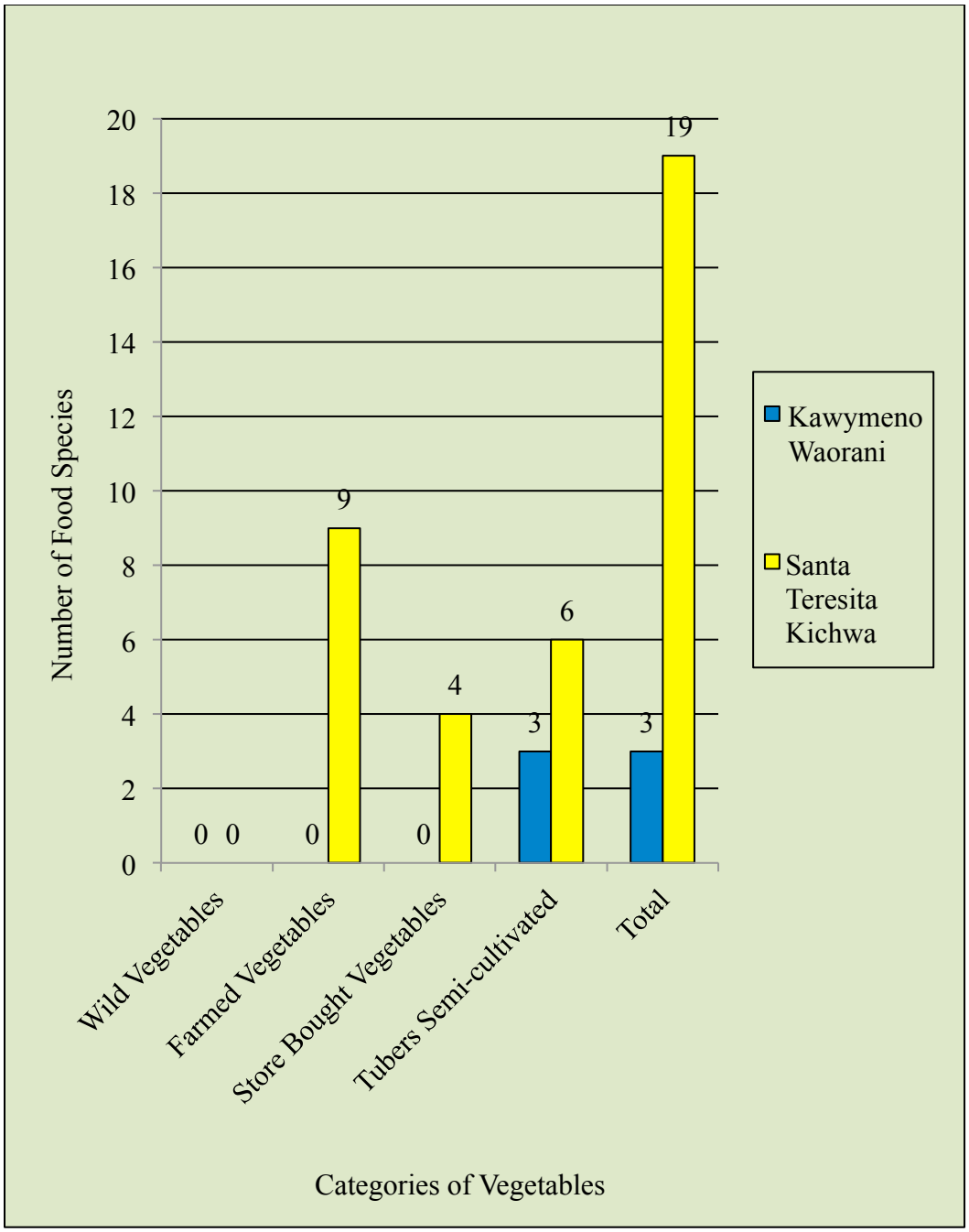


Figure 16. Vegetable Consumption Variety by Category: Kawymeno Waorani vs. Santa Teresita Kichwa Food Systems. 2010

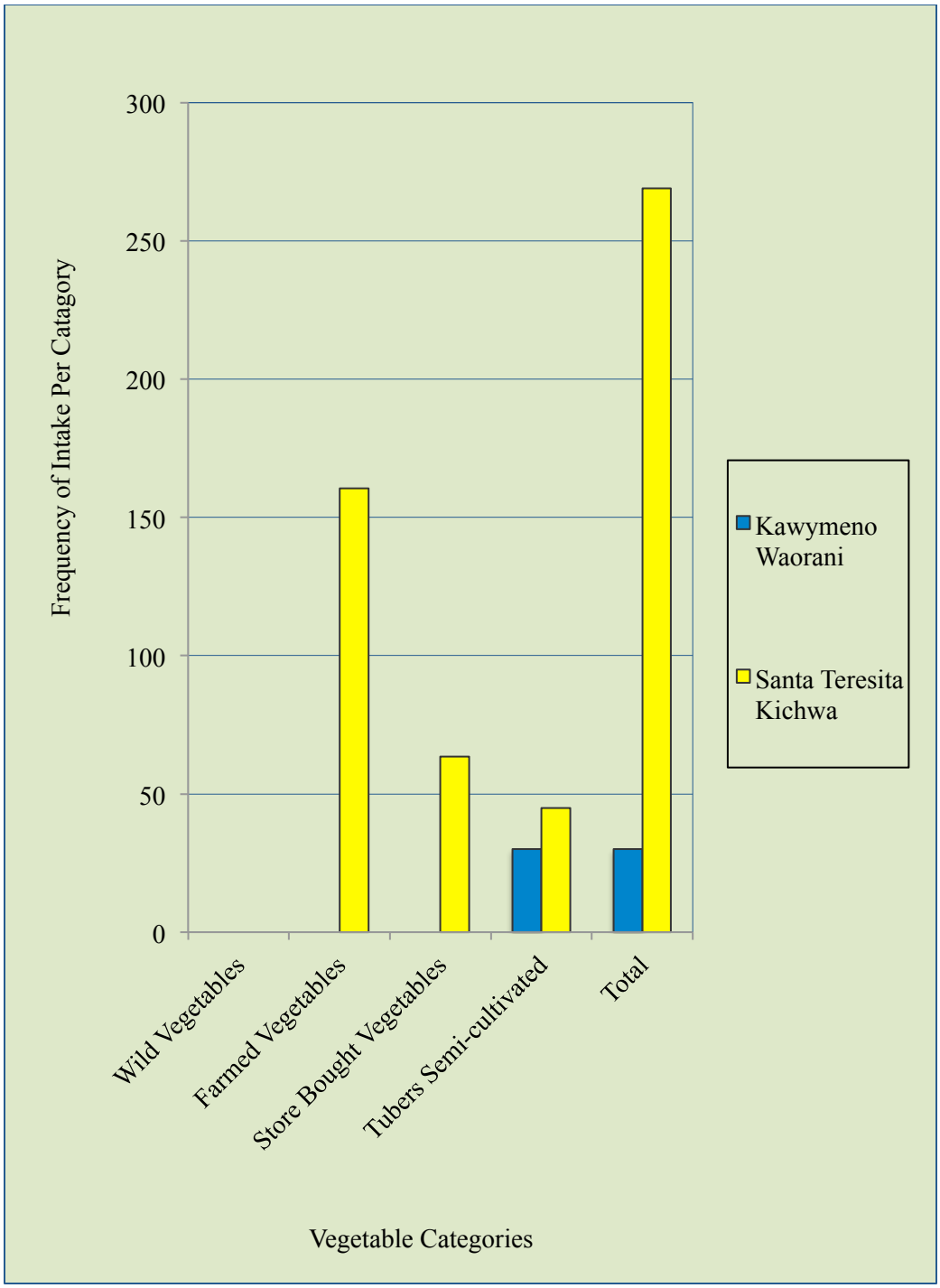


Figure 17. Average per Capita Dietary Intake of Vegetable Foods per Source: Kawymeno Waorani vs. Santa Teresita Kichwa. 2010

These Kawymeno Waorani tuberous vegetables are placed in semi-cultivated areas where trees are cut and left on the ground to provide sunlight, provide some soil nutrients and reduce competing plant growth. The tubers are then planted in the ground and left to fend for themselves. Open tuber spaces/gardens can be found up to 4 hour's walk from Kawymeno, perhaps so far away because of the tradition of having secret garden sources of food in case of enemy raids that might destroy nearby semi-cultivated areas. Bananas (*Musa sp.)* and chonta palms (*Bactris gasipaes)* are sometimes planted nearby these open spaces. The introduced fruit trees Daboka (*Solanum pectinatum),* and Dabamo *(Solanum sp.)* are planted nearer to the Kawymeno community.

The local teacher introduced sugar cane to the Kawymeno Waorani recently. In 2010, during the time all the data was gathered, sugar cane was not common in the diet. At the time of write-up in 2012 sugar cane use has increased in the Kawymeno Waorani and may become a more common food source in the years to come.

Ingestion of Whole Versus Parts of Plants: More Anti-Herbivore Phytochemicals?

In terms of plant food species, the Kawymeno Waorani ingest 80 species of the fruiting part of plants and no other non-fruiting parts of the plant (stems, leaves, roots, bark) are eaten with the exception of the 3 vegetables and 1 grain discussed, and the indirect consumption of hunting and fishing plant phytochemical poisons in their animal foods. On the other hand, Santa Teresita Kichwa regularly ingest all parts of many food species plants including seeds, leaves, bark, sap, vines and roots particularly in their vegetables and medicinal

plants. While eating whole animals may have great health benefits for hunter-gatherers, eating a whole plant may damage human health. The Kawymeno Waorani ingest the whole animal rather than just the meat as is the custom in the USA. In reality, meat represents only a small part of the nutritional (and it is argued phytochemical) diversity of the animal food. While eating the whole animal leads to a dietary intake of a wider variety of nutrients and phytochemicals, the opposite may be true when humans try to eat the whole plant. This is because plants are phytochemical factories whose leaves, stems, roots, bark, and sap have a much higher percentage of the body mass, compared to those stored in animal flesh, of potentially harmful phytochemical pesticides against all types of organisms, which are stored and released from particular parts of the plant, not the whole plant (Alborn 1997, Dare & Tumlinson, 1999; Das et al, 2012; Picchulla & Pott, 2003; Turlings, 2006; Wink 1988; Wink 2003; Wink 2009). In fact, non-nutritional natural plant phytochemicals make up 10% of the dry weight of many plants (Abelson, 1990).

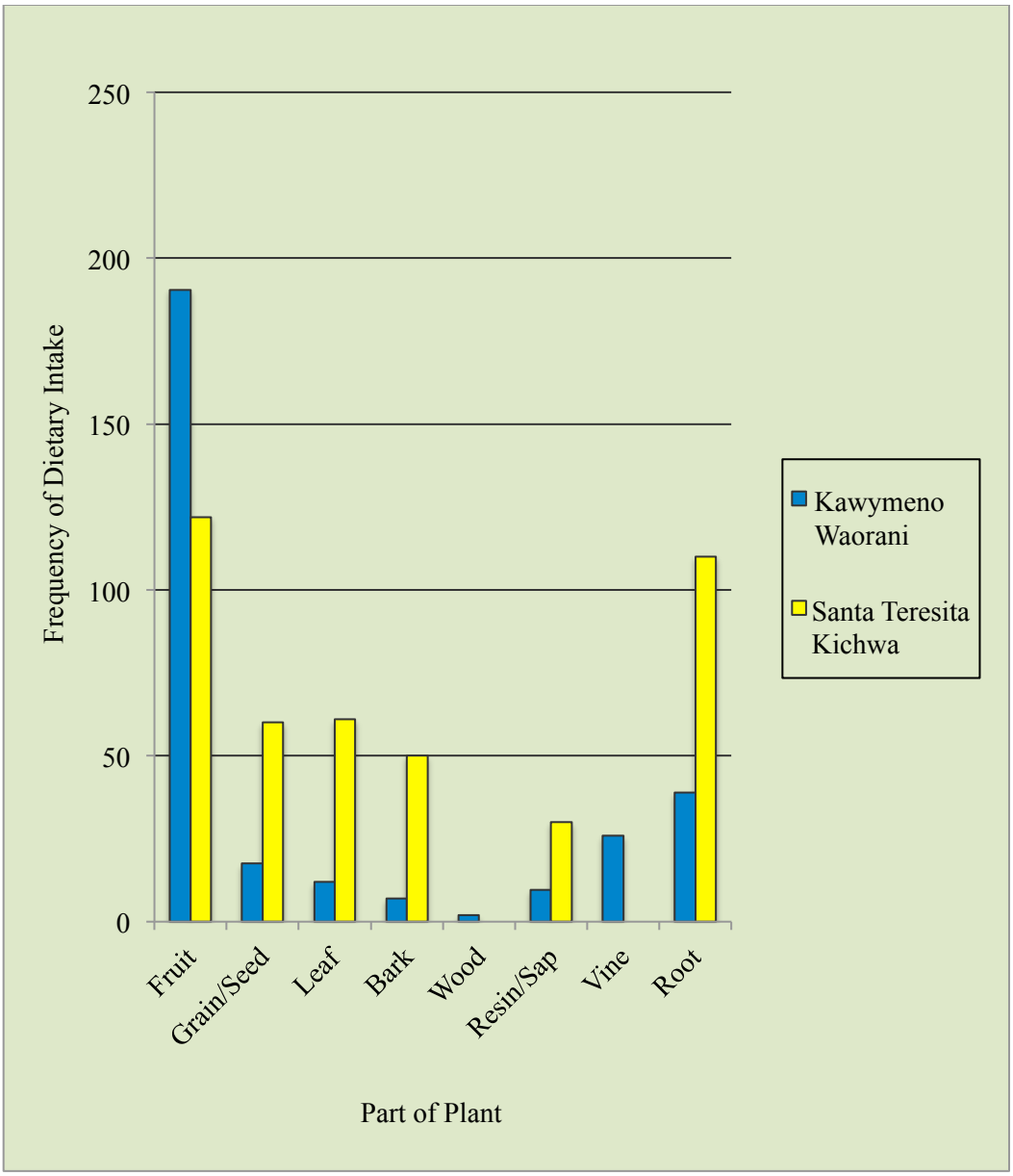


Figure 18. Average Frequency of Dietary Intake per Part of Plant Eaten per Individual in Community: Kawymeno Waorani vs. Santa Teresita Kichwa. 2010

Eating the whole plant may lead to ingestion of more toxic phytochemicals than restricting intake to just the fruiting part of a plant. A case can be made that the fruiting parts of plants are more likely to have a selection of phytochemicals

that benefit human health, while other parts of the plant have defensive phytochemicals that are more toxic (Alborn 1997, Dare & Tumlinson 1999, Das et al 2012, Picchulla & Pott 2003, Turlings 2006, Wink 1988, Wink 2003). Plant food from one part of the plant may be harmless, while another part of the same plant may be toxic for humans, particularly non-fruiting parts that the plant is not offering animals to eat. As is mentioned in the other chapter on Plant-Human Co-Evolution, the ingestion of fruit and fruiting parts, such as flower nectar, is generally a symbiotic action encouraged by the plant to aid in the reproductive strategy of the plant kingdom whose weakness and immobility requires the help of animals to fulfill functions plants cannot, such as seed dispersal. On the other hand, the ingestion or damage of plant roots, leaves, stems and trunks by humans is a predatory and parasitic relationship that in the process damages or kills the plant, often without allowing the plant to reach a size where it can reproduce. Hunter-gatherers throughout the world rarely ate plant parts outside of the fruit, except for a few tubers. The consumption of non-fruiting plant parts started with subsistence agriculture.

This dissertation argues that humans have not adapted through an evolutionary process to physiologically deal with some of the toxic phytochemicals found in leaves, roots, stems that make up non-fruiting vegetables. Non-fruiting vegetables are, in evolutionary time span terms, an almost brand new addition to the human diet. While vegetables undoubtedly have great nutritional value, and agricultural science over time has bred low toxin varieties of vegetables, this dissertation suggests vegetable consumption is

paradoxical in nature, nutritious but ultimately over the long-term also poisonous and may in some cases lead to chronic diseases. Thus, this is one reason why the Kawymeno Waorani today and pre-historic hunter-gatherers of the past did not eat many non-fruiting vegetables other than tubers, which like the poisonous cassava roots eaten by the Waorani were often processed using fermentation and other techniques to reduce toxins. For instance, the vast majority of potato species are poisonous to humans except some varieties bred to have a lower phytochemical toxin that permits human ingestion. Cabbage for instance has 49 known natural phytochemical pesticide poisons (Ames and Profet 1992).

In any case, a lack of dietary intake of vegetables and their constituent nutrients and phytochemicals has not had a negative effect on Kawymeno Waorani health and absence in the Waorani diet of anti-herbivore dietary toxins found in vegetables may play a role in the lack of chronic diseases in the Waorani population.

The general case against grains, which are also absent in the Kawymeno Waorani diet, as well as the diet of most hunter-gatherers throughout history, has been made by Loran Cordain (Cordain, 1999). The case against grains that cause Celiac disease and other chronic diseases, represent a precedent for this dissertation hypothesis, a widely accepted nutritious food that paradoxically causes chronic diseases. Both grains and non-fruiting vegetables, have higher anti-herbivore phytochemical toxin levels than fruits.

In sum: The dissertation makes the case that fruits, eaten historically in large quantities by hunter-gatherers who had access to them, usually have lower

levels of anti-herbivore toxins in their flesh than vegetables and may be safer than vegetables for modern populations to eat as well. Vegetables are largely absent in the Kawymeno Waorani diet, as well as the diet of most hunter-gatherers throughout history. This hypothesis requires much more research to become a dietary consideration for modern populations. However, while this dissertation hypothesis goes against the accepted modern standards of nutritional recommendations for vegetable intake, these nutritional recommendations often do not consider the non-nutritional aspects of foods very carefully.

The Phytochemical Difference Between Farmed and Wild Fruit.

Charts and discussion. In fruits, beneficial phytochemicals are a paradoxical and separate issue from toxic effects of plants in that variety and source of phytochemicals are at the heart of the issue not anti-herbivore phytochemicals. While wild fruit have a larger quantity and more varied phytochemicals than domesticated fruit, most fruit, both domesticated and wild fruit, have lower levels of anti-herbivore phytochemicals than non-fruiting parts of plants. Unlike other parts of the plant, fruits do not usually have the ability to mount a phytochemical response to a threat in the way the rest of the plant parts can, although they do have a certain amount of phytochemicals, including toxins (Das, et al., 2012; Turlings, et al., 2006). However, in nature there are always exceptions, such as wild fruits designed by the plant for particular animals in a mutualistic relationship with the plant that benefits the plant such as seed spreading and pollination. Specialized fruit intended for only particular animals

may be is poisonous to other animal such as humans who have not co-evolved chemically with the particular plant offering the fruit.

A revolving set of wild fruits is eaten throughout every season of the year in Kawymeno, reducing intake of any one phytochemical and maximizing variety. Much of Kawymeno hunter-gatherer ingestion, particularly of wild fruits, takes place in the rain forest, as they are hunting or gathering or just trekking through the forest, although fruit that needs to be cooked is brought back to Kawymeno.

Almost all the food species of the Kawymeno Waorani are rain forest fruits providing a strong phytochemical chemical lifeline to the natural rain forest ecosystem. The Kawymeno Waorani rely on 75 wild rain forest fruit food species while there are 5 Kawymeno Waorani fruits that are domesticated and often planted in primary rain forest where they interact chemically with the wild ecosystem.

On the other hand, the Santa Teresita Kichwa and modern humanity have begun to cut the fruit phytochemical lifeline to their own planet and the phytochemicals that make up part of the natural cycle of life. The Santa Teresita Kichwa regularly eat only two wild fruits (*Bactris gasipaes* and *Oenocarpus bataua)* routinely collected in season from the rain forest. For the Santa Teresita Kichwa, fruit consumption is not the top form of plant phytochemical intake - vegetable consumption is.

Domesticated plants may have the tendency to focus on production of phytochemicals specifically to manipulate humans – the species most critical to their survival. It is well known that plants do not need generations of natural

selection to develop human-manipulating chemicals; they already have the capacity and it is more a matter of "turning on the spigot" and turning off other spigots of chemical production. Quick and adaptable modification of phytochemical output is a fundamental survival strategy of all plants. For instance, it is already known that plants produce scents that drive mammals to assist in behaviors such as pollination (Johnson, 2011). Domesticated plants may expend a lot of energy creating phytochemicals for scents and flavors to stimulate the appetite and motivate humans to eat and disperse their seeds, which is the domesticated plant equivalent of the wild garlicky *Mansoa alliacea* attracting peccary with its scent and taste.

Seasonality of Dietary Plant Intake

The natural biochemically-triggered rhythms of the surrounding ecosystem such as fruiting seasons are an integral part of the Kawymeno Waorani existence, but a less significant aspect of the Santa Teresita Kichwa existence. In essence, the Kawymeno Waorani diet is truly seasonal while the Santa Teresita Kichwa diet is less cyclical because their farming system is largely divorced from many rain forest biochemical cycles and seasonal changes. At any time during the year, some of the 75 native seasonal food fruits of the Kawymeno Waorani are in season. Fruiting seasons are intricate and varied with some fruit trees cycling only once every few years, such as the popular Waorani fruit Opoka (*Micropholis venulosa)* that only bear fruit every two years, while other Waorani fruit trees such as Tepenka (*Theobroma subincanum)* bear fruit multiple times a year.

For the Santa Teresita Kichwa, dietary intake of vegetable, animal, and store-bought foods remains fairly constant and consistent during the year. However, Santa Teresita Kichwa domesticated fruit has some seasonally variation. All 13 Santa Teresita Kichwa food system vegetables and 4 farmed grains provide food periodically throughout the year. The 4 store-bought vegetables and 4 store-bought grains are also available most of the year.



Figure 19. Preparing Seasonal Fruit-based Chicha Drink with the Waorani

There are 22 imported domesticated fruit trees and 2 wild fruits in the Santa Teresita Kichwa food system. Seven of these domesticated trees are seasonal and bear fruit only once a year for a few weeks either between November-December or between May-June. These two wild fruit trees have longer fruiting seasons but Santa Teresita Kichwa trips in the rain forest are infrequent. The Santa Teresita Kichwa have 15 all-season domesticated fruit species that have a certain amount of fruit periodically throughout the year with

no set season, although according to interviews with Santa Teresita Kichwa, for many months of the year fruit from these is scarce. Many of these imported domesticated fruit trees do not do well in the rain forest environment. Grapefruit has been one of the more successful citrus trees while orange trees are one of the least productive.

The imported domesticated Santa Teresita Kichwa fruit trees are not a full-fledged part of the native rain forest's intricate biochemical web, and do not have the diverse phytochemical portfolio of the wild fruit trees in the Kawymeno Waorani food system. Santa Teresita Kichwa domesticated plants, while living next to the rain forest, do not necessarily participate in the rain forest ecosystem. Most native rain forest ecosystem organisms – plants, animals, parasites and microbes alike – are regarded as pests by Santa Teresita Kichwa farmers and are deliberately destroyed and kept away. This human-created divorce between garden and rain forest effectively prevents rain forest organisms from providing much phytochemical stimulation to the imported garden plants. The rain forest is cleared around the Santa Teresita Kichwa domestic fruit trees to allow enough sunlight for them to grow and to keep competing plants away. To let in the necessary sunlight and to protect the Santa Teresita Kichwa fruit trees, they are planted and cared for by humans in a sunny open field instead of a dark, crowded rain forest full of animals and plants that might stimulate protective phytochemical production. Aside from human shielding from potential phytochemical stimulants, these Santa Teresita Kichwa domesticated plants simply do not have the capacity to produce a great variety of phytochemicals.

Cultivated plants have much lower concentrations of natural phytochemicals than their wild counterparts (Ames et al 1990b). High phytochemical content, which includes biochemicals toxic to humans, has been indiscriminately bred out of domesticated plants regardless of any potential preventive health value. As mentioned above, both domesticated and wild fruit have lower levels of phytochemicals than domesticated and wild vegetables although breeding has reduced the anti-herbivore content of domesticated vegetables (Alborn, 1997; Dare & Tumlinson, 1999; Das et al, 2012; Picchulla & Pott, 2003; Turlings, 2006; Wink, 1988; Wink, 2003; Wink 2009). The wild versions of most domesticated plants are well known to have much higher and more varied phytochemical production ability (Moerman, 1999).

As noted in other chapters, all plant foods including regular table foods in the Western diet are double-edged swords containing plant defense chemicals designed to protect the plants. If taken long enough and consistently enough, these chemicals may eventually overwhelm the human ability to detoxify. Throughout evolutionary history humans have adapted to a seasonal food system rather than a constant bombardment from a handful of domesticated plants with very different phytochemical contents than their wild versions. When plant foods are eaten seasonally humans are not taking in the same phytochemicals all the time like in an agricultural diet, which can reach toxic levels of a particular phytochemical through monotonous continuous dietary intake. The Santa Teresita Kichwa, for example, are exposed to toxic phytochemicals present in their 12 non-seasonal vegetables and grains and 17 non-seasonal fruit trees (15

domesticated and 2 wild) for the entire year with no chance to allow the body to properly recover from absorption of ongoing biochemical waves of the same potential toxins. Conversely, seasonal fruit consumption assures that the Kawymeno Waorani rarely consume toxic amounts of specific phytochemicals from specific plants. Kawymeno Waorani are only exposed briefly during the revolving fruiting season to any particular toxic phytochemical properties of any given single plant species.

Chicha: seasonal Waorani food and fixed Kichwa staple food.

Seasonality is at the core of the Kawymeno Waorani food system and even their most staple plant foods, such as manioc *(Manihot esculenta)* are still only part of a changing seasonal recipe. Chicha is the name used by the Lowland Kichwa for the staple manioc root *(Manihot esculenta)* beverage consumed daily by the Santa Teresita Kichwa. The Kawymeno Waorani have adopted the name "chicha" to delineate a group of fermented beverages they consume daily. The differences in the "chichas" of these two food systems is that the Kawymeno Waorani chicha changes ingredients seasonally, while the Santa Teresita Kichwa chicha ingredients do not change seasonally. While manioc roots are now seasonally present in Kawymeno Waorani chicha, there is evidence to suggest that manioc is a relatively recent introduction to the Waorani diet by the Lowland Kichwa and previously Waorani beverages did not utilize any manioc (Rival, 2002). Manioc never had the chance to enter the lore of Waorani rain forest beliefs. In fact, manioc is the only plant in the entire Kawymeno Waorani food system that has no rain forest spirit attached to it in Waorani culture, suggesting recent introduction

(Rival, 2002). To better understand the nature of chicha, which is a fermented beverage, the process of making chonta palm fruit chicha is described below.

Making seasonal chonta chicha. Early in our stay in Kawymeno, my wife and I learned to make a fermented chonta palm (*Bactris gasipaes)* fruit chicha drink by using our own saliva combined with the saliva from our Kawymeno Waorani friends. I was told to chew the chonta palm fruit for about five minutes in my mouth until it turned from fruit flesh paste into a more liquid form due to my saliva interacting with the fruit. I then spit the masticated chonta fruit back into the communal pot, along with all the microbes in my mouth, which evidently do the work of fermenting the drink. Other peeled and mashed chonta fruit were added directly to the pot along with the chonta we chewed and spit into the pot. The whole mixture was heated and then cooled completely and stored for later use. If the chonta mix is reheated, it spoils, presumably because all our donated mouth microbes are destroyed, thereby stopping the fermenting process. The beverage is consumed rapidly as after a week the mixture ferments to the point of becoming an alcoholic beverage. Kai, the Kawymeno Waorani chief, prohibits the use of alcohol in Kawymeno. The Waorani historically did not consume alcoholic beverages.

The seasonal change of Kawymeno Waorani chicha beverage recipes. Unlike the standardized chicha recipe of the Santa Teresita Kichwa with manioc and plantains, the Kawymeno Waorani vary their chicha recipe seasonally. The Santa Teresita Kichwa drink a manioc based recipe of chicha everyday of the year, all of their lives.

The mixing of ingredients in chicha is the exception to the rule that the Kawymeno Waorani do not mix foods in recipes. The chicha mixtures may have been introduced recently to the Kawymeno Waorani with the introduction of semi-cultivated manioc and plantain bananas. The Kawymeno Waorani consume chicha beverages 6 to 7 times a day. Wild peanuts (*Arachis sp.)* called Koromo by the Waorani, are available year round and are often added to the chicha recipes mentioned.

Chonta palm (*Bactris gasipaes)* fruit chicha is made between the months of November and March. The chonta is fermented for four days before being served as a beverage. Chonta is the single ingredient in this Kawymeno Waorani beverage 20 to 25 % of the time. The other 70 to 75 % of the time cooked and mashed plantain bananas are added to the chonta chicha just before it is drunk. Chonta chicha overlaps morete (*Mauritia flexuosa)* chicha in November and December as morete is going out of fruiting season and chonta is coming into fruiting season. Manioc (*Manihot esculenta)* is used by Kawymeno Waorani as the sole ingredient of chicha only from the month of January to half-way through February and again during part of July between the hungurahua fruit and morete fruit seasons. Even during these months, chonta chicha is made half the time and manioc chicha the other half of the time.

Hungurahua fruit (*Jessenia bataua)* is used to make fermented chicha from February through June. Hungurahua fruit is used alone 25 % of the time to make the chicha during these months. The other 75 % of the time the chicha is made in the ratio of 90 % hungurahua to 10 % manioc root. Hungurahua is fermented

separately for 5 to 6 days and then manioc is added on the 6th day. (During the July gap month, manioc is used, as mentioned above).

Morete fruit (*Mauritia flexuosa)* is used to make chicha during the months of August through December. Morete chicha overlaps with the production of chonta chicha in November and December, as one fruiting season ends and the next begins. Morete is used alone to make Chicha 20 % of the time during these months. The other 80 % of the time, between 25 and 30 % of the chicha is made with manioc added to the morete chicha - a roughly 1:4 manioc to morete ratio. Manioc is fermented for four days before being added to the boiled morete fruit.

As the above examples illustrates, even the most staple-like food in the Kawymeno Waorani diet still changes seasonally. Although the Kawymeno Waorani could easily just make manioc chicha year-round, as surrounding indigenous groups do, they choose not to. It is important not to lose site of the fact that the reason manioc is fermented in the first place is because it has such a high level of toxic phytochemicals that fermentation is required to reduce the toxicity level. Continuous consumption of manioc root all year long may still produce toxic phytochemical effects on the human body.

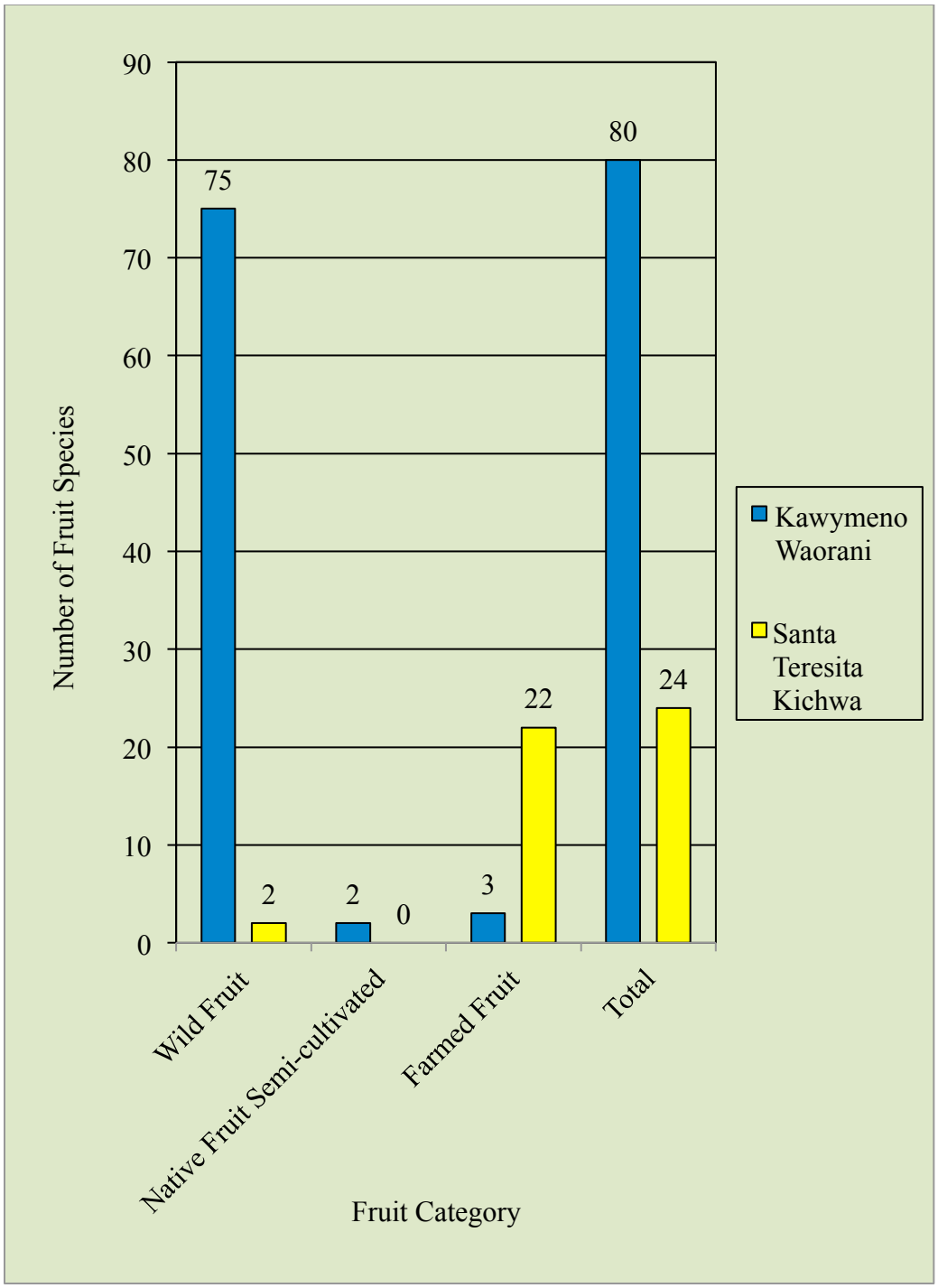


Figure 20. Number of Fruit Species Consumed According to Source: Kawymeno Waorani vs. Santa Teresita Kichwa. 2010



Figure 21. Butchering a White-Lipped Peccary *(Tayassu Pecari)*

The Santa Teresita Kichwa do cultivate a number of domesticated fruits, including oranges, with some difficulty since these fruit are not adapted to the rain forest. The Santa Teresita Kichwa have had better luck with grapefruit, which seems to do very well in this region of the Amazon and may have more active plant defense chemicals. Grapefruit appears on the label of many American pharmaceutical prescription bottles as to be avoided with medication perhaps because of the higher natural phytochemical pharmacological content and potential for interaction. The Santa Teresita Kichwa food system has 24 fruits

species, 22 of which are imported domesticated fruits and 2 wild native species. Unlike the Kawymeno Waorani, Santa Teresita Kichwa fruits, like their vegetables, are planted in cultivated gardens segregated from the rain forest. The rain forest is cleared around the Santa Teresita Kichwa domestic fruit trees to allow enough sunlight for them to grow and keep competing plants away. Is there a way of still using agriculture that might allow the Santa Teresita Kichwa to better connect to the diverse rain forest phytochemical resources so close to them? The dissertation conclusion offers some thoughts on this matter.

Summing up the last few sections, there are phytochemical reasons why health may decline in the Santa Teresita Kichwa population compared to the Kawymeno Waorani population. Domesticated fruits of the Santa Teresita Kichwa are less phytochemically diverse than wild fruits with a lower quantity of more monotonous phytochemicals. In contrast, wild fruits of the Kawymeno Waorani are linked to the revolving phytochemical cycles of the rain forest and whose phytochemicals are much more varied and abundant in nature. The vegetables the Santa Teresita Kichwa principally consume may be more toxic than the fruits the Kawymeno Waorani almost exclusively consume. All domesticated plants such as those the Santa Teresita Kichwa consume may produce more anti-herbivore (specifically anti-human) phytochemicals because domesticated plants, frequently handled by humans, are capable of and may maximize anti-herbivore chemicals due to constant contact with humans.

CHAPTER 9

FOOD SYSTEMS III: ANIMAL FOODS OF THE KAWYMENO WAORANI AND SANTA TERESITA KICHWA

Variety of Wild Versus Domesticated Animal Foods Species

In this chapter, it is argued that animal foods are a significant source of processed phytochemicals coming from the plant foods these animals eat. In addition, animals produce their own phytochemical-like compounds. Thus, considering animal food dietary intake, as well as plant dietary intake, is vital to get a complete phytochemical picture of these two study food systems.

While there is more parity in terms of wild animal dietary intake in terms of the number of species consumed across the Kawymeno Waorani hunter-gatherer food system and the Santa Teresita Kichwa farming food system, there are significant differences in the quantity and frequency of consumption of these species. The Kawymeno Waorani food system consists of 42 wild animal food species in total, and no domesticated animals. These animal food species include 16 mammals, 8 birds, 3 reptiles, 13 fish and 2 insects. In addition, no domesticated animal products, such as milk or eggs, are consumed. The Kawymeno Waorani consume more mammal species than the Kichwa (16 Wao mammal food species, 9 Kichwa food species), and more importantly in much greater quantity. Mammal consumption for the Santa Teresita Kichwa is a sporadic thing. The four of the top Kawymeno Waorani staple foods are mammals; two monkeys (*Lagothrix lagotricha, Ateles belzebeth)* and two peccary *(Pecari Tajacu, Tayassu Pecari).*

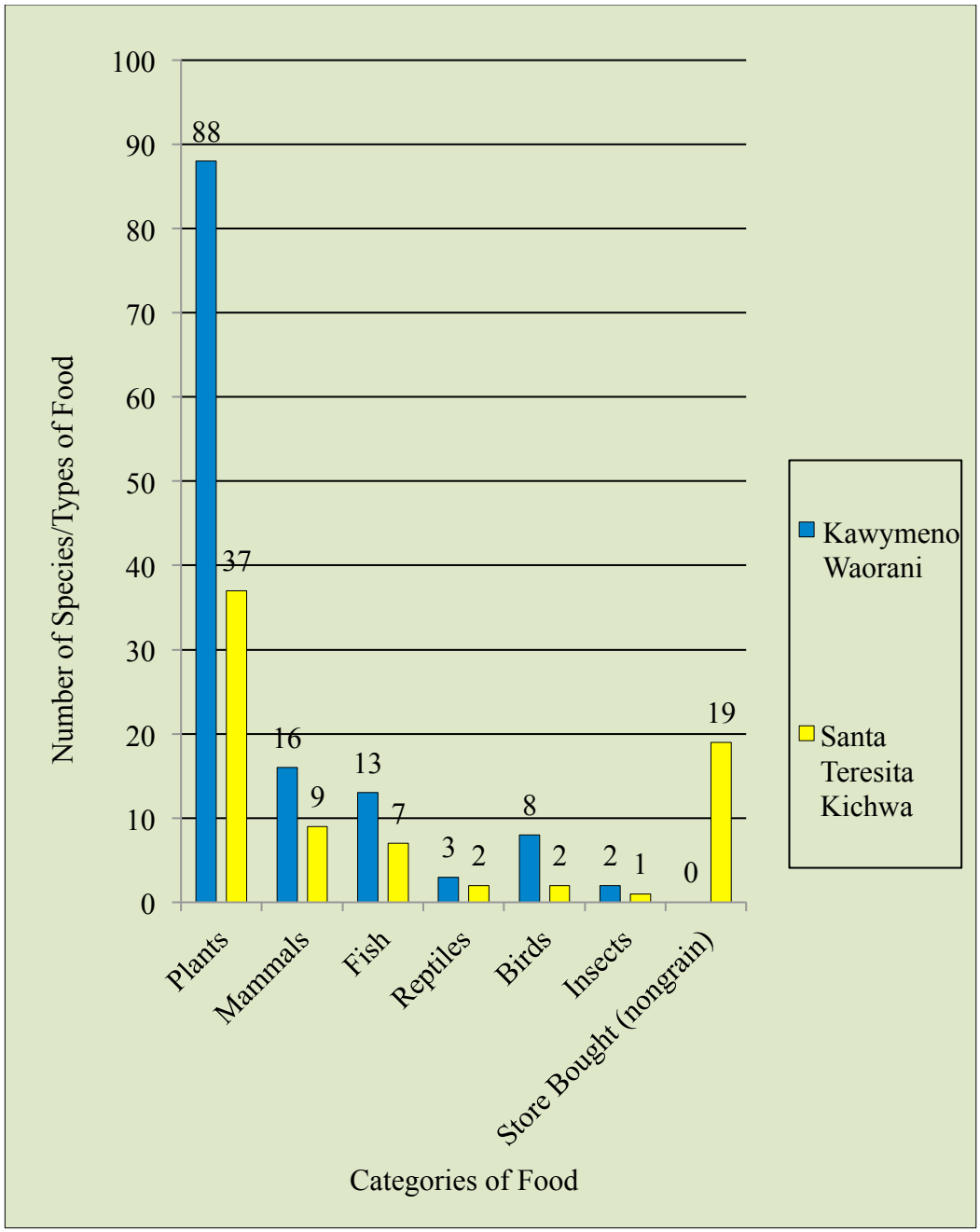


Figure 22. Total Food Species Consumed per Food Category: Kawymeno Waorani vs. Santa Teresita Kichwa Food Systems. 2010

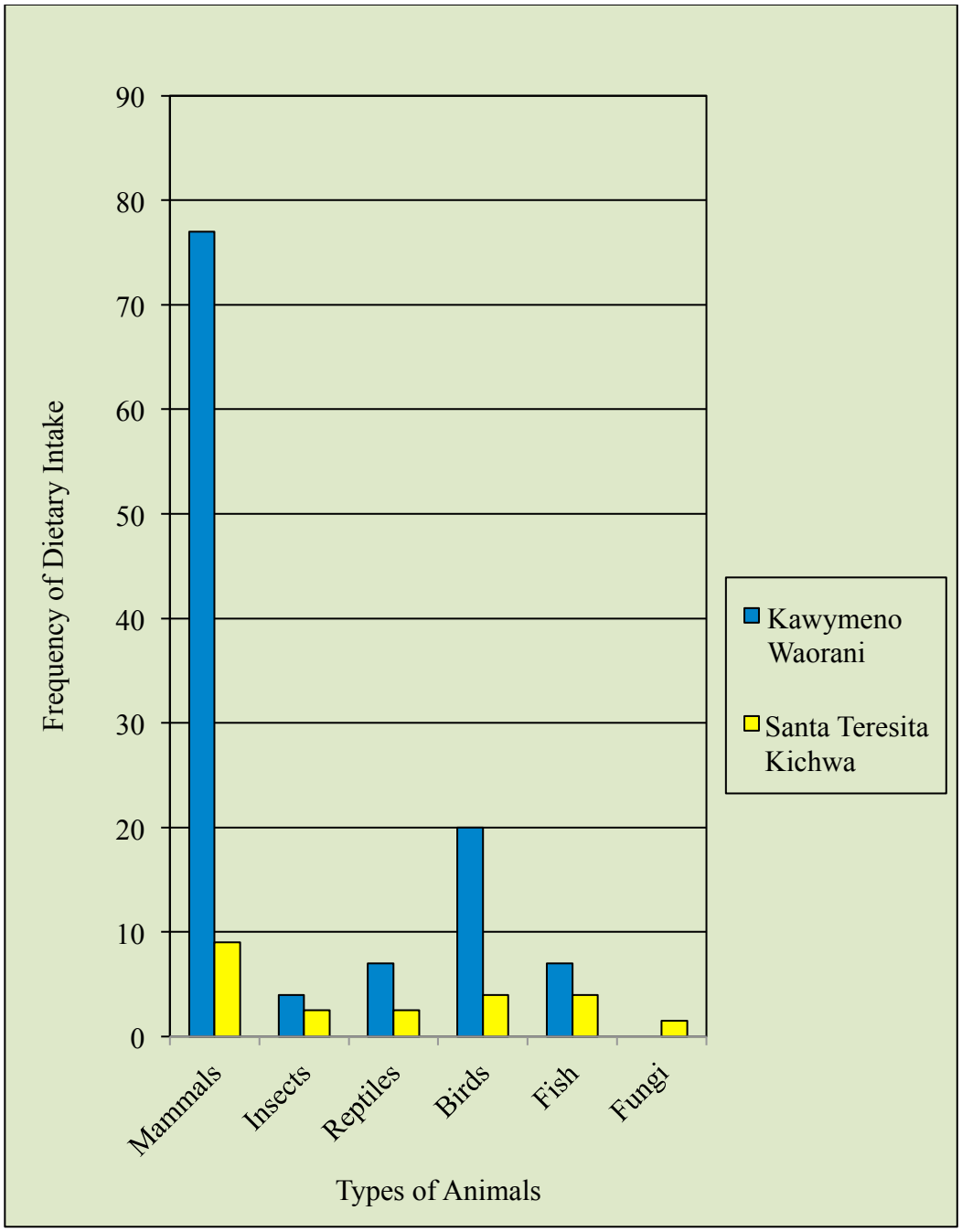


Figure 23. Non-plant Frequency of Dietary Intake: Kawymeno Waorani vs. Santa Teresita Kichwa. 2010

The Santa Teresita Kichwa food system has 20 animal species, less than half the total animals in the Kawymeno Waorani food system, of which 4 are domesticated animals and 16 are wild animals. Santa Teresita Kichwa animal food species include 6 mammals (4 of which are domestic farm animals), 2 reptiles, and 7 fish species. In the dissertation cataloging system, the two Santa Teresita Kichwa farmed animal products, chicken eggs and milk, are put with the respective food animal species, chickens and cows.



Figure 24. Returning from Successful Kawymeno Waorani Spearing Hunt for Peccary

By USDA standards, and accepted norms for protein ingestion, Kawymeno Waorani red meat intake is excessive, but this preponderant mammal consumption does not negatively affect their health. All of the 6 wild mammals in Santa Teresita Kichwa food system are hunted sporadically and close to the community. On the other hand, both Kawymeno Waorani men and women have

been recorded in this dissertation study eating from 1 to 1.5 pounds of peccary and monkey meat on many days of the week, along with plentiful birds and fish. The Santa Teresita Kichwa eat smaller mammals, birds and reptiles 3 times a week on average, in much lesser quantities, but the Santa Teresita Kichwa children also eat free-range eggs daily while adults eat eggs only a few times a week. The Santa Teresita Kichwa hunt large mammals such as peccary and large monkeys only a few times a year since they have to travel far from their community, while peccary is a staple for the Kawymeno Waorani. Typically, peccary meat is sold rather than eaten by the Santa Teresita Kichwa community.



Figure 25. Author participated in many Waorani Peccary Hunting Expeditions

Insects and fungi are not addressed in the rest of the chapter so these food groups are mentioned here briefly. Insects are seldom eaten neither by the Kawymeno Waorani nor the Santa Teresita Kichwa groups, and make up only a

small amount of the dietary intake for either group. Fungi are eaten by Santa Teresita Kichwa and mixed in foods containing animals, but the Kawymeno Waorani do not eat fungi, although in the past Waorani shamans used one type of fungi as a hallucinogen for ceremonies. The Santa Teresita Kichwa eat 3 species of fungi, which they call cachi cayamba, monda cayamba and shigra cayamba. The Kawymeno Waorani eats only 2 species of insects; an undetermined *Atta genus* ant and the Lemon Ants described earlier *(Myrmelachista schumanni).* The Santa Teresita Kichwa eat 2 species of insects, principally a flying ant which dies in great numbers for a couple days a year *(Undetermined Atta genus).* The Santa Teresita Kichwa only occasionally eat the grubs (*Rhynchophorus palmarum*) that are so favored by other Lowland Kichwa groups.

Cooking preparation and combining animal and plant foods: downgrading phytochemical content. Preparation of animal foods differs across food systems as well, the phytochemical significance of which is discussed later in this chapter. Many phytochemicals, and certainly nutrients, are distributed in all parts of the animal body. The Santa Teresita Kichwa concentrate on consumption of the meat and certain body organs of animals and do not eat the entire animal. The Kawymeno Waorani eat the whole animal, including the skin, feathers, eyeballs, brain, other head parts, blood and bones. For instance, with a peccary consumption only the colon and hooves are left behind while the fat is especially enjoyed. With monkeys, the Kawymeno Waorani eat the entire monkey including the skin. The Kawymeno Waorani do not eat the “rabo” (tail) because they believe that if they eat the tail, the monkey will not fall from the tree during

the next hunting expedition. Monkey meat is boiled first and any remaining meat is smoked to preserve it. The spinal column, ribs and brain of the monkey are eaten first. The Kawymeno Waorani also eat the feathers of birds they hunt. Kawymeno Waorani infants are introduced to meat through fat and bone marrow consumption at 6 months of age and other parts of the animal as their teeth develop.

Most of the Kawymeno Waorani mammal, bird and fish food is cooked over a fire or boiled and if preserved, it is smoked. Smoking allows the mammal food to last about 15 days, while portions can be eaten and the meat re-smoked.

The weight of the principal food mammals is about 100 pounds for adult White-Lipped Peccaries, and around 70 pounds for Collared Peccaries. While these peccaries look quite similar in many respects, the color of the meat is completely different; the Collared Peccary has lighter-colored meat and the White-Lipped Peccary has darker-colored meat. Fully-grown Woolly Monkeys and Spider Monkeys weigh between 20 and 35 pounds.

The Santa Teresita Kichwa mix animals with vegetables in recipes, altering the phytochemical content of both. On the other hand, the Kawymeno Waorani eat their animal food plain and alone. Santa Teresita Kichwa sometimes fry their food in lard, a cooking method that is more likely to alter phytochemical content. Animal food flavor is influenced by animal dietary phytochemical plant intake as is demonstrated later in this chapter. The Santa Teresita Kichwa add salt, flavorings, and spices such as chili from the garden, effectively removing the taste acquired from natural phytochemicals consumed by the animal.

Seasonality in Hunter-Gatherer Food Systems: Chart and Discussion

The Kawymeno Waorani eat particular plant and animal foods in cycles over the calendar year. Both animal and plant seasonal consumption are at least partially phytochemically driven as is elaborated in this section. Prior to the advent of agriculture and the habit of adding spices, salt and sauces to plain whole foods, most of the smell and flavor of plant foods came from their phytochemical content. The Kawymeno Waorani recognize many potential health-related phytochemicals in foods through a sense of smell and taste that is the key sensory link/language between humans and the plant kingdom, which agricultural populations have lost. When a choice of foods is readily available in an environment, hunter-gatherer seasonal dietary intake preference may be based largely on the smell and taste of food, which is a property of plant phytochemical content. Hunter-gatherer ancestors with common sense picked the richest dietary places to live where there were always dietary options, not desolate African wastelands classically portrayed as hunter-gatherer environments.

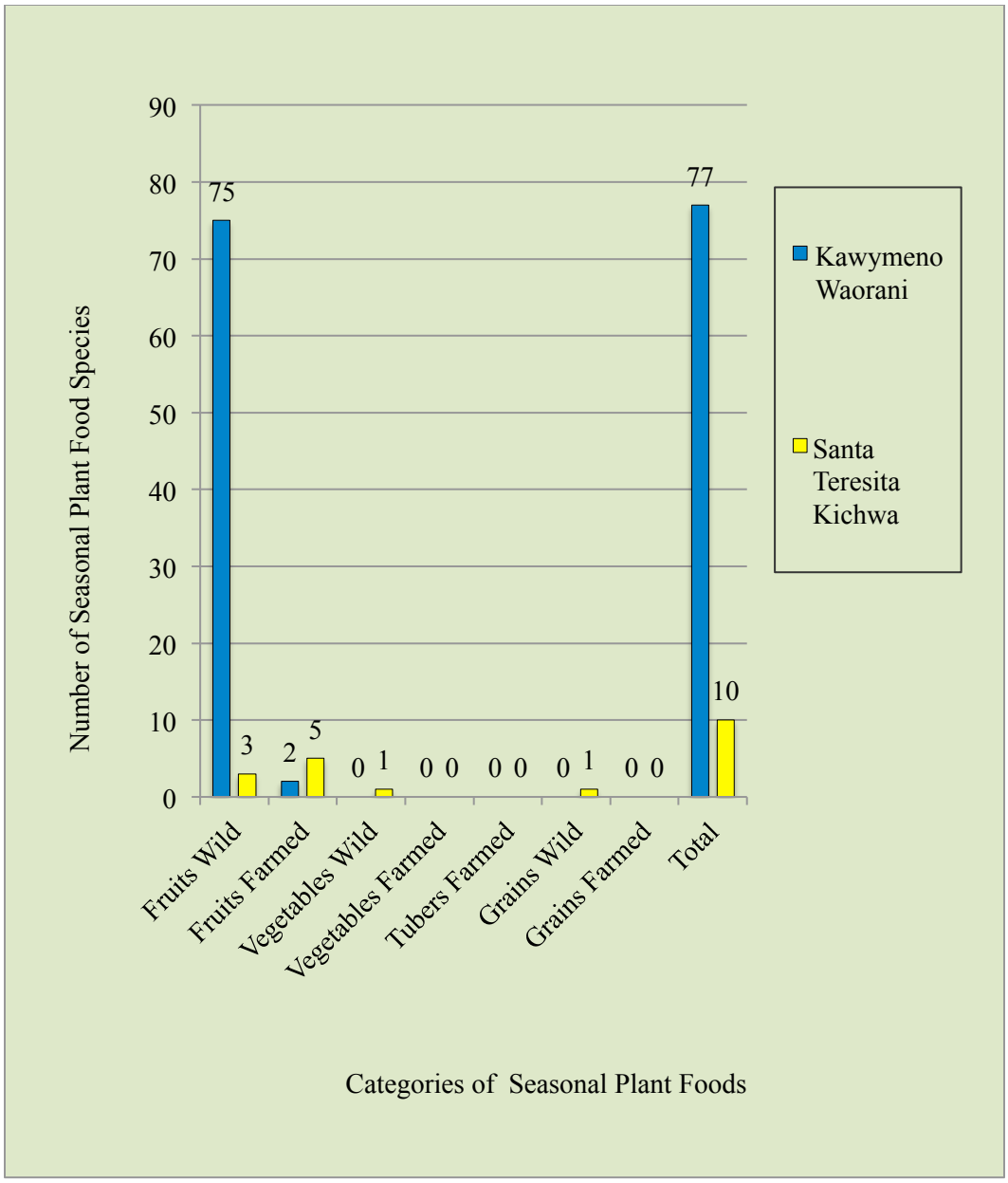


Figure 26. Variety of Dietary Intake of Seasonal Plant Foods by Plant Type: Kawymeno Waorani vs. Santa Teresita Kichwa. 2010

Phytochemical scents and seasonal dietary intake of animal food species. Seasonal change in Kawymeno Waorani animal food species consumption is driven, at least in part, by changes in the smell and flavor of the animal flesh, particularly the fat. Fat and animal flesh flavor are modified

seasonally by dietary intake of plants with strong scent producing phytochemicals. The lack of these phytochemical triggers in modern diets may have consequences for diseases such as obesity as is discussed at the end of the chapter.

Kawymeno Waorani animal food species are still eaten seasonally in spite of their year-round availability. Most animal food species were ignored during part of the year by the Kawymeno Waorani and then suddenly sought after during other parts of the year. Living in the Kawymeno hunter-gatherer community, I learned that as the seasons passed that animal dietary intake seasonality is actually tied to plant and fruit seasonality. For the Kawymeno Waorani, actual availability of game, bird and fish species was a secondary issue as almost all Waorani animal food species are not seasonal, but rather plentiful and available year-round close to Kawymeno. Water and food are available year-round near Kawymeno and the food species animals remain close to the community, other than minor movement in the dryer months.

Variety of flavors and smells create a diversity rather than monotony of animal and plant consumption, even in the case of animal foods available to the Kawymeno Waorani year round. The underlying purpose of flavor and smell in food that results in satiation of a given food with a given flavor and smell is discussed more below and in upcoming chapters.

Peccary hunting: part of a lifestyle that is vanishing.

"*Went on a hunt for peccary with the Waorani in the rain forest. We went out on a canoe about half a mile down river then jumped on the bank and*

went a mile into the jungle running through it. Crossing slippery moss covered logs that they used as bridges over sections of swampy areas, running through dry areas. I could smell the peccary even though I could not see them as they had an overwhelming garlicky odor. The Waorani had bare feet, many were naked. I couldn't think of a place where boots would have been more useful with all the sharp objects on the forest floor. Men armed with wooden spears taller than me. Spear shaft made of wood with notches in it so its stays in the animal. Waorani circled around the peccary, they could track them by their smell, and even I could smell the peccaries, as the garlicky odor is so strong. A group of peccaries, not sure how large. The spear throwing was very accurate, one of the middle-aged hunters put a spear through the hide of a peccary downing it as it ran through the jungle. The force needed to put a wooden spear tip through a thick peccary hide must be enormous. The spear tip broke off so the hunter re-cut the wooden end so it was sharp again. Both men and women came on the hunt and everyone was very animated and excited, especially after each kill. The chief's wife cut out the intestines of the downed peccary to kill it then whipped the peccary symbolically with reeds and then whipped her own legs with the same reeds and chanted. The Waorani tied the peccary's legs with palm bark to make a sort of backpack. The Waorani take little into the rain forest as they can manufacture things from the plant life such as baskets to carry palm nuts, which were also gathered

during the hunt. We returned to the canoe with three peccary." (Field Journal Entry, Douglas London. June 5, 2009)

A key dissertation case study: the case of garlicky peccary as seasonal phytochemical flavor-driven animal flesh consumption. The seasonal intake of both White-Lipped Peccary *(Tayassu Pecari)* and Collared Peccary *(Pecari Tajacu)* by the Kawymeno Waorani is an excellent example of phytochemically-driven animal food consumption. White-Lipped Peccary and Collared Peccary are eaten seasonally based mostly on taste and smell of the meat, rather than seasonal scarcity or abundance of peccary. Peccary are available year-round and many hunting trips I have been on involved traveling only 20 minutes to reach peccary groups. Seasonal changes such as water level in the swampy areas that surround Kawymeno only slightly affect peccary movement, not greatly inconveniencing Kawymeno Waorani hunters.

Phytochemical smells and tastes influence Kawymeno Waorani animal hunting and eating behavior. The smell of peccary changes seasonally as peccary ingest a revolving set of powerful smelling wild phytochemicals present in the seeds of their favorite fruits as these fruits come into season. These ingested phytochemicals alter the smell of the living peccary running through the rain forest, as well as the taste of dead peccary flesh, particularly the fat. These powerful phytochemically-derived scents are present in both species of peccary, White-Lipped and Collared Peccary, eaten by the Kawymeno Waorani. Again the relationship of flavor and smell of a particular animal food available year round

that eventually triggers satiation of said food is discussed below and more in upcoming chapters.

The Kawymeno Waorani recognize several different seasonally-fruiting plants that peccary eat that affect the peccary meat flavor and the Waorani desire to eat those peccary. The first plant food species, *Mansoa alliacea,* is called Wegamoñi in Waorani and is also referred to as "wild garlic" by other locals. Indeed the smell and taste of the *Mansoa alliacea* seed pits, referred to as "Pepe Negro" by locals, is reminiscent of domesticated garlic. The fruit flavor has a sweet flavor and smell that is in marked contrast to the garlic-like seed. Both the garlicky scent of the seed and the sweet smell of the fruit flesh stimulate animal and human consumption of *Mansoa alliacea.* Both the Kawymeno Waorani and peccary consume the fruit flesh of *Mansoa alliacea.* However, only peccary consume the hard seeds along with the fruit. Kawymeno Waorani humans only ingest the *Mansoa alliacea* seeds indirectly by eating the peccary.

Way, the wife of my Waorani Assistant, Ima, first mentioned what all Kawymeno Waorani have later confirmed; the peccary meat tastes best during the season when the peccary are eating *Mansoa alliacea.* She went on to tell me that when the peccary stop eating *Mansoa alliacea* seeds as the fruiting season ends, the peccary fat begins to taste less appetizing and the Waorani stop hunting peccary, even though there are still plenty available. Thus, peccary species themselves are not seasonal, rather the phytochemicals that the peccary ingest are seasonal, so the Waorani are responding to a phytochemical flavor to maintain

seasonal intake of peccary and their animal dietary intake habits are actually plant-driven.

This garlic flavor produced by plant phytochemicals in *Mansoa alliacea* seeds flavors the peccary meat and fat to the extent that even I and other Westerners can easily smell and taste the garlicky flavor difference of peccary meat during the wild garlic (*Mansoa alliacea)* fruiting season. Scientific samples and testing are not required to note the strong garlic phytochemical flavor in the peccary meat and fat, which has the same smell and flavor as the *Mansoa alliacea* seeds themselves. The whole peccary is phytochemically flavored in garlic. When hunting peccary with the Kawymeno Waorani during *Mansoa alliacea* fruiting season, even my untrained nose can smell the peccary herd a 100 yards away in the rain forest, which makes tracking peccary possible even for a non-hunter-gatherer Western scientist such as myself (see above journal entry). In the *Mansoa alliacea* fruiting season when wild peccary are nearby, this scent of wild garlic smell travels through the rain forest alerting all humans, and probably other animals, that peccary are available to be caught and eaten, which may be more to the hunter rather than the peccary's advantage.

The passing of a phytochemical that retains its trademark smell all the way up a food chain from plant origin to peccary to Kawymeno Waorani human is evidence that phytochemicals are passed along the food chain in recognizable chemical form. This supports an important dissertation thesis that phytochemicals can be passed to humans via consumption of intermediary animal food species without the necessity of eating the actual plant that produced the phytochemical.

It is rare that such a clear biomarker traces the path of a phytochemical from plant to animal to human so clearly through the food chain. Wild Garlic is only one example of rain forest phytochemicals traveling in animal bodies.

Way further noted that the flavor of the peccary meat changes as the peccary eat a different fruit later in the season. *Mansoa alliacea* is not the only food plant species that peccary eat that flavors peccary meat and fat, driving Kawymeno Waorani eating habits. Both the Kawymeno Waorani and the peccary eat a fruit called "Wengamo". Unfortunately, neither I nor the experts consulted were able to determine the scientific name of Wengamo, which may only grow locally in the Kawymeno area. While *Mansoa alliacea* may be a positively motivating phytochemical that attracts animals to eat peccary, the consumption of Wengamo by the peccary has the opposite effect on humans, repelling the Kawymeno Waorani from eating peccary meat. Similar to the garlicky *Mansoa alliacea,* Wengamo fruit is eaten by both Kawymeno Waorani humans and peccary. Also similar to the case of the *Mansoa alliacea* seed, the Wengamo seed is only eaten by the peccary, but not by Kawymeno Waorani humans. However, unlike the pleasant *Mansoa alliacea* odor of wild garlic, the seed of the Wengamo fruit has a very disagreeable smell, which my Waorani assistant describes as resembling the smell of human feces. The Wengamo seed flavors the fat of the peccary during its fruiting season and this unpleasant flavor repels the Kawymeno Waorani from hunting or eating peccary during the Wengamo fruiting season. Wengamo is another example of a phytochemical that controls human consumption of food via scent, this time in a negative repelling sense. Wengamo

is also another example to support the case that phytochemicals travel intact enough to retain a signature odor through the food chain.

Several things are apparent in the proceeding peccary example. First, wild animal food flavor is not a constant, but changes with the seasons, whereas domesticated animal flesh, with a consistent feed diet, maintains a consistent flavor. Thus, humans consuming domesticated animals are not motivated to change their diet with the change of the seasons. Second, it is interesting to note that the animal food flavor is dominated by phytochemical flavor, not by the animals' own flavor and it is the plants that are controlling the eating habits of humans. In fact, plants are underestimated in their ability to control animal behavior particularly through the human sense of taste and smell that is part of humanity's connection to the plant world and an intimate sensory driver of plant human co-evolution. While this sensory communication with plants is retained in the hunter-gatherer group, it is lost in the transition to agriculture, as the Santa Teresita Kichwa demonstrate.

The hunting style of the Santa Teresita Kichwa is opportunistic while the hunting style of the Kawymeno Waorani is driven by rain forest rhythms and particular seasonal scents. The Santa Teresita Kichwa hunting and fishing patterns seem to be constant and unaffected by changes in the season and flavor of the wild animals. On the few occasions when I have gone hunting with the Santa Teresita Kichwa, I noticed that while the Santa Teresita Kichwa are aware of the garlic smell of the peccary during *Mansoa alliacea* fruiting season, they are not motivated to hunt or eat peccary more because it has a wild garlic flavor.

Typically, any meat the Santa Teresita Kichwa eats has its natural phytochemically-derived flavor drowned out when it is salted, spiced and cooked with other foods. Thus, modern seasoning of meat eliminates the motivation to eat it seasonally. Santa Teresita Kichwa typically sell much of the peccary meat they hunt so peccary is not a significant source of dietary intake. However, these Kichwa usually eat a small portion of the peccary before selling the rest. Even beyond peccary I have not noticed any seasonal trend in any animal food species consumption on the part of the Santa Teresita Kichwa that is related to flavor or smell, as in the case with the Kawymeno Waorani. For the most part, if the food animal shows up in front of the Santa Teresita Kichwa it gets shot with a shotgun, trapped with a trap, or fished with a net, fishhook or poison. As will be discussed later, the ability to distinguish subtle phytochemical flavors and scents is visible even in the vocabulary of the Kawymeno Waorani, while Santa Teresita Kichwa farmers and modern humans neither develop the ability to distinguish between phytochemical scents, nor the vocabulary to express the difference in phytochemical odors to others. Thus, an entire human sensory system designed for plant-human signaling and communication has been marginalized and as discussed later distorted to the extent it may promote habits that lead to chronic disease.

This dissertation makes the case that Kawymeno Waorani may be able to sense flavors and smells associated with many phytochemicals that have beneficial characteristics. Classes of phytochemicals that contain known anti-microbial phytochemicals such as saponins and tannins have a characteristic

aromatic smell that is attractive to humans. Dr. Michael Wink elaborates on a point below.

> *"As you know near all plants produce bioactive secondary metabolites and almost all have substances with antimicrobial activity. As plants have to defend themselves against bacteria, such activity is not surprising. We know that plants with essential oil (aromatic smell), saponins and tannins usually show good antimicrobial activities without being very toxic to animals. Seasonal rotating sources of anti-microbial phytochemicals from a broad variety of wild phytochemical-rich plants have attractive aromatic smell that encourage human contact and consumption."* (Personal communication with Botanist Dr. Michael Wink from the Institute of Pharmacy & Molecular Biotechnology at University of Heidelberg, Germany)

The seasonal cycles of the Waorani hunter-gatherer food system: birds and fish. In addition to the seasonal dietary intake of peccary discussed above and the seasonal consumption of monkeys discussed in the chapter on poisons, there are also seasonal variations in Kawymeno Waorani fish and bird dietary intake. The high seasons for fish are July through September and again in December when the water levels in the Kawymeno part of the Amazon rain forest are at their lowest, permitting maximum effectiveness of the poisons put in the water. (Waorani plant-based fish poisons are discussed at length in chapter 22). Again, revolving phytochemicals are involved because the fish are caught with phytochemical toxins and fish food contains large quantities of these

phytochemicals. The seasonal rise and fall of the water levels drives the rotation of powerful fish poisons with other methods of procuring food. Low water levels in feeder streams are required for effective fish poison use. Particularly in the case of the powerful fish poisons used, extended dietary intake may be harmful. The phytochemically-based poisons the Kawymeno Waorani use to hunt and fish alone are in themselves toxic enough that rotation may be required. The most popular Kawymeno Waorani food birds are the "wild turkeys" (*Penelope jacquacu* and *Pipile pipile)* that are particularly sought after in May. Wild turkeys do not fly well nor do they migrate long distances. Whether wild turkey ingestion of special seasonal fruit in May plays a role in Kawymeno Waorani seasonal preference for wild turkey during that time period is not clear. However, like the fish, birds are also poisoned with plant phytochemicals, in this case curare hunting poison (*Curarea Tecunarum*).

In fact it is difficult to find an aspect of the seasonal rotation of Kawymeno Waorani hunter-gathering foods that is not affected by phytochemical intake. As this dissertation has shown, the Kawymeno Waorani dietary intake of peccary, monkey, birds, fish, and wild fruits all are impacted by phytochemicals. Plants and their phytochemicals have a lot of control over hunter-gatherer food systems and are at the heart of most dietary decisions and any consequent health outcomes affected by dietary preferences.

Herbivorous animals that specialize in eating non-fruiting plant parts throughout their evolutionary history probably have more physiological mechanisms for neutralizing anti-herbivore phytochemicals from non-fruiting

plant parts. Humans eating the flesh of these herbivorous animals may benefit from the beneficial aspects of the non-fruiting plant part while avoiding the toxic aspects of phytochemical intake. The ability of myself (and the Waorani) to eat for a year fish poisoned by the Waorani with an otherwise deadly plant phytochemical for humans with no apparent negative consequences is a good example of rapid conversion of phytochemicals by other animals. However, in a constant chemical war between plants and animals that eat them, new anti-herbivore phytochemicals are probably produced regularly by plants. Ironically one could speculate, vegetarians seeking the nutritional aspects of non-fruiting plants may be, from a strictly phytochemical toxin point of view, better off eating the meat of animals that consume these plants than eating the plants themselves.

This chapter discusses dietary animal intake, and demonstrates animal foods are a source of stored phytochemicals in augmented by their own animal defense chemicals. Similar to diversity of plants in Kawymeno Waorani diet, a revolving diversity of animal sources of phytochemicals and animal defense chemicals also provides less exposure to potentially long-term toxic affects of any phytochemical in excess and maximizes diversity. While variety of dietary rain forest wild animals consumed by the Waorani is less diverse than plants, wild animals consume constantly revolving seasonal wild plants, and as we have seen in this chapter. These phytochemicals remain in the wild animal flesh and are not simply excreted, thus providing a rich variety of stired phytochemicals for human consumers. Domesticated animals, with a more monotonous year-round domesticated grain and plant-based diet, correspondingly may have flesh with a

very limited variety of phytochemicals. While lacking in variety of phytochemicals, domesticated animal flesh may be a high and even toxic concentrated source of partuclar plant phytochemicals coming from monotonous grain consumption.

CHAPTER 10

FOOD SYSTEMS IV: ECOSYSTEMS, FOOD CHAINS AND THE PHYTOCHEMICAL HIGHWAY

The Myriad Wild Food Chain Links to Better Hunter-Gatherer Health

This dissertation makes the case that the separation from the rain forest food chain, caused by the subsistence farming of the Santa Teresita Kichwa, is at the heart of the vast difference in health status between the two groups, and that it is the change in plant phytochemical intake brought on by this separation, more than the difference in standard nutrients in the diet, that accounts for this health disparity. The Kawymeno Waorani rain forest food chains go back through many species that are interconnected with each other. Each species in turn is consumed by another species, which in turn adds its unique array of connections to other organisms' biochemicals/phytochemicals. They come together in an intricate and balanced exchange tapestry connecting hundreds of thousands of organisms, which are all exchanging biochemicals. So human hunter-gatherer participation in the rain forest ecosystem provides a diversity of phytochemical intake, ensuring that a larger number of different fruits and their phytochemicals are ingested, which combined with seasonal changes in fruit phytochemicals prevents over ingesting of any particular fruit phytochemical.

As opposed to studies of traditional nutrients, for phytochemical research understanding food chains is vital, in part because phytochemical production is dependent on the being stimulated by the surrounding environment, while

standard nutrients are constantly on hand to power the plants energy levels and thus less dependent on outside ecosystem stimuli. Further, the variety of phytochemicals directly depends on the variety of environmental stimuli provoking phytochemical production, thus dealing with 100s microbial, insect, parasite and plant enemies will produce a much wider variety of defense phytochemicals than fighting off 10 enemy species of the plant. The standard nutritionist's focus only on the amount of nutrients in the food on the plate is inappropriate for studying phytochemicals, since the way to improve the phytochemical dietary intake is not to eat more of a given food, but to eat food that is stimulated by a natural or farmed ecosystem to have more phytochemicals. There is a need for nutrition science to understand a food system – how one food is linked to others in a natural environment. The present piecemeal nutrient-by-nutrient approach by nutrition science to understanding the connection between diet and disease is seriously lacking both theoretically and systemically resulting in conflicting results and advice.

Hunter-gatherer groups, such as the Kawymeno Waorani, are intimately intertwined, biochemically speaking, to their wild ecosystem through a daily interchange and intake of phytochemicals with the wild animals and plants embedded in their food chain, which is in turn linked firmly to the biochemistry of the Amazon rain forest. These biochemical pipelines to the riches of the rain forest's hidden chemical world come through a food chain whose first link – the actual foods consumed – is listed in the food species tables of this chapter. During our year with the study groups, we were able to piece together the closest links of

both the Kawymeno Waorani hunter-gatherer and Santa Teresita Kichwa farmer food chains, which are the immediate foods they ate, and thereby trace back from food species the direction these phytochemicals were coming from.

The Kawymeno Waorani physiological connection and sensorial awareness of their phytochemical intake is evident through their extensive vocabulary of smell and taste of the phytochemicals that create the natural flavor of their foods. This Kawymeno Waorani ability to sense phytochemicals in their food and describe the flavors through a large sensory vocabulary was actually very helpful to this study, as will be demonstrated further in this chapter.

Humans eat wild animals and those wild animals eat the same plants as humans: combining and overlapping of phytochemical sources. The Kawymeno Waorani are master observers of animal habits, and know the plant foods that are eaten by the animals the Waorani hunt and fish eat. It was straight forward determining what plant food species overlap diet wise, that is food that is consumed by both the Waorani and the animals they hunt. The determination of the overlap of dietary intake of the humans and the animals they hunt was also straightforward for Santa Teresita Kichwa study groups because the Santa Teresita Kichwa farmers eat only a few wild animal species that the Kawymeno Waorani also consume. There are only a few rarely eaten wild species by the Kichwa such as the caiman and grubs that the Waorani do not also eat. Kawymeno Waorani naturalist observations are accurate and applicable no matter who is actually eating the animals in question.

There is universal agreement between all Kawymeno Waorani on the types of plant foods eaten by animals. Animal habits are common knowledge, necessary for survival, and observed every day as the Kawymeno Waorani trek through the rain forest looking for signs of their animal prey.

Medicinal Use of Plants by Rainforest Animals

Beyond knowing the diets of different food species animals, the Kawymeno Waorani hunter-gatherer are also aware of the medicinal plants the rain forest animals use. Humans are not the only species to take advantage of the phytochemical pharmacy the rain forest offers. Wounded peccaries and monkeys, for instance, break tree branches and rub different plant parts on themselves and on their wounds - such as sap from the Wingimonkawe (*Iryanthera juruensis)* and Namontaque trees and the bark of the Naikymo tree –which may have anti-microbial properties. Animals also eat the same plants decribed above that they use medicinally on their skin. For instance, peccary eat the roots and trunk of the Namontaque tree, and absorb any anti-microbial phytochemical compounds. The peccary may then have antibiotic chemicals stored in its flesh suitable for human use. Thus, The Kawymeno Waorani in turn would receive anti-microbial phytochemicals when they ate the peccary. Of the above three peccary medicinal plants used by peccary the Kawymeno Waorani only eat the fruit from *Iryanthera juruensis* species. The topic of the passing of the anti-microbial properties of the rain forest to humans via food is continued in the next chapter.

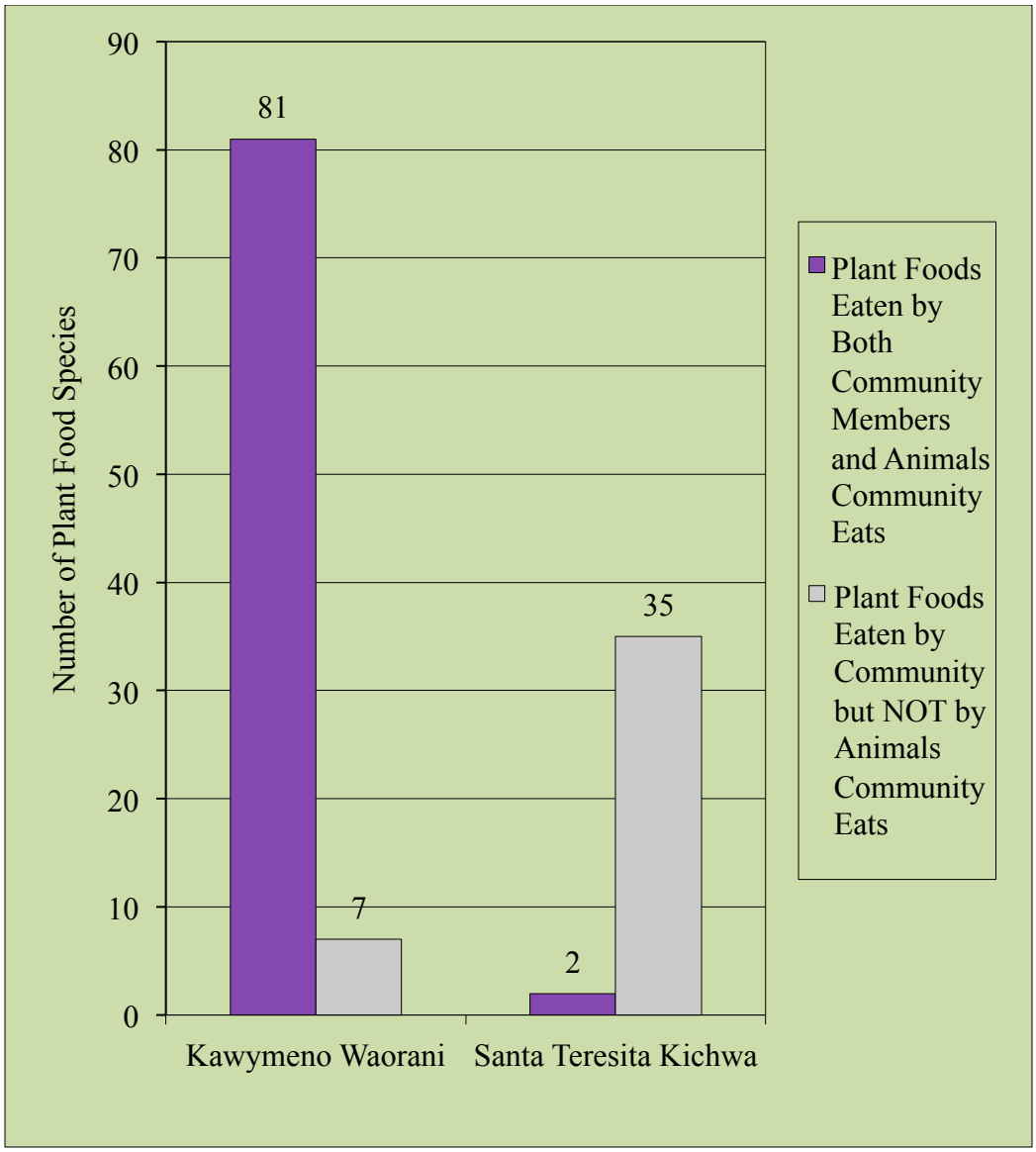


Figure 27. Number of Plant Food Species Eaten in Common or Apart by Community and Principal Food Animals

Santa Teresita Kichwa food plant species mutually consumed by animals in their food chain. As shown by figure 28 above, there is a difference in percentage of animal - human dietary overlap of plant food across the Kawymeno Waorani and Santa Teresita Kichwa. Overlap of plant food species

also means overlap of plant phytochemical ingestion as well as plants. Most Kawymeno Waorani food plants (81 out of 88) are also eaten by the wild animals they eat. Since the Santa Teresita Kichwa only eat 2 wild species of plant, and both are eaten by the few wild animals the Kichwa consume, there is a small, (2 out of 37) dietary overlap between Kichwa food plants being eaten by animals the Kichwa also eat. Santa Teresita Kichwa domesticated plants are rarely eaten by either domesticated or wild animals.

Domesticated animals and plants do not necessarily participate in the rain forest ecosystem although they live next to the rain forest. Most rain forest ecosystem organisms, both plant and animal, are regarded as pests by Santa Teresita Kichwa farmers and are deliberately destroyed and kept away from gardens. Segregation from the surrounding natural eco-system is more extreme in modern agriculture where vast plots thousands of acres are bombarded by an array of powerful chemicals killing off competing life forms, while vast tracts of plowed soil disconnect domesticated plants from the world and ecosystem outside the farmed plot. Santa Teresita Kichwa domesticated animals are fed grain and also allowed to free range, typically in open grassy areas, but do not have access to most of the surrounding ecosystem partly because they are physically prevented from wandering into the rain forest and also, after generations of eating domesticated food, domesticated animals may not be adapted to ingesting rain forest food which is often toxic phytochemically to domestic animals.

Kawymeno Waorani food plant species mutually consumed by animals in their food chain.

In contrast with the Santa Teresita Kichwa, 81 out of the 88 plant food species in the Kawymeno Waorani food system (92%) were eaten by both the Kawymeno Waorani and the food animals in their food system. The dietary intake of all the principal animals in the Kawymeno Waorani food system overlapped considerably with the Kawymeno Waorani, including the major food species of peccary, monkey, birds and even fish (that eat many of the same riverside berries). Thus, the Kawymeno Waorani phytochemical overlap is even greater than what a plant food species comparison would indicate because the food animals the Kawymeno Waorani eat the most of, actually eat most of the same plants the Kawymeno Waorani eat.

One such example of dietary plant defense chemical overlap in the Kawymeno Waorani food system is the peccary-human phytochemical dietary overlap. The principal foods of the White-Lipped Peccary (*Tayassu Pecari)*, the most eaten animal food of the Kawymeno Waorani, are morete fruit (*Mauritia flexuosa)* and hungurahua fruit (*Jessenia - Oenocarpus bataua)*. Morete and hungurahua are also utilized seasonally as the principal ingredients of the Kawymeno Waorani Chicha beverages. The Kawymeno Waorani and the Collared Peccary (*Pecari Tajacu),* the other species of peccary eaten by the Kawymeno Waorani, both consume wild coconut-like fruit such as (*Astrocaryum chambira*) species, and Opoka fruit (*Micropholis venulosa),* as well as the hungurahua and morete, which are also eaten by the other aforementioned species

of peccary eaten by the Waorani, (White-Lipped Peccary). Peccary and Kawymeno Waorani mutually consume a variety of other wild fruits. In another example of food overlap, most monkey species eaten by the Kawymeno Waorani also eat many fruits species in the Kawymeno Waorani food systems such as Han (*Inga edulis),* Iwa *(Inga sp.)* and Kemogohiva *(Inga sp.)*.

Dietary overlap increases sources, variety and quantity of phytochemical intake. Food transfer is more circular and interwoven in a natural ecosystem such as where the Kawymeno Waorani co-exist within a rain forest with their food species, compared to the agricultural food system the Santa Teresita Kichwa have carved out of that same rain forest. The fact that 92% of the wild plants the Kawymeno Waorani have in their diet are co-consumed and stored in the body in some form by their food animals, indicates a sharing of phytochemical resources across a broad system where more interchange between species is possible long after the phytochemical leaves the plant, resulting in even more varied compounds from the original phytochemicals produced. When animals process ingested phytochemicals, they eliminate toxic phytochemicals and store valuable phytochemicals in their tissue (Andres-Lacueva et al 2005, Kalt et al 2008, Matsumoto et al 2006). Phytochemicals stored in animal flesh may be useful to other animal species, including predators one step further along a food chain, such as humans are to peccary (or even domesticated livestock, poultry and fish). If there are dietary phytochemicals beneficial to one animal species' health, it is reasonable to suggest these phytochemicals would also be beneficial to the health of similar mammal species that routinely ingest the same

foods. To use an analogy, a double-lane phytochemical wild food chain highway accessible by the Kawymeno Waorani hunter-gatherers, which includes animal intermediaries as well as plant originators, considerably enriches what was already a large intake in wild phytochemical consumption, another avenue to obtain animal processed version of their plant food system. Indirectly consuming phytochemicals by eating animals that have consumed and processed these phytochemicals may have advantages to consuming the plants directly in terms of reduced toxicity and perhaps a more bioavailable pre-processed form of the phytochemical.

This dissertation makes the case that animal-based compounds derived from phytochemicals may be more bioavailable than plant-source phytochemicals. To elaborate, animal-based phytochemical derivations are often more easily physiologically absorbed and readily used than the direct plant food versions as is described below in the case of nutrients. This is due in part to the benefit of the animal's body doing part of the digestive work beforehand, and eliminating many of the toxins while preserving many of the useful phytochemicals that may be mutually beneficial to both the food animals and the humans that eat them. In addition, phytochemicals and nutrients may be stored in a more concentrated manner compounded from multiple dietary plant phytochemical intake.

Unlocking of the nutrients that are interlaced with phytochemicals in plants can be used as a parallel dietary example. It is well known that unlocking nutrients from dietary plants foods, ranging from iron to omega-3 fatty acids, uses

more energy than unlocking nutrients from dietary animal foods. It requires greater amounts of energy to get a bio-available form of iron out of spinach or a bio-available form of omega-3 out of chia plant than getting that same amount of bio-available iron out of red meat or omega-3 out of fish oil. Non-bio-available iron just gets washed out. Phytochemicals are physically located right next to the nutrients in the plant food. Actually, there is a grey area biochemically between where phytochemicals end and nutrients begin. The case is made here that both phytochemical and nutrients are passed into animal food and both are processed by animal physiology and both are redistributed throughout the entire animal body. The human body does not have to do all the hard work processing toxic compounds and concentrating these phytochemicals into larger concentrations of more useful compounds.

The term "food chain" makes sense if there's a one-way flow of phytochemicals and nutrients from lower animals to "higher" animals (meaning humans) that demarks the artificial agricultural system. However, in a natural wild food system there is a give and take in phytochemical and nutrient transfer and tapestry between all species, where even tiny simple one–celled microbes and parasites eat the biggest most complex mammals. The natural food tapestry is lateral; there is not a complex mammal at the top of the food chain and a simple micro-organism at the bottom.

The ratio of plant versus animal food content of pre-historic hunter-gatherers has been a point of controversy among ancestral diet nutrition researchers (Cordain, 2002b), but is a less critical point in a phytochemical dietary

intake argument if both plant and animal foods are potential sources of phytochemicals. Certainly the fact that the phytochemicals that humans have ingested for much of their evolutionary history have two potential routes to reach humans – directly through plants or via animal intermediaries – has significance for hunter-gather culture examples that live in arctic regions with few direct plant food resources. The ratio of animal to plant foods that prehistoric hunter-gatherers consumed probably varied depending on their environment, but phytochemical content of diet would not change much even if fewer plant food species were available, if there was an animal source for phytochemical derived compounds.

The Problem of Different Foods with the Same Phytochemicals in Agricultural Food Systems

On the other hand, in an agricultural food system there is very little overlap or mutuality of phytochemical intake. A food chain takes on the appearance of a single strand, rather than an interwoven organic tapestry of a hunter-gatherer food system. The common use of the word "chain" to describe transfer of nutrients and phytochemicals among organisms is probably based on an agricultural perspective of food rather than reality in wild ecosystems. In a human-made agricultural food system, humans are at the top controlling other organisms to meet human dietary needs. This impacts dietary intake of phytochemicals drastically. At the foundation of animal food products in the agricultural food chain there is a very narrow range of grains used to feed the animals, grains chosen principally for cost effectiveness and longevity in storage. Nutrients and phytochemicals spoil more easily that carbohydrates in grains thus storage considerations eliminate most plants and plants are genetically bred to

have fewer nutrients because they spoil more easily. This strand of grain feed moving up the trough of the human agricultural chain takes the place of the tapestry of an entire rain forest, like that from which the Kawymeno Waorani hunter-gatherers still have the luxury to draw phytochemicals from. In modern industrial food systems phytochemical overlap is very restricted, limited mostly to those phytochemicals found in grains, as large scale agriculture relies on grains to feed livestock, fish and poultry, as well as humanity. Thus, rather than any phytochemical overlap there is really just a grain "feedback" loop.

Overlapping dietary plant sources among humans and their food animals is a signal of "mutuality" in a food system. Since most Kawymeno Waorani food system plant foods are also consumed by the animals eaten by the Kawymeno Waorani, this hunter-gatherer food system is a mutual one. Most agricultural food systems are exclusive, not mutual with no cycling, seasonality or other circular flowing of phytochemical and biochemical resources. Mutually ingested plants mean mutually ingested phytochemicals and mutual communication and relationship with the same species.

Of course in the Kawymeno Waorani food system, animal food species also eat many plants that the Kawymeno Waorani do not eat. Beyond mutuality there is still a diversity of plant food species rich with phytochemicals that the Kawymeno Waorani have access to via animal foods that they cannot get from plants because the plants are too toxic to human physiology. Other animals have adapted evolutionarily to absorb these toxin phytochemicals. Animals, including humans, are often specialists adapted to eating the plant species that are toxic for

other animals. Food animal species can break down and transform these toxic, but often medicinal and physiologically active phytochemicals, into an edible form of phytochemical compounds for humans.

CHAPTER 11

FOOD SYSTEMS V: WAORANI SENSE OF SMELL AND TASTE: WINDOW INTO THE PHYTOCHEMICALLY-DRIVEN SENSORY CONNECTION BETWEEN PLANTS AND HUMANS

Scent: examples of the language the plant world uses to communicate with, motivate and destroy other organisms. Phytochemicals can seduce humans and other animals to do what the plant wants. This is accomplished through phytochemicals that release scents and flavors that trigger physiological responses in animals, such as humans. Kawymeno Waorani can smell phytochemical signals - the scents and flavors given off by the plant kingdom. The letters of the plant language are phytochemical formulas.

Many phytochemicals serve a function as scents and flavors designed to motivate animals to do what plants need them to do, such as eat their fruit and seeds or alternatively avoid eating non-fruiting plant parts; pollinate plant flowers; (Picchulla and Pott, 2003) and even kill other animals that attack the plant (Alborn, et al., 1997). Plant fragrances play a role in communication between organisms, including other plants. For instance, sagebrush and tomato plants have been documented communicating with each other via phytochemicals (Alborn, 1997). Recently, plants have been found to purposively attract mammals with scents to pollinate their flowers and of course are well known to attract insect pollinators (Johnson, 2011). Scents are used to send signals long distances – sometimes miles – while other scents are actually biocides and used to kill

animals (Picchulla and Pott, 2003).

Many volatile chemicals are released when a plant is damaged by an insect or other herbivore (such as a human). Vegetables are particularly well known for their reaction to herbivore threats. Maize (Degan, et al., 2004), cucumbers (Mercke, et al. 2004) and cabbage (Vuorenin, 2004) all release powerful scents to destroy herbivores through various, and sometimes unusual, strategies. One such defense strategy is the use of scents to attract predators to come and eat any herbivores presently attacking the plants. In other words, motivating one animal to kill another animal for the plant's benefit via smells the predator cannot resist (Alborn, et al. 1997). Plants can distinguish the difference between mechanical and herbivore-induced wounding and respond chemically only to damage caused by animals, which has significance for agriculture techniques (Alborn, et al. 1997) as discussed in the conclution. Leaves and other non-fruiting parts of plants routinely release small quantities of volatile phytochemicals, but when a plant is damaged by an herbivore many more volatiles phytochemicals are released (Pare and Tumlinson, 1999). In particular, leaf and root damage by herbivores triggers the release of volatile phytochemicals that kill or repel herbivores. This release of plant defense chemicals can alert and prepare neighboring plants against attack by herbivores (Das, et al., 2012).

To truly be included in the rain forest ecosystem and food chain requires the pocession of this delicate sensory awareness of the taste and smell of the rain forest and its multitude of phytochemicals that help drive the ecosystem communication between all plants and animals. The rain forest is full of scents

created by plants and each scent has particular purposes that drive change in the food chain and other apparatuses in the rain forest ecosystem. The Waorani have an exceptionally keen sense of smell and taste and a large vocabulary to describe these subtle differences in the phytochemical content of the environment and food system. The Kawymeno Waorani ability to communicate with plants by sensing phytochemical signals keeps them in constant, intimate (if largely unconscious) dialog with the rain forest plants.

Scent and flavors are only one of the more obvious ways plants can influence human preferentiality for or against foods through their phytochemicals. However, branching into other ways plants influence human behaviors will await another publication, but it is important to keep in mind there are many ways though millions of years of plant-human co-evolution and countless alliances and wars that have created a double-edged chemical relationship between human and plants. The double-edge plant – human sensory communication means a symbiotic, as well as hostile chemical interchange between plants and animals. Human researchers do not have the sensory capabilities to perceive the constant interchange between plants and animals thus they rarely study them. These mixed messages show natural selection based on immediate needs at the time span has shaped both a hostile and helpful bio-chemical exchange between plant and humans. In the relatively pristine rain forest inhabited by the Kawymeno Waorani plant and human inter-change still goes on largely uninterrupted, at least for a few years longer until oil drilling begins.

The Case of Bitter and Sweet Tastes: Extensive Waorani Vocabulary Reflects Invisible Phytochemical Communication with Plants and Animals

The Waorani language "Wao" is an isolate linguistically and only two apparent loan words were found within the language at the time of initial contact with outsiders starting in 1958 (Peeke, 1973). Being an isolate means the Waorani vocabulary is only related to Waorani cultural experience. While contact with outside cultures now in 2010 has introduced some words from outside languages into the Waorani vocabulary, the sustained interaction with the outside world has been brief, a few decades in total. References and grammatical structures relating to the food system smells, flavors and tastes still come from the rain forest cultural context at the heart of the Wao language and cultural reference. The cultural uniqueness of the Wao language makes Waorani-specific conclusions possible that would be impossible in most languages where words and grammar have been influenced by many other surrounding languages for many years or centuries. This is an important factor when considering the topic of this section – the vocabulary used to describe the sensory aspects of the Kawymeno Waorani food system in general and phytochemicals in particular. Waorani linguistic references and vocabulary about plant smells, odors and tastes come striclty from contact and communication with the plant world surrounding them not outside cultural influences. The few loaner words introducedfrom outside agricultural cultures over a few decades of contact do not, to the best of our knowledge, relate to sensing the wild rain forest.

Communication with plants: distinguishing between phytochemical-based smells. There are a number of ways the Kawymeno Waorani avoid over ingesting toxic levels of phytochemicals. Unlike agricultural peoples – the Waorani seem to do so by diversifying their food sources, seasonal food consumption and using a keen sense of taste and smell to stimulate satiation and avoid over consumption, which is a key topic in this chapter.

The smell and flavor of plant foods is usually due to the plant phytochemical content and may be utilized in human physiological interactions with their food as an evolutionary safety mechanism to prevent excessive consumption of a particular plant self-defense pharmaceutical toxins (Fenwick, 1983; Garcia, 1975; Kingsbury, 1983; Rozin, 1986).

Hunter-gatherers use no flavor altering additives to distort the natural phytochemical taste of whole wild foods. Having the ability to describe an array of bitter and sweet subtleties, indicates the Kawymeno Waorani have the physiological ability to discriminate between phytochemically based flavors of foods. This ability to discriminate subtle differences between phytochemical content drives Kawymeno Waorani preferences for certain foods at certain times of the year. The extraordinarily large vocabulary of the Kawymeno Waorani for bitter and sweet smells indicates an ability to sense these smells and tastes in their plant food and further this ability reflects the need to detect subtleties in smell and flavor to make appropriate dietary selections of food.

This vocabulary and physiological ability to distinguish subtleties in taste and smell gives the Kawymeno Waorani the ability to better discriminate between

different phytochemical contents of plant foods than agricultural communities who are without large vocabularies to describe the grades of bitter and sweet characteristics of their food. Food flavor and taste, prior to the agriculturalists' practice of adulterating their foods with additions and recipes, was almost exclusively a product of the phytochemical content of plant foods. The Waorani language, which includes many words to indicate subtleties of taste and smell that in most languages are covered by one word such as bitter or sweet, suggests that phytochemical content matters in dietary preference and food selection to assure survival.

This large hunter-gatherer plant scent vocabulary is an example of the co-evolution between plants and humans/animals, as plants send signals to animals via scents produced by phytochemicals to warn, attract or otherwise alter human and animal behavior to suit their survival needs, while leading animals to appropriate plant foods that keep animals such as humans alive and healthy, either by avoiding phytochemical poisons, or providing nutrients and beneficial phytochemicals (Wink, 1998; Wink, 2003; Wink, 2009). Examples are provided later in the chapter. Thus, the plant is not benevolent, plant smells are simply a symbiotic survival strategy as plants need animals to reproduce and for other survival purposes and humans need to be able to sense phytochemicals for regulation of dietary intake and survival.

Distinguishing subtle phytochemically based tastes and smells of foods helps control and regulate dietary intake of food plant species and their constituent phytochemicals intake as the flavor of most raw plant foods comes

from their phytochemical content. The Kawymeno Waorani language demonstrates these hunter-gatherers, and probably all hunter-gatherers, had the ability to communicate with plants through the perhaps largely unconscious language of smell, taste and odor, which controls many natural cycles of the rain forest eco-system. There is a masking of original phytochemical food flavor with salt, sugar, cooking oil, spices, preservatives, artificial flavors, unnatural "natural flavoring", and processing techniques that appeared with the advent of agricultural food systems (Billings, 1998; Johns, 1998).

My Waorani students' ability to sense phytochemicals. The focus groups I conducted with my Kawymeno Waorani health promotion students about food led to conversations describing the taste and smells of food. My wife had the idea of bringing a variety of foods to the class and asking my Waorani students to describe the flavor and smell of these foods. I asked each Waorani to bring in a number of varieties of native fruit they eat and I brought in some Western fruit (apples, oranges and pears) we had gotten from a recent trip to the Kichwa region. We then asked the Waorani to smell and taste the different fruits and describe the flavor of the food. The sheer variety of Waorani vocabulary words to describe subtleties of foods flavors was surprising. I tried this taste and smell experiment later with the family of my Waorani assistant, Ima, as well. Thus, towards the end of my stay in Kawymeno I began to compile a list of vocabulary used to describe the smell and taste of foods. A brief, surprisingly long, but probably incomplete listing of the some of the Kawymeno Waorani vocabulary used to describe phytochemically-based flavors is found in the table below.

Table 8. Kawymeno Waorani Taste and Smell Vocabulary and Descriptions

Kawymeno Waorani Word	Description According to Kawymeno Waorani Informants
General	
bikinka	To eat something with good flavor
gwereke	All classes of bitter or spicy
meñeka	General word for fruit
nanoka	All classes of sweet
ogiwapa	A lot of flavor, where there is no bitterness
Bitter	
gee abanpa	Menthol flavor
gere kempa	Bitter like something over-fermented
gwiñeme	Smell of poison (like the smell of a vine used for fish poison)
jimome	Like a burning sensation (spicy)
katipe	Like water with salt in it
monka	Flavor that makes it difficult to eat (like the liver of an animal that has spots). Applies to animals and birds, not fruit. Like a poison.
nanhi mankapa	Very bitter - applies mostly to fruit
nemmoca/nimoca	Bitter peel of fruit

Kawymeno Waorani Word	Description According to Kawymeno Waorani Informants
nemoka	Bitter lemon
nogeime	Disagreeable – a little bitter, like over-fermented chicha
nogemonte	Bad smell of spoiled food (refers more to meat; meat that is dry and no longer moist)
nogente	Food with a bad odor that shouldn't be eaten
ñomey	Smells of something rotten. Can't be used like spoiled meat
omenta	Takes all the flavor away- very bitter like poison
opoca	Distinct flavor referring to the gummy part of opoca fruit
paingonka	Smells like manzanilla
pankabokabo	Smells like onion
pepa paigowenka	Bitter
tewitepe	Dangerous smell – something that should never be eaten
tin nampa	Very bitter but still good to eat (like lemons)
tinaba/ tinaba yenekapa	Bitter but salty

Kawymeno Waorani Word	Description According to Kawymeno Waorani Informants
tiname	Smells like over-fermented chicha with alcoholic odor
tinanka	Fruit or beverage that is strong and bitter
tinanpa	Fruit that is spicy hot
wegono	Bitter medicinal plant substance that has changed from its original color (e.g. Sangre de Drago sap that is no longer red)
winte ñon mempa	Bad smell, spoiled food. Refers to most foods that are overripe or rotten
wiyenyen	Smells like *ajo de monte* (wild garlic)
yerekepa	Bitter acid taste
yowe	Bitter menthol
Sweet	
gweñeme-bay	Honey from bees
mega	"Well dressed smell" little sweet, use for wedding, perfume
omentaka	First tastes sweet, then turns sour
owannoca/wyrobecay	Identical to sugar cane
waime	Very sweet
waynempa	Sweet like an overripe fruit

Kawymeno Waorani Word	Description According to Kawymeno Waorani Informants
wirobe waime impa	Very sweet
wirobe/wyrobe/wanoka	Very sickeningly sweet, like sugar cane

Kawymeno Waorani diverse vocabulary for bitter and sweet: table and discussion. There are at least 29 Kawymeno Waorani variants of the English equivalent word "bitter" and 8 Kawymeno Waorani variants of the English equivalent word "sweet". Within the bitter category are descriptions such as "spicy hot" and "salty" that while not variants of bitter to Western audiences, are considered to be considered variants of bitter to the Kawymeno Waorani perhaps simply because Westerns cannot taste these flavors.

Many phytochemicals have a bitter taste and 4 of the Kawymeno Waorani interviewed indicated they believed that a more bitter taste was associated with a greater medicinal effect of the fruit or plant in question. Most Kawymeno Waorani fruits, at least to my limited tasting ability, are bitter compared to domestic varieties of fruits I am used to which may be an indication that there are more powerful bitter phytochemicals and less natural sugar in the native fruits.

My whole Kawymeno Waorani health promoter class agreed there were very few sweets in the diet; honey was eaten in large quantities once or twice a year for medicinal rather than food purposes. The only other somewhat sweet food eaten are Acage (*Ipoemoea batata)* and Capamo (*Pachyrhizus angulatus)*, which are types of semi-cultivated sweet potatoes planted next to the manioc roots

(Acage and Capamo are often dug up and eaten raw although they can be cooked).

I was surprised by the amount of Kawymeno Waorani vocabulary words used to describe sweetness. Then it occurred to me that if getting sugar from fruit was a nutritional priority for immediate energy in a diet that lacked refined sugar, being able to detect subtle levels of sweetness had survival value. Unfortunately, the teacher in Kawymeno has recently introduced sugar cane plants to the Kawymeno Waorani, which may soon dispense with the extensive Wao vocabulary to describe levels and types of sweetness, as sugary foods, rather than being scarce in the Kawymeno Waorani food system, are now in excess.

Waorani have an intimate relationship with the rain forest flora and fauna, thus their vocabulary cues for taste and smell reflect the environment and organisms they interact with. To create a common ground for communication to speak with other members of the community, the Kawymeno Waorani sometimes use specific foods as a root for a word to symbolize a particular variant of bitter or sweet that this selected food has in common with other foods. Other Kawymeno Waorani taste and smell categories are more abstract and do not appear to be referring to a particular plant species.

There are 3 different Waorani words with different semantic meanings that are very similar except for one phoneme that has 3 variants at the same location. Tinan***k***a is a fruit or beverage that is strong and bitter, Tinan***b***a means bitter, but salty and Tinan***p***a means fruit that is spicy hot. This variation shows that minute phonemic sounds differentiate meaning. This phonemic example also shows a

grammatical structure built around the sensory perception of "bitter" which indicates the Wao language is grammatically structured to facilitate distinguishing between flavors caused by phytochemical contents of plant foods in a way languages like English are not.

How the ability to distinguish tastes and smells affects health outcomes. Farming communities, like the Santa Teresita Kichwa, add spices and preservatives that change the flavor and smell of food. The Santa Teresita Kichwa prepared food does not match the actual taste of the plain food contents, distorting any taste and smell cues related to the underlying real food being eaten. It is interesting that the first things the Santa Teresita Kichwa buy from the store are three types of flavorings. Examples of spices and preservatives used by the Santa Teresita Kichwa include salt and three artificial flavorings from the store (commercial brands "Sabora", "Magi", and "Alino"), as well as garden grown cilantro (*Eryngium foetidum)*. Natural spices such as cilantro are actually powerful-smelling phytochemicals in themselves with a more pleasant, less bitter smell and taste that drowns out the original more bitter taste of the native plant foods.

The case of salt taste blocking phytochemical triggered hunger and satiation signals. Interestingly enough just using salt in foods is enough to eliminate any phytochemical flavoring of whole plant foods very effectively. Tonic water and salt is good example. Tonic water has a bitter taste that is from the phytochemical quinine, an anti-microbial plant defense chemical from an Amazonian tree bark very effective in killing malarial parasites by Westerners.

The use of quinine is still very effective against Malaria as my own example points out. When I had drug-resistant malaria in a remote part of Angola, Africa and could not get out of the country due a civil war, the use of quinine by Russian doctors saved my life during the civil war there while I served as administrator for a United Nations hospital. Sprinkling salt on quinine water turns the bitter drink into an almost sugary taste as a presentation at the Monell Chemical Senses Center in Philadelphia by Gary Beauchamp last year demonstrated. Salt actually suppresses bitter flavor of alkaloid phytochemicals better than sugar, though the reason is not known. This is an example of how additives like salt used by the Santa Teresita Kichwa immediately neutralize any phytochemical flavoring of the food. Many Westerners sprinkle salt on grapefruit to get rid of the phytochemical-based bitter taste of grapefruit.

Hunter-gatherers, like the Kawymeno Waorani ate their food immediately, or a short period after procuring it, and probably relied on the plant food's natural phytochemically-based flavor as a guide to the advisability of eating a particular food. With subsistence agriculture, there arose the need to store and preserve food for long periods of time, while at the same time assuring enough food flavor to be appetizing. Salt was an early choice in subsistence agriculture societies to preserve food and in the process destroy any phytochemical flavoring of the food itself. Hunter-gatherers, like the Kawymeno Waorani do not use any salt and seem to survive without any salt, at least in the form of added sodium chloride.

This dissertation makes the case that sodium chloride damages health, not only by its own chemical properties, but by its ability to drown out warnings,

triggered through reaching receptor capacity for a particular phytochemical smell and taste, indicating toxic levels of phytochemicals have been reached.

Alternatively phytochemically driven taste or smell can signal hunger that is triggered when a known phytochemical associated with a food is smelled, triggering a physiological signal that the body needs this food, such as fruit to function effectively. When the receptors in the body are filled with the phytochemical for the particular food, satiation occurs and hunger is shut off. This dissertation hypothesis needs of course to be tested, but the general principal has been stated. It may not be so much that the plant itself is signaling the human, but that humans have developed the ability through plant-human co-evolution of millions of years of bio-chemical exchange to sense plant chemical presence in food. Humans use the sensory aspects of their food to determine satiation and phytochemicals are what humans have developed physiological triggers for.

It would be interesting to note dietary changes in Westerners who removed salt from their diet and if any reactivation of the ability to taste phytochemicals occurred and if there was any move to increase fruit consumption or other phytochemically rich food or move away from less desirable more fattening foods produced by the agro-food industry. Losing weight and increasing desire for phytochemically rich food could be as simple as eliminating salt, spices and other flavor changing compounds from your diet that enter or block receptors for phytochemical scents that trigger hunger and satiation which is discussed in the conclution.

In agrarian systems like the Santa Teresita Kichwa there is a move away from consuming a hunter-gatherer raw wild plant diet, and the smells and taste of food become a property of additives and processing rather than the natural phytochemically-produced taste of the plant food itself. Thus, the Santa Teresita Kichwa are unable to properly regulate intake of phytochemicals for optimal health outcome.

Phytochemical sensitivity and satiation. Thus, signals between humans and the plant kingdom were interrupted with the advent of agricultural systems. Plants normally manipulate animals through scents and flavors by attracting mammals to pollinate or even summoning animal enemies of the herbivores attacking the plant (Johnson, 2012; Pare and Tumlinson, 1999, Alborn 1997). But the plant kingdom lost touch with global human agriculturalists, like the Santa Teresita Kichwa, when these farmers could no longer sense many of the rain forest plant scents. Ironically humans who no longer have any control exerted on them by plant sesory devices are destroying the globes plant species.

The large disconnect and drowning of original food flavors and smells caused by the modern food system render the subtle taste and smell skills that hunter-gatherers (such as the Kawymeno Waorani) use, essentially useless in the modern world. There are some potentially serious effects of losing the human ability to sense subtle tastes and smells due to the move to subsistence agriculture, compounded by the plethora of chemicals used in the modern food system, as the salt (sodium chloride) example demonstrates. Appetite satiation may be one of the

physiological confusions that occur when taste and smell guidelines that humanity depended on for appropriate dietary intake vanish from the food system.

Taste and smell can trigger several reactions including disgust, nausea and complete avoidance of certain foods right from the start, such as my Kawymeno Waorani friends experience when they are offered vegetables, or during peccaries' seasonal consumption of Wengamo seed that makes the peccary meat unpalatable for the Kawymeno Waorani. Beyond preventing ingestion by bad taste right from the start, gradual build-up of exposure to phytochemicals eventually trips a physiological wire that causes a feeling of satiation for a particular food flavor, thereby stopping consumption temporarily. Satiation is triggered only after the phytochemical ingredients in these foods reach a certain level in the human body. The person can still be hungry, but the satiated food is avoided while another food is sought.

Satiation has helped humans to naturally balance their diet for eons before nutritionists came along. Satiation does not seem to be working in modern society anymore as evidenced by an increasingly large percentage of the population becoming obese. This dissertation puts forward the case that satiation was partly a property of sensitivity to phytochemical content of foods, which the Kawymeno Waorani still retain, but the Santa Teresita Kichwa and the American consumer have lost. Humans receptors for plant phytochemicals that triggered satiation still exist in human bodies, but the question is what is filling these receptors in the absence of the evolutionarily norm of highly varied scent and flavor phytochemical triggers from wild foods?

Mixing and adding ingredients to foods, which become recipes instead of real food, may also reduce human ability to taste and smell the phytochemical content of their food. Even mixing of simple foods, as occurs in the diet of the Santa Teresita Kichwa, may confuse the human body's ability to distinguish through taste and flavor the phytochemical content of a particular food. Humanity through most of its existence has ingested simple whole foods that were unmixed with other foods. One characteristic of the Kawymeno Waorani hunter-gatherer diet is the tendency not to mix foods in recipes and to eat each separate food by itself, one-ingredient, whole and in the case of plant food often soon after picking, uncooked and unaltered. Even cooking food occurred relatively recently in hominoid history, a half million year ago, although half a million years ago still is long before the recent rise of stable agriculture 10-15 thousand years ago.

How human sensitivity to taste and smell alters microbe populations in the human body. Among other physiological interactions, this dissertation makes a case that a more subtle sense of taste and smell of foods was originally a guide to ingesting an optimum plant defense chemical anti-microbial and anti-parasitic diet that prevented infectious disease. Antimicrobial phytochemicals themselves or phytochemicals associated with antimicrobials have distinct flavors and smells that animals may have developed the ability to sense and thus ingest these antimicrobial compounds for their own use. This loss of the ability to sense the microbial content of food may effect the balance anti-microbial dietary intake may be an underlying cause of disease in agricultural societies. Recall the conversation about the attractive aromatic smell of edible plant phytochemicals

saponins and tannins I had with Dr. Wink in personal communications earlier in the chapter. This theme is elaborated on further in the next chapter describing the health outcomes resulting from the transition to agriculture and including the loss of these natural antimicrobials in the human diet.

Evidence that phytochemicals are passed along food chains. As the peccary example demonstrates, this dissertation makes the case that phytochemicals are passed down food chains in the same routine manner as nutrients. However, beyond signaling scents other properties of phytochemicals such as anti-microbials, anti-parasites and antioxidants that have a major impact on human health, are passed through the food chain from their plant species origins to animals that eat these plants (such as peccary), and in turn to humans that eat these food animals. In the case of most plant phytochemicals, it is difficult to note empirically the trail of phytochemicals through the food chain from plants to animals to humans as there is often no easy way to trace the biochemical passage via blood tests or other physical evidence. However, phytochemical transfer down the food chain is documented in this dissertation though easy to trace scent biomarkers of unmistakable signature smells of certain phytochemicals that maintain their scent along the food chain from plant to animal consumers. The human sense of smell is a reliable empirical tool and perhaps the best way to gain knowledge about the language of plants. The language of plants extends into animals tagged or influenced physiologically through phytochemicals. Humans may unconsciously perform certain behaviors due to a plant scent they are not even aware of existing and influencing them. Scents cause animal action as the

graphic example of a plant phytochemical scent motivating one animal to kill another demonstrates (Alborn et al 1997). Also, animal foods contain physiologically activating phytochemical origin compounds. Perhaps researchers may be able to sensitize themselves to "read" the plant signals, like the Kawymeno Waorani can read the smells and flavors of their ecosystem, which would promote better understanding of the dynamic interaction between plants and humans.

Driving human food consumption: phytochemicals create food preferences. There is evidence of a phytochemically driven food chain present in hunter-gathering food systems. The term "phytochemically driven food chain" means that food animal species are eaten preferentially and seasonally because the given animal species was tagged with phytochemical odors from the plants they ingested. This scent tagging is an intentional plant survival strategy to assure the spread of its seeds and maintain a food chain structure that includes animals that will be willing and available during the season the plant flowers and fruits. Seed dissemination is no doubt only one of many reasons animal foods are tagged with plant scents. Plants compete with each other to secure symbiotic relationships with animals, thus are constantly evolving more appealing scent and flavor lures to get more animal cooperation than their plant competitors. Thus, the stronger and more volatile the plant scent the more likely to create animal obedience against other competing plant scents.

To a much greater degree than in an agricultural system, plants in a hunter-gatherer food system are like master puppeteers manipulating animal and

human behavior via phytochemicals the plant has chosen to provide to the animals. To use a metaphor: there is no need for a snake to tempt Adam and Eve in this Amazon rain forest Garden of Eden. The "apple" tree functions very well on its own by tempting humans with its chemical arsenal. Rather than being a destructive force, it is in the interest of the plant that animals continue to survive, thus nutrients are provided in fruit. This dissertation builds the case that plants also deliberately provide phytochemicals in fruit that have positive preventative health benefits for the animal (such as antimicrobials) to ensure animal survival. The Santa Teresita Kichwa have left the Amazon Garden of Eden and its pharmaceutical helpers, and like populations in modern food systems, have struck out on their own trying to create a synthetic and domesticated Garden of Eden – with mixed results – right next to the original pristine garden the Kawymeno Waorani live in. This dissertation study provides a peek into both gardens.

CHAPTER 12

HEALTH OUTCOMES I: DEALING WITH CONFOUNDING FACTORS

> *"The old Waorani woman was lying in the hammock when Chus passed by. She hit him in the testicles with her hand. All the Waorani laughed and told him to run. Chus jogged outside just for fun, after all, the woman was 72 years old. To his surprise she sprang up and sprinted after him and Chus took off running, but to his surprise the old woman ran so fast she caught up to Chus running full speed. Chus is a young man and a tough jungle guide in top physical condition. He was astounded that a 72-year-old woman could run faster than he could, as we could tell from his expression, when she hit him in the testicles while he was sprinting".*
> (Field Study Journal, Douglas London, August 5, 2009)

The above excerpt from my journal is a typical and everyday normal depiction of a Kawymeno Waorani in advanced age. Kawymeno Waorani retain excellent health into old age with no signs of the chronic diseases that face most elderly in Western society. I spent many hours doing athletic activities with another "elderly" warrior, KI the chief of Kawymeno, who although 72 years old, plays sports with the teenagers, hunts with deadly accuracy and is the undisputed leader in Kawymeno. Indeed KI can athletically outperform many Western 20 year olds and is still feared as a warrior. KI still demonstrates excellent decision-making skills and shows no sign of neurological impairment. KI, his wife (62 years old) and his brother (58 years old), and indeed all the older members of

Kawymeno, are in excellent physical condition, with no chronic or infectious diseases. The blood pressure of these three older Kawymeno Waorani is very low and measured respectively at KI (89/61), HT (99/65) WO (91/55). In addition all three have the same 20/20 visual acuity they had as children. All three are athletic, participate in sports, hunt, run and canoe. No one in Kawymeno has died of diseases typical of old age since its foundation several decades ago. While the group of older Kawymeno Waorani is a small sample, this elderly group is not a selected sample in that all of them are in remarkable health and none of them have died.

Data on three people is only relevant when it is a consistent part of the health patterns of the whole Kawymeno Waorani population. This chapter reviews some of the remarkable Kawymeno Waorani consistent health characteristics that do not change with advancing age, and compares them with the neighboring Santa Teresita Kichwa agriculturalists. This dissertation makes the case that the absence of disease is related to the Kawymeno Waorani hunter-gatherer dietary intake of wild varied phytochemicals, which if true, has significant health policy implications for agricultural scientists, nutritionists and government policymakers.

Dietary intake of phytochemicals in turn leads to transfer of some of these phytochemicals into longer-term biochemical residence throughout mammalian body tissue, including the eye, liver and brain where they may have a steady and long-term impact on mammal and human physiology (Andres-Lacueva et al 2005, Kalt et al 2008, Matsumoto et al 2006). Interventional and clinical studies indicate

that fruit phytochemical consumption reduces cancer (Bub et al 2003), improves immune functioning (Bub et al 2003), improves age-related disease affecting neurological functioning (Youdim 2000, Joseph 1998, Bickford 2000), improves urinary tract health (Kiel et al 2003, Kontiokari et al 2001, Strothers et al 2002), lowers blood pressure (Erlund 2008, Grassi et al 2005, Peng et al 2005, Ruel 2008, Taubert et al 2003), prevents and even reverses of age-related eye diseases such as glaucoma, cataracts and age-related macular degeneration (Beaty 2000, Beit-Yannai 2007, Fernandez and Ashari 2008, Head 2001, Ko et al 2005, Ohira et al 2008).

An overview of these Kawymeno Waorani health life span consistencies contrasted with the Santa Teresita Kichwa farming group health characteristics is found in the detailed Health Summary Table (below), which demonstrates the lack of chronic disease, debilitating health conditions, and few manifestations of infections other than those brought in from the outside. In this chapter, beyond just comparing with Kichwa farmers Kawymeno Waorani health is also compared to outside groups such as other hunter-gatherers worldwide as well as modern agricultural populations.

Table 9. Summary Table of Overall Health Status, Diseases, Health Indices and Factors Related to Disease: Kawymeno Waorani Hunter-Gatherers and Santa Teresita Kichwa Farmers. 2010

Factors	Kawymeno Waorani	Santa Teresita Kichwa	Variation
Lifestyle and Environment			
Total Population	121	321	Different
Natural Environment	Amazonian Center of Yasuni National Park	Amazonian Fringes of Yasuni National Park	Similar See Population Chapter
Isolation from outside world	Extremely isolated. Very difficult for outsiders, including neighboring Waorani to get in. Several day canoe trip.	Isolated requires boat travel. Rarely visited by outsiders.	Some difference See Population Chapter
Environmental Contamination by humans	One of the few places in the world with virtually no human contamination	Vast wilderness for hundreds of miles. Occasional boats on river.	Similar See Helminth Chapter
Sanitation: water, latrines, sewage etc.	None other than some toilets left by oil company teams that are	None other than some latrines built by public health	Similar See Helminth

Factors	Kawymeno Waorani	Santa Teresita Kichwa	Variation
	not used.	projects	Chapter
Heavy Exercise/Activity hours per week	24	21	Similar See figure on exercise this chapter
Water source	Pristine primary rain forest rivers, streams, rainwater	Remote rain forest rivers, streams, rainwater	Similar - See figure this chapter
Health Measurements and Vital Signs			
Blood pressure	One of the world's lowest recorded BP levels.	Generally very low but 4% of population had high BP by AHA standards.	Different – see this chapter
BMI (Body Mass Index)	24.5 kg/m2 men (n= 28) 24 kg/m2 women (n=14)	24.9 kg/m2 men (n= 54) 23.0 kg/m2 women (n=24)	Similar: both populations in good physical condition

Factors	Kawymeno Waorani	Santa Teresita Kichwa	Variation
IgE Antibody Levels	World's highest recorded 11.850 IU/ml (Kron, 2000)	High by Western standards but 1ow by Waorani standards 2964 IU/ml (Kron, 2000)	Different (Note: Western norm less than 100 IU/ml)
MUAMC (Mid-upper arm muscle circumference) male population average	23.27 cm	24.19 cm	Similar - both groups have well developed muscle tone
MUAMC (Mid-upper arm muscle circumference) Female population average	19.34 cm	22.22 cm	Similar - both groups have well developed muscle tone
Maternal mortality during childbirth	None since community founded 25 years ago	Present – in study family medical histories	Different

Factors	Kawymeno Waorani	Santa Teresita Kichwa	Variation
Child mortality after birth through 3 years of age	0% (0 out of 62)	4.4% (7 out of 157)	Different
Breastfeeding infants	Communal infant breastfeeding by many women typically up to 3 years old	One mother to one infant private breastfeeding typically up to 3 years old	Different – (single vs. multiple sources of breast milk)
Medicinal use of plants to treat disease	Less than 20 medicinal plants -sporadically used	Some medicinal plants consumed daily. Hundreds of remedies	Different
Death due to medicinal plant overdose	None	Common	Different
Use of modern human-made pharmaceuticals	None	Uncommon	Different
Average Population Body	Lower than biomedically accepted	Same as modern populations	Different

Factors	Kawymeno Waorani	Santa Teresita Kichwa	Variation
Temperature	human norm		
Genetics	Genetically isolated. (See Watkins 1992) However, comparison across Waorani groups suggests lifestyle/dietary rather than genetic explanations for health differences	Not genetically isolated	Different
Average population age in years	22	44	Different
Chronic Diseases			
Chronic disease presence	No chronic diseases in population	Some present - cancer, diabetes, heart disease, high blood pressure,	Different

Factors	Kawymeno Waorani	Santa Teresita Kichwa	Variation
		neurological disorders.	
Heart disease	Absent in community	Present	Different
Cancer	None	Several deaths from cancer in Santa Teresita Kichwa	Different
Diabetes	None	Low- local hospital recorded 40 diabetes cases in all 10 lower Napo River Kichwa communities in 2010.	Different
Death from hernias	Only one hernia in community. No deaths.	Common - 3 deaths recorded	Different
Eye disease/vision problems	Visual acuity does not change with advancing age	Visual acuity deteriorates with age	Different (See section this chapter)
Anemia	None	Possibly some	Different

Factors	Kawymeno Waorani	Santa Teresita Kichwa	Variation
		iron deficiency, perhaps due to large infestations of leishmaniasis and parasites	
Broken Bones	Very rare in spite of common traumatic injuries	Present	Different
Cysts	Present	Common	Different
Inflammatory reaction to endemic allergens	Largely absent	Present	Different
Infectious Diseases			
Death due to infectious disease	Only one death due to infectious disease in community in 15 years - hepatitis	Common	Different
Pneumonia - viral & bacterial	Rare to absent historically	Common cause of death	Different
Staphylococcus aureus infections	Absent in community- unusual characteristic	Common	Different

Factors	Kawymeno Waorani	Santa Teresita Kichwa	Variation
Streptococcus infections	Absent in community- unusual characteristic	Common	Different
Rheumatic Fever –post streptococcus infection	None in history of community –unusual characteristic	Present – recorded in study medical histories	Different
Time wounds stay infected/inflamed. Presence of staphylococcus aureus infection	Minor and even serious wounds rarely become infected or inflamed at all–unusual phenomena	Wounds stay infected for extended periods of time	Very Different
Tuberculosis (introduced to region)	Present - 3 cases in last 2 years – no deaths in Kawymeno. Apparent remission/asymptomatic without long-term drug treatment	Present - common cause of death historically and today	Similar
Fungal pneumonia	Exists – may have to do with dynamics of unusual absence of	None recorded but may exist	Different

Factors	Kawymeno Waorani	Santa Teresita Kichwa	Variation
	competing bacterial infections		
Fungus skin infections	Common, particularly on scalp–may have to do with absence of competing bacteria	Present but to a lesser degree than Kawymeno Waorani	Different
Tooth problems	Common - may have dietary cause but they still have most teeth	Common –more tooth loss	Similar
Hepatitis (introduced to region)	One case in 15 years	Common- 3 deaths recently	Similar
Leishmaniasis (endemic)	Complete absence presently & historically	Common - 33% of population have been effected	Different
Falciparum malaria (introduced to region) Vivax malaria	Falciparum malaria – recent appearance Vivax malaria -absent historically yet endemic to region	Both Falciparum malaria and Vivax malaria are common. Present since founding of	Similar Falciparum Difference Vivax

Factors	Kawymeno Waorani	Santa Teresita Kichwa	Variation
(Endemic to region)		community in 1960s	
Urinary disease/problems	One case – cause unknown	Very Common	Different
Venomous Snakebites – many species present around Kawymeno	Almost half of Kawymeno Waorani population already bitten by venomous snakes Some venom resistance – No deaths, short disability Historically Waorani hold record for highest mortality rate in the world due to snakebite	High Kichwa fatality rate and disability rate than Waorani, yet much lower % of the Kichwa population actually bitten.	Different – see this chapter
Neurological, Developmental and Psychiatric Disorders			
Developmental disabilities	None in population historically and today - Note: selective infanticide may be	Present – incapacitating disorders: Down's Syndrome,	Different

Factors	Kawymeno Waorani	Santa Teresita Kichwa	Variation
	practiced at birth	deafness, dumbness, mental retardation	
Depression	Absent in population	Common	Different
Epilepsy	Absent in population	Present – grand mal	Different
Homicide	No homicides within community except possible infanticides – however violent fights with outsiders still occur	Homicides present within community. Eight homicides recorded in family medical histories	Similar
Stress Level	Low	Medium	Some differences - see this chapter
Migraines	Absent in population	Present	Different
Suicide	Absent in population	Present	Different

Objectives Health Outcome Chapters 12-16

The point of this first health outcome chapter is, first to provide evidence that indeed there is a large difference in human health across these hunter-gatherer and subsistence agricultural food systems, and second that phytochemical intake can account for these health differences better than competing explanations.

In this chapter, evidence of the effect phytochemicals in the diet have on microbial disease, parasitic disease and chronic illness is laid out and discussed. The impact of phytochemicals on human physiology is as wide-ranging and diverse as the myriad of chemical structures and bio-chemical mechanisms of phytochemicals themselves. A few of the many examples of the dynamic, mutually beneficial health outcomes associated with contact between human physiology to plant physiology were touched on in the previous food system chapters. Beyond these upcoming Health Outcome chapters detailed case studies are provided to back-up the Health Outcome chapters including a critique of the helminth hypothesis and phytochemicals control over parasitic worms that inhabit human bodies (chapter 18) and plant human phytochemical dynamics that relate to human hormonal systems are discussed starting in chapter 23.

The health results of the Kawymeno Waorani and Santa Teresita Kichwa in this dissertation chapter are among the most interesting and unusual in this dissertation study. While particularities of individual food systems in different cultures will vary, this dissertation makes the case that plant-human relationships have commonalities that apply to cultures everywhere on the planet. Cultures may ameliorate what plant – human evolution imposes on them by varying their food

system. However the universal realities and limitations set by plant – human co-evolution apply to all humans starting from the plant produced air we breath and all the plant based food we eat, down to the diseases we contract and the way our human physiology functions in concert with plant phytochemicals. The later two subjects are the focus of these health outcome chapters.

Kawymeno Waorani Do Not Die of the Chronic and Infectious Diseases That Take the Life of Modern Humans

The Kawymeno Waorani health data results of this dissertation are unusual, but consistent with earlier researchers' observations of Waorani health at the time of the Waorani's first sustained contact with the outside world. Namely, that in the 1970s and historically, Waorani rarely died of infectious disease, chronic disease or diseases associated with old age, and the elderly remained in remarkably good condition (Yost 1981, Larrick et al 1979, Davis and Yost 1983, Kaplan et al 1979, Kron 2000). Yost discusses the cause of death of Waorani going back several generations and concludes that older Waorani rarely died of diseases associated with advancing age in Western societies (Yost 1981). Only a few percent of the Waorani population died of anything that resembles the types of chronic or infectious diseases that take the lives of Westerners (Yost 1981). Rather, deaths occurred through accidents, as well as homicides due to invasion of outsiders in addition to inter-tribal combat.

Confounding Factors

Exercise and genetics appear not to be significant factors in the health outcomes in this dissertation. The large health differences between Kawymeno Waorani hunter-gatherers compared to acculturating Westernizing Waorani

indicates that the maintenance of exemplary Kawymeno Waorani health is brought about by lifestyle and dietary factors, rather than genetic factors. Both Kawymeno Waorani and pre-contact Waorani have similar outcomes to each other, but vastly different health outcomes than the Westernizing Protectorate Waorani. The health of Protectorate Waorani, three decades after regular contact and acculturation to Western food systems, resembles the surrounding modern Latino and indigenous agricultural groups. There are numerous researchers working with the Protectorate Waorani, but their research no longer focuses on health, because the unusual health aspects are no longer present in these acculturating Waorani, as obesity and other chronic diseases begin to appear regularly. This is discussed in other chapters. More research comparing Protectorate Waorani to Kawymeno Waorani will solidify this argument regarding genetics, and since the data is readily available will be followed up in post dissertation study.

Genetic differences as a possible explanation for Kawymeno Waorani hunter-gatherers unusually healthy outcome are discussed in the chapter on populations. The genetically identical Westernizing Protectorate Waorani have a poor health outcome suggesting lifestyle and food system rather than genetics plays the central role in explaining the health outcome differences between both groups of the Waorani. Indeed, like the Protectorate Waorani, almost all, if not all, global hunter-gatherer studies that followed the particular hunter-gatherers through their transition to agriculture observed deterioration in health related to the lifestyle change and not genetic characteristics of individual hunter-gatherer

groups. Since all modernizing hunter-gatherers have had similar negative health outcomes when transitioning to farming, indicates that likewise the genetic component of the Waorani is not a significant factor that changes their health outcome circumstances.

Dissertation evidence builds a case that diet plays a much larger role than exercise. The lifestyle factors of exercise and stress in the Kawymeno Waorani hunter-gatherers and the Santa Teresita Kichwa farmers are discussed in this chapter. Furthermore, it was and will be demonstrated in previous and upcoming chapters (particularly the population and helminth chapters) that environment, access to health care, isolation, non-phytochemical dietary intake, and other factors that affect health, are quite comparable between the Kawymeno Waorani and Santa Teresita Kichwa. In contrast, as demonstrated in the previous food system chapter, dietary intake, particularly wild varied phytochemical intake, is very different across the Kawymeno Waorani hunter-gatherers and Santa Teresita Kichwa, while factors such as exercise are comparable. In other words, other lifestyle and dietary variables that affect health are similar in the two populations. The only major difference is phytochemical intake, making phytochemicals a more probable cause of health differences than traditional nutrients and lifestyle factors.

Ruling exercise out as a significant health outcome factor in this dissertation study. This dissertation shows these two study populations are equally physically fit, but not equally healthy. Many articles discuss the superior physical condition of hunter-gatherers as a principal differing factor between

hunter-gatherers and modern populations. This study demonstrates that while physical condition is important for health maintenance, physical fitness is not an explanation for the large health differences between study hunter-gatherer and agriculturalist populations.

A summary of the control of confounding factors discussed in other chapters is provided here, but readers need to refer to other parts of the dissertation for details. This section takes a more detailed look at exercise and stress, which were confounding factors not covered in detail previously. Exercise is a factor cited by most studies as a principal explanation for health differences between hunter-gatherers and modern humans. The case is made in the food system chapter that human physical condition, including obesity, is driven by phytochemical interaction with human physiology not lack of will power, and that exercise is a symptom rather than a factor in itself. This chapter lays out the rationale and evidence to support it, that in the comparison across these food systems, exercise is largely ruled out as a significant health factor. Evidence of parity of hours of rigorous activity per week and physical fitness across both study populations is demonstrated through BMI and exercise measurements and participant observation of activity levels. There is no significant difference in level of exercise or indicators of physical fitness between the two populations, therefore exercise is not likely a major factor accounting for health differences.

The idea that a hunter-gathering lifestyle is one of constant physically demanding labor has been shown by Lee in his study of the Kalahari bushman to not necessarily be the case (Lee 1968). Both Waorani hunter-gathering and

Kichwa farming study groups were very active for roughly the same amount of time a week. However, as the figure in this chapter shows, more of the Santa Teresita Kichwa farmers' activity hours are geared to farming while the Kawymeno Waorani hunter-gatherer hours of activity are more leisure than struggling for survival. Farming can be more demanding physically than hunter-gathering because of the constant daily hours of work to assure crop survival. Certainly the Kawymeno Waorani had more time for leisure activities. A small group of 6 or 7 hunters who go out a few times a week can keep the whole community of around 125 members supplied with mammal, fish, bird and reptile foods. On the other hand, the Santa Teresita Kichwa are tied to their gardens day in and day out and any let up in agricultural care of their gardens and animals could have serious dietary intake and survival implications for the entire community. This is a source of stress for these farmers.

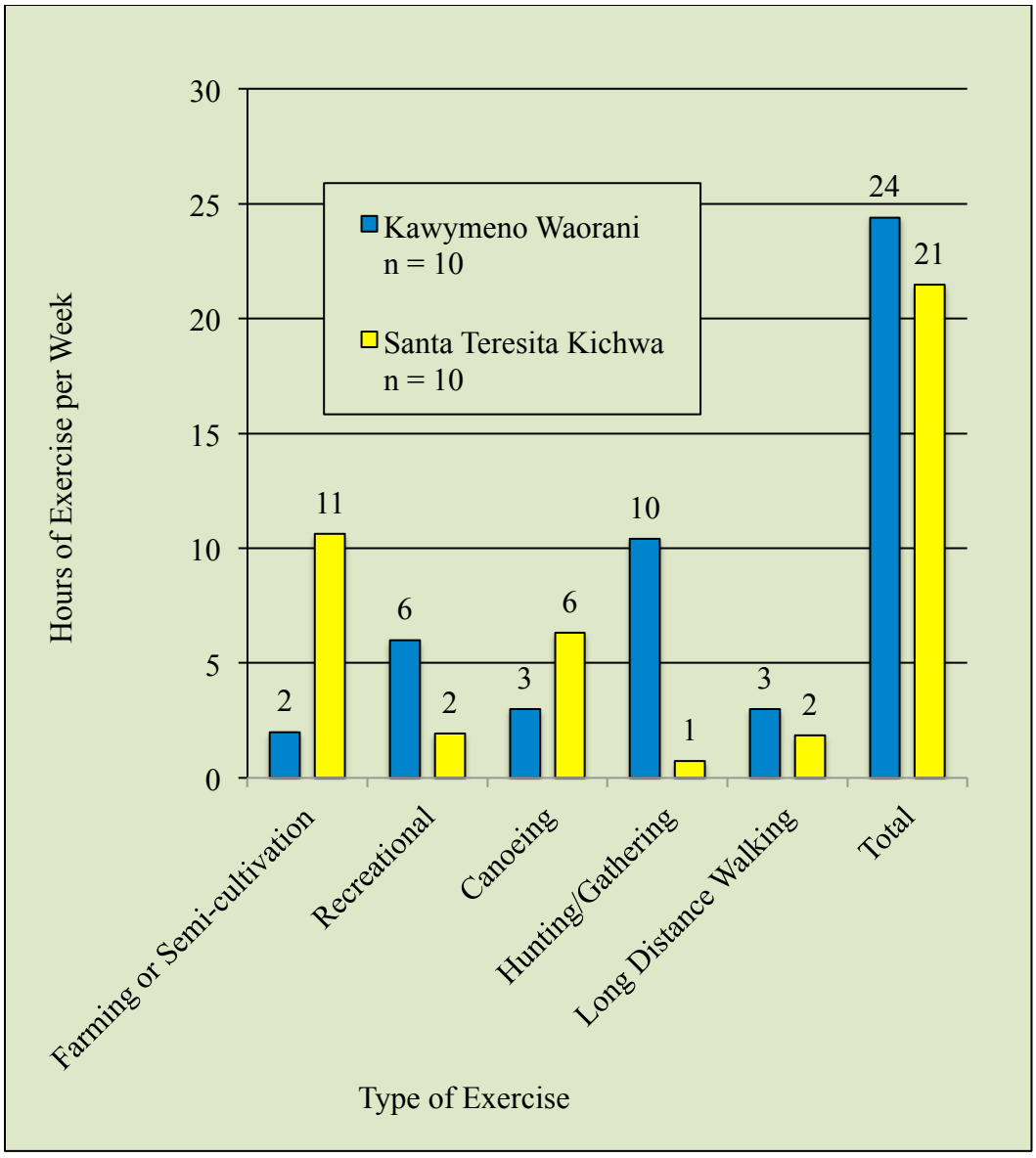


Figure 28. Hours of Exercise per Week: Kawymeno Waorani vs. Santa Teresita Kichwa. 2010

However, aside from quality of life issues associated with the way in which exercise is achieved, the actual average number of hours per week both Kawymeno Waorani and Santa Teresita Kichwa were very active is similar. The Kawymeno Waorani have just a few more hours a week of activity per person.

I recorded the amount of daily exercise for 10 members of each community by following them around during their daily activities. I then asked them at the end of the day of tracking to tell me how they spent their day and how typical was this pattern. Hours of exercise recorded were rounded up or down, 30 minutes past the hour and below were rounded down and time beyond the half hour was rounded up. However, after a year of participant observation I already have a good idea of typical activity patterns of both groups. I participated in many Kawymeno Waorani and Santa Teresita Kichwa activities several times over the year, which also helps to confirm the accuracy of the amount of hours of daily activity. Pedometers were also attached to participants, but since farming, canoeing and many other activities do not register equally the pedometer results only serve as indicators of walking.

In sum: both groups were physically active for approximately the same number of hours a week.

Average time of physical activity for the Kawymeno Waorani was 24 hours a week including canoeing, walking, hunting, gathering, sporting activities. Average hours of activity a week for the Santa Teresita Kichwa was 21 hours, which included gardening, walking, canoeing and sporting activity. Compared to a Western 40 hour work-week, hours of activity of both study groups are equivalent to half-time jobs.

The Kawymeno Waorani tended to go out in the morning to hunt, fish and gather and be back in Kawymeno by early to mid-afternoon, working 5-6 hours, 2 to 3 times a week. Beyond these hours most of the other active hours were spent

canoeing, walking and engaging in sporting activities that can be viewed as leisure activities. Canoeing was also often part of recreational activities. In the case of some of the Kawymeno Waorani males and some females there would be a tendency to do long distance trekking for a day or so every few weeks, which would push the exercise hours up a bit.

The Santa Teresita Kichwa were easier to follow because they usually stayed close to home. The Santa Teresita Kichwa hours of activity were more work oriented, 3-4 hours in the garden for 3-4 times a week. Canoeing was not a leisure activity and meant negotiating and canoeing upstream in the Napo River, which is almost a half-mile wide in some places with an extremely fast and dangerous current. The Yasuni River used by the Waorani can be crossed by a strong swimmer, a feat virtually impossible in the Napo River.

Comparable BMI (Body Mass Index): Measuring physical condition of study hunter-gatherers and farmers. Comparison of BMI across Kawymeno Waorani and Santa Teresita Kichwa, combined with activity measurement, confirm the Kawymeno Waorani hunter-gatherers and the Santa Teresita Kichwa farmers are equally physically fit and get a similar amount of exercise per week. BMI is a proxy for measuring the percent of the human body that is fat, utilizing just a person's weight and height. BMI measures are designed to determine the relative obesity of a whole population, but although perhaps inappropriate has also become popular with bio-medical doctors to measure individual patient physical fitness.

The dissertation study recorded the weight, height, age, birth date, vision (Snell Chart), triceps skin fold, arm circumference and body temperature of both populations. Measures for physical fitness were derived from these anthropometric measurements.

Body Mass Index (BMI). The expectation was that the hunter-gatherer group would be in better physical condition than the farmers. Indeed, the Kawymeno Waorani hunter-gatherers are in top physical condition. BMI figures indicate very comparable physical fitness in both populations. Neither group was overweight.

BMI figures for compared across the Kawymeno Waorani hunter-gatherers and Santa Teresita Kichwa farmers were age and sex stratified. Measurements were similar when divided across age and sex categories of both study groups as figures in this chapter show. One can refer to the age adjusted charts comparing BMI in men and women across Kawymeno Waorani hunter-gatherers and Santa Teresita Kichwa farmers.

The only male age group that differed more than a point between the Santa Teresita Kichwa and the Kawymeno Waorani was males ages 18 to 29, and only by 2 points. Overall, the population average Kawymeno Waorani and Santa Teresita Kichwa male BMI figures were 25 kg/m2 for the Kawymeno Waorani men and 24.9 kg/m2 for the Santa Teresita Kichwa men.

The only female age group that differed more than a point between the Kawymeno Waorani and the Santa Teresita Kichwa was females 40 to 49 years old, although the difference was only 3 points. As the age and sex stratified chart

shows the overall BMI was 24 kg/m2 for the Kawymeno Waorani women compared to a BMI of 23.0 kg/m2 for the Santa Teresita Kichwa women.

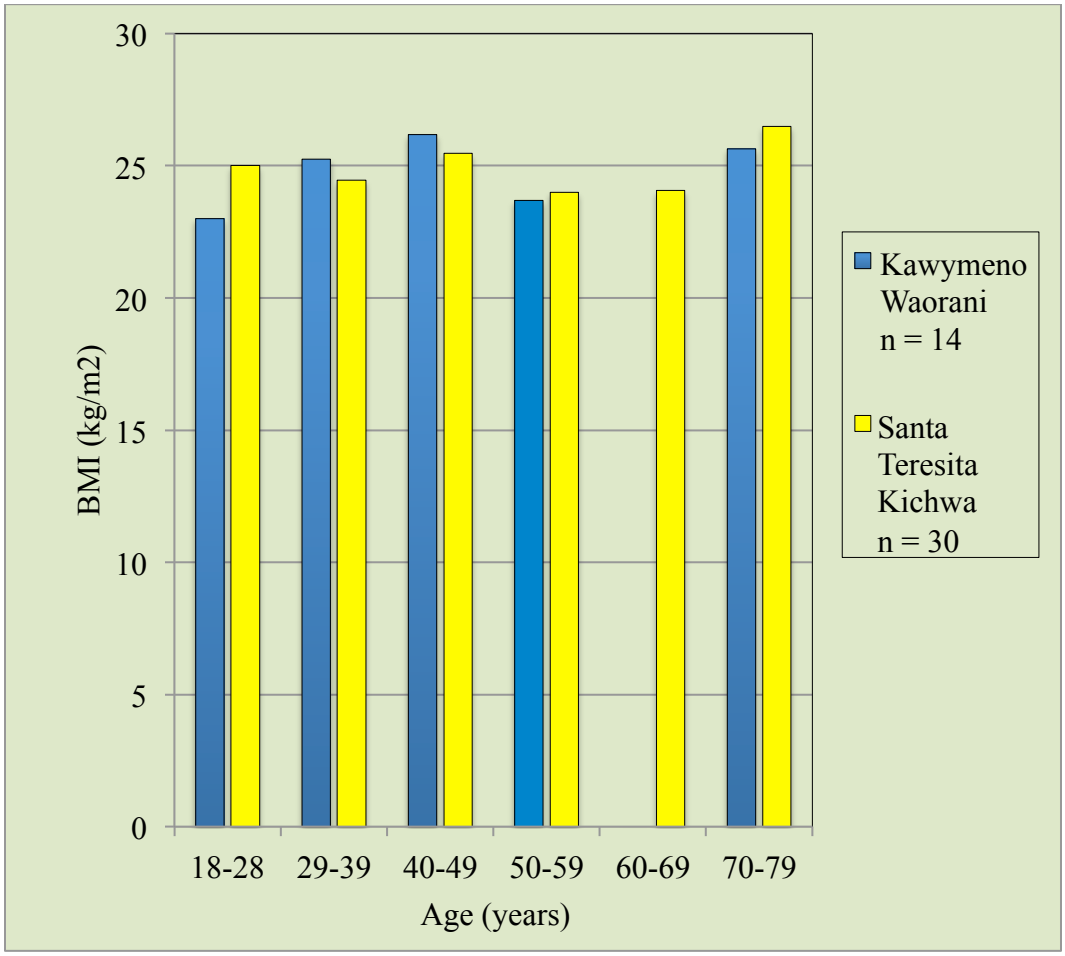


Figure 29. Average Body Mass Index (BMI) Kawymeno Waorani vs. Santa Teresita Kichwa, Age-and Sex-Stratified Male Populations. (statistical analysis in Appendix H) 2010

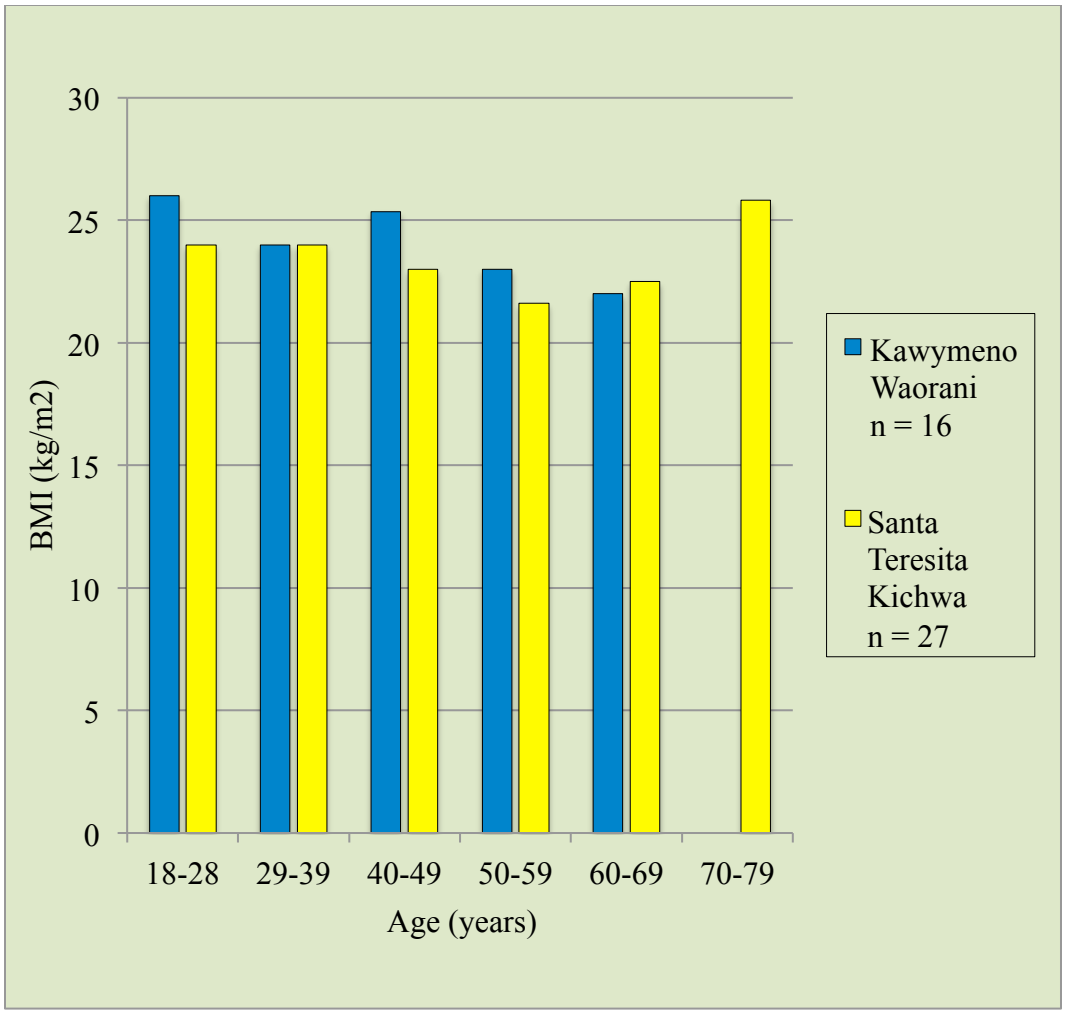


Figure 30. Average Body Mass Index (BMI): Kawymeno Waorani vs. Santa Teresita Kichwa, Age-and Sex-Stratified Female Populations. (statistical analysis in Appendix H) 2010

A year of participant observation, in which I engaged in all the exercise-related activities measured in the study, gives me an excellent idea of the physical effort required by both groups in their daily routine. Participant observation corroborates the more quantifiable measurements of BMI and activity levels. There is a general parity of exercise and physical fitness between both the hunter-gatherers and the farmers in this study.

This dissertation recorded Kawymeno Waorani red meat consumption from a pound to a pound and a half many days of the week. Surprisingly in-spite of this heavy red meat consumption Kawymeno Waorani population BMI measurement average for males and females is below the cut off for overweight usually considered around 25 kg/m2. In addition, the Kawymeno Waorani showed no sign of protein poisoning which might be expected with this level of meat consumption. However, dealing with nutritional non-phytochemical aspects of the Kawymeno Waorani diet, such as protein poisoning, is beyond the scope of this dissertation.

Other hunter-gatherer groups around the world in general are not overweight (personal communication with Loran Cordain, Department of Exercise Science, Colorado State University). The Kawymeno Waorani hunter-gatherers population BMI averages are similar to the Kren-Akorore Amazonian rain forest hunter-gatherers of Brazil when they were measured for BMI, a few years after the Kren–Akorore first sustained contact with the outside world (Baruzzi 1977).



Figure 31. Musculature of Kawymeno Waorani Hunter-Gatherer

Being able to control for exercise and physical fitness is a major advantage of this dissertation study design, which uses a comparison between a subsistence

agricultural group that has a very similar level of physical fitness as the hunter-gatherer group. Most theoretical and secondary data source studies by ancestral diet specialists compare between hunter-gathering groups and Western or industrialized societies, where obesity and lack of exercise are commonplace. A study that compared hunter-gatherers to modern societies would never be able to put the confounding factor of exercise to one side when discussing causes for health outcomes as the exercise and physical fitness differences are so great. Thus, with no real proof researchers have assumed exercise played such a major role in the difference in health outcomes across hunter-gatherer and agricultural systems while this study shows that when exercise is held constant the large, across the board health differences between hunter-gatherers and agriculturalists are still present.

If this dissertation study had used the acculturating westernizing protectorate Waorani as a comparison group, while helping control for genetic factors, this study would not be able to control for exercise, as visits to the protectorate showed many clearly obese individuals. Thus, while a parity of physical condition was not expected across the hunter-gatherers and subsistence farmers, this parity allows this dissertation study to control for the confounding variable of exercise and physical condition so the study focus on dietary comparison has more validity.

Review of control for confounding factors covered in other chapters: environment, isolation, genetics, sanitation, access to health care, similar or different regional pathogens and contact between study groups. This study tries to control for both confounding factors that may improve health, such as exercise, as well as confounding factors that can affect health adversely (contaminated drinking water etc.).

The Kawymeno Waorani hunter-gatherers and Santa Teresita subsistence farmer communities are both indigenous groups living in the same uncontaminated rain forest, isolated from the modern world, lacking access to basic Western health care and lacking sanitation facilities. In addition, neither group has entered the Ecuadoran monetary-based economy and associated lifestyle, nor has contact with outsiders. Nor has either has entered the modern food system, although the Santa Teresita Kichwa buy a few items from the local store. Neither group has much access to clean water, sewage, electricity, forms of modern communication, transportation, or health care.

Both these isolated but neighboring hunter-gatherer and farming study groups share the same environment. Both groups produce almost everything they need themselves. Most modern life factors are not present in either Kawymeno Waorani or Santa Teresita Kichwa study groups. The reduction in confounding variables allows this study to rule out confounding factors that a study on hunter-gatherers and modern populations would not be able to control for. All this is discussed in the population, food system and helminth chapters. Differentiating the potentially confounding effect the dietary intake of nutrients versus intake of

phytochemicals has on study health outcomes is discussed in the conclusion of the dissertation as this topic pertains to the critique on nutritional science presented.

Finally and importantly due to fear and mistrust between the two study groups, both food systems are completely separate functioning units with almost no contact with each other. Contact would have added additional confounding variables.

Age difference across study groups. Health results that typically vary with the age of the population have been age stratified to compare across age groups rather than whole population averages. The Santa Teresita Kichwa have an older population, an average of 44 years old while the Kawymeno Waorani have a younger population with an average of 22 years old. The age of the population obviously can affect population chronic and infectious disease measurements, but age stratification allows a look across age groups rather than whole populations.

Drinking water sources across study groups. Both the Kawymeno Waorani and Santa Teresita Kichwa drinking water sources are compared in the figure in this chapter. Both Kawymeno Waorani and Santa Teresita Kichwa use the same drinking water sources, although in different proportions, but are essentially exposed to the same pathogens and contaminants. Neither group has access to bottled, piped or treated water, thus, the water comes straight from the natural environment. It is possible by virtue of using more feeder streams, rather than rainwater, that the Kawymeno Waorani drinking water may have a slightly different mineral, and pH level than Santa Teresita Kichwa drinking water. In the end, drinking water sources are comparable for both groups, providing exposure

to similar Yasuni regional rainforest microbial and parasitic diseases while human pollution is limited to self-contamination by the communities themselves. Neither the Santa Teresita Kichwa nor the Kawymeno Waorani use any sanitation system and both groups wash clothes in the river. While the Santa Teresita Kichwa have a few domesticated animals, the Kawymeno Waorani have many wild animal pets, thus both wild and domesticated animal feces are found near both groups households. Population density and subsequent potential per individual to contaminate water is comparable because although the Santa Teresita population is larger, they are more spread out along the banks of the river, while the smaller Kawymeno Waorani are more concentrated together in one area on the river bank.

In sum: health differences across Kawymeno Waorani hunter-gatherers and Kichwa subsistence farmers cannot be accounted by the potentially confounding factors of environment, pathogens and other health hazards such as water, sanitation, access to health care, infrastructure factors, stress, communication, transportation, and isolation because all these factors are similar across study groups. Both groups produce almost everything they need themselves. Neither do genetic factors, exercise or differences in consumption of standard dietary nutrients play a principal role in health outcomes.

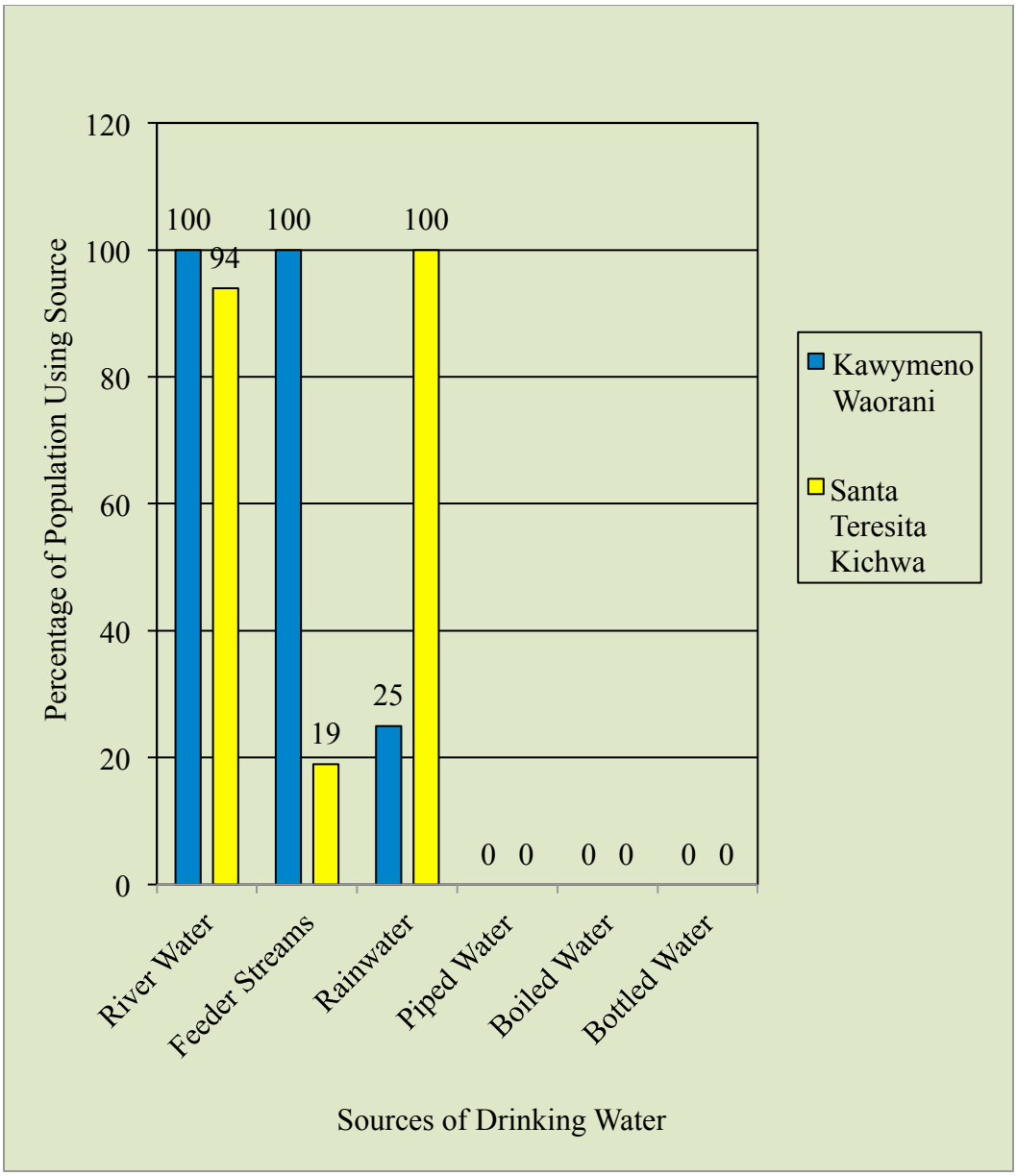


Figure 32. Drinking Water Source Usage by Percentage of Population: Kawymeno Waorani vs. Santa Teresita Kichwa. 2010

CHAPTER 13

HEALTH OUTCOMES II: WHY IS THERE A COMPLETE LACK OF STAPHYLOCCOCAL AND STREPTOCCOAL DISEASES IN THE KAWYMANO WAORANI POPULATION, WHICH ARE OTHERWISE PRESENT UNIVERSIALLY IN MODERN POPULATIONS?

Exercise level and BMI indicators suggest excellent, and on the surface, comparable physical fitness of the Santa Teresita Kichwa to the Kawymeno Waorani, in terms of muscle and fat body content. However, when one turns to other indicators of chronic disease the picture is very different. Chronic and infectious diseases that are very much present in the Santa Teresita Kichwa community are completely absent in the Kawymeno Waorani community. The summary table, which compares indices, diseases and key factors related to disease across the two study populations, shows health differences between the hunter-gatherers and farmers are dramatic, and across the board.

The actual effect of phytochemical intake on health of the Kawymeno Waorani hunter-gatherers and the Santa Teresita Kichwa subsistence agriculturalists is discussed below in a summarized form. Major differences in health across populations are summarized and discussed briefly with a more in-depth look at blood pressure, vision and wound healing.

Previous Health Outcome Studies of the Waorani in the 1970s.

Mortality rates show that no type of disease posed a great threat to the Waorani prior to contact with the outside world. A genealogy of the past 5

preceding generations of Waorani prior to peaceful contact with outsiders showed that Waorani did not usually die from any kind of infectious or chronic disease, but rather from trauma and violence (Yost 1981). Yost's survey taken over 5 years of residence with the Waorani showed that 78% of Waorani mortality was caused by intertribal spearing, violence, snakebite and other trauma, while another 12% of mortality was due to aborted births, stillborn births and infants dying within the first week of life, leaving only 10% of population mortality due to other causes such as infectious and chronic disease (Yost 1981). The dissertation makes the case that dietary intake of phytochemicals played a principal role in the complete lack of many diseases in the Waorani population prior to contact with outsiders. Why phytochemical intake might not initially prevent novel diseases that Westerners introduce into isolated indigenous populations is elaborated on in this chapter. This chapter focuses on endemic diseases like streptococcus and staphylococcus that maintain a constant low-lying presence in many human bodies until a wound or other illness permits them to mount in numbers.

The Tri-Evolution Hypothesis: Resident versus invading microbial pathogens: why phytochemicals may work better with long-term human microbial residents of the human body

Paleolithic hunter-gatherers probably fought a more limited range of infectious diseases than agricultural populations because their small, isolated population size afforded limited opportunities for the major virulent microbial and parasitic killers of modern humans to pass from host to host (Cohen 1989). For example, the measles virus will die out in a small population in a single local unless new victims replace those measles kill off. Anthropologist Francis Black

documented the disappearance of the measles virus from isolated island populations and made a convincing case that measles and other virulent infectious diseases could not have persisted before emergence of large population centers (Black 1966, 1975). Hunter-gatherers probably did not get many outside pathogens that caused quick virulent and deadly diseases, because their small and isolated group size did not permit these pathogens to spread (Black 1975). Therefore, in Paleolithic humans microbial pathogens needed to be able to co-exist in the human bodies for long periods of time without killing their human host. Thus it follows that the human evolutionary norm is daily confrontation with diseases that are carried long-term in humans, while outside virulent pathogens were rare and quickly wiped out available human populations, thus causing these microbes to go extinct themselves.

Modern virulent diseases such as plague, measles, typhoid fever and rabies are probably recent afflictions of large groups of inter-connected agriculturalists. These virulent infections are the type of infections that hunter-gatherers would have had little contact with and thus no evolutionary reason to develop physiological receptors to process the type of plant anti-microbials that specifically dealt with virulent infectious disease.

Thus, the most common afflictions of hunter-gatherer bands would have been chronic infections from microbes that survived a long time in a human host and could be transmitted person-to-person for the lifetime of the carrier, who would be asymptomatic most of the time. These resident microbe pathogens of the human body were probably present in many hunter-gatherer groups and

include staphylococcus and streptococcus bacterial infections which wait until an opportunity arrives, such as a wound, to rise in massive numbers from the small resident colony to infect (Cohen 1989).

There appears to be an absence of any sign of streptococcal or staphylococcal-related manifestation of disease in the entire Kawymeno Waorani population although the microbes are present. Staphylococcus and streptococcus infections are of particular interest to this study. If phytochemical intake can control some of the biggest microbial killers of humans in modern societies (staphylococcus and streptococcus), this has great significance in the battle to control diseases in the 21st century. What if daily dietary phytochemical intake from wild plant foods could prevent the manifestation of many of these deadly long-term diseases from humanity?

Low-grade preventative anti-microbial phytochemical intake found in wild plant food may regulate but not always eliminate microbes such as staphylococcus. Thus, regular intake of wild antimicrobial phytochemicals, while not completely eliminating the human body staphylococcus population, may prevent quick rises in numbers of staphylococcus microbes that can cause diseases in wounds. On the other hand, rapid virulent infections that are from pathogens found outside the human body, and not regularly carried by human hosts, are less likely to be protected by daily low-grade phytochemical anti-microbial intake, and human physiology may not be stimulated to absorb or maintain anti-microbials that are not normally useful in hunter-gatherer groups.

Thus by virtue of their diet, the Kawymeno Waorani hunter-gatherers may be protected phytochemically against diseases that are carried long-term in the body, such as streptococcus and staphylococcus, while at the same time vulnerable to outside pathogens whose contact with humans was rare in human evolutionary history.

Because of the noticeable vulnerability to outside diseases hunter-gatherers have often been branded as universally susceptible to disease. Thus, it has not occurred to researchers that indigenous hunter-gatherer populations may conversely also have invulnerability to other groups of slower acting microbial diseases Westerners and other invading agriculturalist may be vulnerable to. Further, as the indigenous quickly convert to agriculture this invulnerability caused by diet against certain types of diseases may have been missed by researchers, who only see first a hunter-gather population decimated by introduced diseases, then a hunter-gatherer population quickly transformed into a subsistence agriculture population plagued by infectious and chronic diseases.

These resident bacteria living in their human hosts are behind some of the most serious microbial-based infectious and chronic diseases that confront humanity in the 21st century, such as Staphylococcus aureus infections resistant to all human antibiotics, and streptococcus infections that lead to scarlet fever, and rheumatic heart disease. It is known that an imbalance of intestinal microbial populations plays a role in obesity and inflammatory bowel syndrome (Candela et al, 2010). Perhaps auto-immune diseases such as AIDS, Crohn's disease, and

Celiac disease may have microbial factors that could be prevented or controlled through phytochemical anti-microbial intake.

In an age when many virulent outside pathogens can be controlled by vaccines, long-term, resident microbes in human hosts may be more of a priority. The body's immune system has already largely failed with pathogenic microbes that have successfully taken up permanent residence in human bodies. Human-made pharmaceutical options run into microbe resistance much too fast and are much too toxic for lifelong consumption to control staphylococcus and streptococcus microbe populations in the human body. In contrast varied and long-term ingestion of anti-microbial phytochemicals, naturally present in humanity's diet for most of human history, may be able to regulate microbial residents and keep up with development of resistant strains in a way modern human made anti-microbial production cannot.

Staphylococcus and Streptococcus Disease in Paleolithic Hunter-gatherers.

Among the most common afflictions of hunter-gatherer bands were chronic infections from microbes that survive a long time in a single host, in particular staphylococcus and streptococcus bacterial infections, which can be transmitted person to person for the lifetime of the carrier who is often asymptomatic (Cohen 1989). Staphylococcus and streptococcus infections are of particular interest to this study. A unique feature of Waorani health, that is not present in agricultural societies, is the complete absence of any manifestation of streptococcal or staphylococcal related infection in the entire Kawymeno Waorani population. Other remaining hunter-gatherer groups need to be studied to confirm

if this apparent resistance to staphylococcus and streptococcus infections is unique to the Waorani, or common to all humans consuming a phytochemically rich hunter-gatherer diet.

Absence of Staphylococcus in Waorani Wounds Close to Sustained First Contact in the 1970s.

Close to sustained first contact by the Waorani with the outside world scientists from NIH, Duke and Harvard noted a remarkable characteristic of the Waorani, that is, a complete absence of any sign of infection in serious wounds. Having a population with many large serious wounds, such as spear wounds and burns that never show any sign of infection in a bacteria rich tropical rain forest environment defies germ theory.

> *"In eight years among the Waorani, one of us (JY) [James Yost] has observed numerous major puncture wounds, which have not become seriously infected - for example, three incidents in which overly zealous hunters completely skewered their feet on sharp "punji" sticks in the trail. One incredible case concerned the report of a woman who was seriously wounded in a spearing raid. The triangular spear perforated her belly and emerged from her back. The raiders left her for dead, but when her kin arrived, they treated her. Because of the reversed barbs on the spear, they could not risk removing the weapon. Instead, they cut it off back and front and, leaving the remainder of the spear in her, plastered the wound with the standard treatment-mud from the watering hole of the peccary. They carried the wounded woman to her hammock, where she remained for a*

couple of weeks. As the tissue around the wound became necrotic, the woman felt well enough to return to work in the gardens. One day, as she bent over to harvest yucca (Manihot escuelentu), the long spear fragment slipped out. The wound healed over and today the woman has only scars to show for it. Although such an incident is clearly very unusual, it reinforces the numerous other reports of severe spear wounds that healed with relatively few problems. These injuries demonstrate that post-trauma infection was not a severe problem for the Waorani even when complicated by the addition of mud from an animal watering hole."
(Davis and Yost, 1983, p.278)

"In the past spear wounds were a common injury which required extensive treatment particularly since the toxic palm wood spear points were often cut off and left in the wound because the jagged barbs prevented easy removal". (Larrick, et al., 1979, p.171)

Larrick then goes on to describe "treatment" as putting mud from the watering holes of the peccary or alternatively applying termite nests to major wounds.

"Of course those of us trained in the germ theory are surprised that the Waorani are able to survive this treatment. However those who survive the

bleeding caused by spearing usually survive the subsequent treatment. "

(Larrick, et al., 1979, p.172)

The major complicating bacterium in wounds is usually staphylococcus aureus. Dissertation case studies below document the lack of serious wound infection, swelling, redness or fever and or the manifestation of a staphylococcus aureus presence.

Outside Medical Examinations of the Dissertation Study Groups over 10 Years Confirm Dissertation Study Findings.

The dissertation study supported a medical team from Franklyn Tello Hospital in Nuevo Rocafuerte, to do a medical exam on the Kawymeno Waorani. Franklyn Tello is a Catholic hospital located on the lower Napo River study region. This group of doctors has been providing vaccines for the Waorani sporadically for the past 10 years. The Franklyn Tello medical team consisted of 1 doctor, 2 dentists and 2 nurses. The team saw 25 children and 28 adults, half the population of Kawymeno. Children received vaccinations and pregnant women were examined. The medical team was nervous around the Waorani hunter-gatherers because of their reputation for violence and anxious to leave Kawymeno immediately after finishing and indicated they were amazed that we would want to stay alone in the rain forest with the Waorani.

This medical examination was a collaborative effort between the Franklyn Tello Hospital and the dissertation study. I was able to be of assistance to the hospital staff for many months of this dissertation study, particularly with the Santa Teresita Kichwa population and there were a number of collaborative efforts. Having run a rural medical clinic for five years with Harvard Medical

School, I was able to offer skills, including maintaining good working relationships with these indigenous groups, that were useful to the hospital. In the case of the Kichwa, the hospital was able to offer treatment to patients I referred to them.

A reputation for previous violence is one of the reasons the Kawymeno Waorani receive little outside medical treatment. The hospital medical teams rarely visit Kawymeno, although the ministry of public health now includes Kawymeno as part of the riverine Kichwa district, largely due to fear and the reputation the Waorani have of killing outsiders with spears. Indeed a Catholic priest and nun trying to convert the Waorani, who often worked from the Franklyn Tello hospital, were killed by the Waorani in a well-known case a number of decades ago. The Waorani around the same time period also massacred a group of evangelic missionaries. The Franklyn Tello hospital and particularly its director, Dr. Ammunariz, a Catholic priest who has dedicated himself to helping save lives in the Santa Teresita Kichwa Riverine Kichwa region for 25 years, have been very supportive of this dissertation. However, these hospital doctors are reluctant to go to Kawymeno, and in fact we were the first outsiders to have been granted permission by the Kawymeno Waorani to stay in Kawymeno.

In spite of a yearly vaccination being the only form of outside medical care routinely received by the Kawymeno Waorani, there were no serious infectious diseases in the population including streptococcal and staphylococcal based diseases. The doctor noted this was the case every year the team came to vaccinate in Kawymeno. The Kawymeno Waorani hunter-gatherers rarely had

any serious medical problems over the last 10 years. On the other hand, the doctor noted when the hospital medical team visited Santa Teresita Kichwa and other agricultural Kichwa communities nearby, there were many infectious diseases including streptococcal and staphylococcal based diseases absent in the Kawymeno Waorani, again confirming this dissertation study's findings.

Absence of Staphylococcus Aureus and Streptococcus in the Kawymeno Waorani Population.

There is no doubt that exposure to modern staphylococcus strains, including antibiotic resistant strains, has occurred in Kawymeno Waorani after many years of exposure to the outside world. There are Kawymeno community members who chose to leave Kawymeno and were exposed to potential nosocomial anti-biotic resistant microbes during stays in rural and often less than hygienic, Ecuadorian hospitals.

The examples below are case studies from this dissertation study demonstrating a complete absence of infections in wounds that those that believe in the germ theory might say are impossible. A series of case studies is presented below, rather than a single case to provide multiple sources of evidence, because inflectionless major wounds and burns are considered a medical improbability and numerous cases provide more proof.

Further, this dissertation makes the case that lack of infection in wounds was a human norm for those hunter-gatherers consuming a phytochemically rich diet until the advent of agriculture, which then universally and routinely prevented intake of dietary wild phytochemical anti-microbial in agricultural populations.

Case studies documenting absence of any inflammation, redness, fever or staphylococcus infection in serious wounds.

Case 1: The photo below shows a 34-year-old Waorani woman with third degree burns and raw flesh three days after an explosion accident on a motorboat. From the photo one can see exposed inches of raw flesh with no skin covering the wound. I returned from a trip outside Kawymeno to find her with these burns. She is a health promoter trainee of mine learning about disease, but in reality she has a lot she could teach me as the photo shows. Burns are particularly susceptible to staphylococcus aureus infections. As one can observe, there is no inflammation/swelling, no redness, no pus, no signs of infection and there was no fever when I took her temperature. She lives in a house with many pets and animal excretion on the floor and never applied any type of dressing. She also has been out in the jungle gathering with her exposed raw flesh burn wound. This burn healed up in a week with no treatment and with never any sign of infection or inflammation.

The photo of this burn wound provides visual evidence of what I witnessed daily. Kawymeno Waorani wounds, even the most serious wounds such as spear wounds that pass through the body and the spearhead stays lodged in the body, and 3rd degree burns, such as this one, do not become infected in spite of the wounds being covered with excretion, mud and receiving no treatment whatsoever. Isolation or lack of exposure to antibiotic resistant bacteria are a

thing of the past and no longer explain this phenomenon as the Kawymeno Waorani have had too much contact with outsiders.

This indicates either something remarkable is taking place, or as the dissertation thesis suggests, what we are witnessing is actually a human norm. Human wounds in hunter-gathering individuals, with a diet rich in varied phytochemicals, may not become infected due to the high intake of anti-microbial and anti-inflammatory phytochemicals, which prevent fast infectious growth of resident microbes in the host human body such as staphylococcus aureus.

In contrast, Protectorate Waorani that are converting to a Western/agricultural diet no longer have this ability to avoid staphylococcus infections in wounds, which early visiting scientists observed in the Waorani, but believed to be a product of isolation from the outside world in spite of several years of regular Waorani contact with Westerners and hospitals (Larrick et al., 1979, Kaplan et al., 1979).



Figure 33. No Sign of Infection or Inflammation in Kawymeno Waorani Burn Wound After Being Left Untreated for Three Days

Case 2: KU came to me with her 2 year-old daughter who had cut the tip of her finger off with a machete. As the photo shows, the fingertip was severed ¾ of the way and just hanging there. I was sure she would lose the fingertip, the flesh was already turning grey and the wound was gaping. I bribed her, into letting me apply a bandage, with candy that I keep handy for the children. It was enough to keep her from crying even though the finger was chopped. I tightly bandaged the wound without much hope. To my surprise, when I visited the child over the next few days there was no sign of infection, pus, swelling, redness or fever to start with and as the wound closed it was healing. Within a week the wound was hardly noticeable. (See photo). The child had been playing on a mud floor strewn with pet animal excrement, which had soaked through the bandage, which seemed to have no effect on healing.



Figure 34. Kawymeno Wao Child's Finger Wound with No Sign of Infection or Inflammation

This Kawymeno Waorani hunter-gatherer child's fingertip (photo above) was almost severed. During the course of three days, the wound never had any inflammation, redness, pus or signs of infection despite being constantly dirty. The finger healed together with no complications.

Case 3: A complete spear wound perforation of the abdomen, then a head wound, both remained uninfected from start to recovery.

"A 43-year old Waorani man was speared in a dispute and the spear went right through the one side of his abdomen and out the other. Because of the barbs in the spearhead, the spearhead could it not be removed without ripping the flesh apart. Both protruding ends were cut off and the spear was left in the body until it fell out of its own accord a month later. There was never any infection or any treatment. One can still see the scar where the spear went in on the side of the abdomen and where the spear came out through the side of his back. Apparently it did not pierce a vital organ. I talked to many people including the schoolteacher about this wound and they all said this is normal and common.

"I later had the opportunity to treat AP myself. AP split his forehead open leaving a five-inch wound and came to me for treatment. AP told me about his spearing wound experience although at first he said he had fallen on a branch. I had a suture kit so I stitched up the wound. I cared for the wound for several days, there was absolutely no fever, swelling/inflammation, redness or visible sign of infection. Bleeding was minimal considering it was a five-inch gash on the forehead that went ¼ inch down to the skull. There was never any sign of infection, redness or swelling on the wound from the start. At around a week the wound was completely closed and healed". (Field Journal Entry Douglas London, July 10, 2010)

Case 4: All Waorani by virtue of walking through the jungle with bare feet periodically get lacerated with these large spines often going through the entire foot and out the other side. After being wounded the Kawymeno Waorani then walk with perforated bare feet through the mud of the jungle floor for kilometers, but the feet never become infected.

> *"We were walking through the rain forest hunting with G wife of K. G and her 3-year old girl were walking through the rain forest with bare feet. The 3-year old stepped on a huge 4'' spine that went completely through the bottom of her foot and out the other side. The 3-year old didn't say a word because we were hunting for peccary and she had been trained to be quiet. G pulled the embedded spine out of her three-year old's completely perforated foot and kept going. We felt bad and carried the little girl part of the way but the parents got annoyed with their daughter when she started crying. So we put the 3-year-old back on the ground. A few minutes later she was running through the jungle again her bare feet completely covered with mud. The wound never became infected; there was no swelling, redness fever, nothing. One of these spines penetrated my boot sole and just pierced the skin of my foot the other day. The Waorani get these spine wounds regularly walking in bare feet in the jungle and simply pull them out and keep going. G said that all Wao get spines but don't worry about them, the feet never get infected".* (Field Journal Entry, Douglas London, March 2, 2010)

Case 5: As you can see from the next journal entry below, a dirty machete is often the instrument used by Kawymeno Waorani mothers to cut the umbilical cord after giving birth. All the Kawymeno Waorani mothers who described their birth experience to me and those that gave birth while we were present in the Kawymeno community indicated there were never any signs of infection in the baby or mother after cutting the baby's umbilical cord with the machete. Usually the machete was used to cut their way through the rain forest to reach the place where they gave birth.

One of my Kawymeno Waorani health promotor trainees describes her own birthing experience:

> *"W. describes birth of her second child. One week before birth she started to feel pains and knew she was going to give birth soon. She worked all week hauling heavy loads often over 100 pounds including yucca, jungle fruits and peccary carcasses. On the day she gave birth her water broke. She went out alone in the early afternoon with a machete and Ortiga leaves. She walked a kilometer. She applied the Ortiga leaves to her back. She got on her knees to give birth. Wao women do not squat giving birth. The baby came out fast. She took the machete and cut the placenta. (I confirmed the machete had not been washed in fact she used it to cut her way through the undergrowth). She described the baby as clean. She said with her first baby she had used the stalk of a plant [Yemingo] that is also used as a knife by Wao women to cut the placenta. She got up and carried*

the baby back to Kawymeno washed it in the river and presented it to the other women. Men were barred from seeing the baby. The next morning she went hunting and ended up carrying another 100-pound peccary carcass many kilometers in the jungle back to Kawymeno. She then participated in a sporting event in the afternoon. (Field Journal Entry, Douglas London, February 23, 2010)



Figure 35. Kawymeno Waorani Woman Chopping Down a Tree, New Born Babies are Rarely Allowed to Touch the Ground

As with other women who described their birthing experience neither my health promotor mother nor her baby had any signs of infection, swelling, redness, pus or fever after cutting the umbilical cord with a dirty machete.

The danger of antibiotic-resistant Staphylococcus aureus bacteria to modern society. Staphylococcus aureus is a bacterium found only in human beings, although related bacterial species are found in animals. The animal

versions of staphylococcus infestations are not normally infectious in humans so animal to human transfer is not common. Staphylococcus aureus colonizes humans and although the person feels well, someone with Staphylococcus aureus is what can be called a long-term normal carrier of the bacteria. By normal carrier that means that people carry the bacteria for a lifetime and when a suitable site comes up for infection, such as a cut or wound, the staphylococcus aureus reappears as the cause of disease. Staphylococcus aureus can persist in small groups, such as isolated hunter-gatherers, because complete immunity is not achieved and the bacteria is close to a permanent fixture in human body bacterial fauna and fauna (Tyrrell 1977, Levy 1998). While other bacteria are present in wounds, strains of staphylococcus aureus are the most commonly found bacteria in wounds. Around the world, more and more frequently, there are patients that do not respond to Vancomycin and the last few antibiotics that had previously been effective against all strains of the deadly staphylococcus aureus infections (Levy 1998). The appearance of a strain of staphylococcus aureus, not readily eliminated by Vancomycin, and the few other last resort antibiotics is trouble globally for the human race since numerous strains of staphylococcus aureus are already resistant to almost all other human-made antibiotics.

The fact that the Kawymeno Waorani have a natural and apparently complete immunity to manifestations of staphylococcus aureus may be a very important finding for modern medical science. This dissertation makes the case that staphylococcus infections in the Kawymeno Waorani are controlled by the anti-microbial contents of the Kawymeno Waorani dietary intake of

phytochemicals. A similar case is made later for streptococcus infections, another deadly resident bacteria in most humans. There are several plants in the Kawymeno Waorani diet in particular that warrant investigation for anti-staphylococcus aureus properties, but these plants are not discussed in this dissertation and may be part of a future publication. However, this dissertation evidence suggests that the combination of a large variety of revolving powerful antibiotic phytochemicals in the Kawymeno Waorani diet, rather than a particular phytochemical component, would more likely be a potential long-term answer to a public health nightmare of a staphylococcus aureus epidemic waiting to happen. Understanding the anti-staphylococcus aureus properties of the Kawymeno Waorani diet may be of great relevance to developing a dietary intervention model for infectious diseases that does not use human-made antibiotics or wait until the disease manifests itself. Worrying about a disease like staphylococcus becoming resistant to plant antibiotics is not necessary because plants are able to modify their antibiotic arsenal relatively rapidly. It is unlikely a vaccine will be developed for staphylococcus aureus, as the human body's own immune system antibodies do not destroy the bacteria, although blood serum indicates the immune system has mounted an unsuccessful defense against staphylococcus aureus and staphylococcus aureus in most modern humans. Thus, a failed immune response leaves these staph and strep bacteria that co-inhabit the human body free, waiting for an opportunity to infect.

Inca open brain surgery: historical parallel to absence of infection in major wound and further discussion of Waorani immunity. The apparent lack

of infection during unsterile brain surgery by the pre-Columbian Incas and other indigenous groups was one reason many researchers believe that staphylococcus aureus was not common in indigenous cultures prior to contact with Europeans and Africans. There is debate as to how prevalent staphylococcus was in the New World. Trepanation is a form of brain surgery where holes are put in the skull and was practiced by the Inca and other indigenous groups in South and Central American region prior to the arrival of the Spanish Conquistadors (Ackerknecht, 1947; Brothwell 1981; Crump 1901; Oakley 1959; Sankhyan and Weber, 2001). Skeletal skull evidence suggests that those who received the Inca brain surgery in an unsterile environment without antibiotics survived without evidence of infection in the skulls.

The diet of the Incas probably was much higher in anti-microbial phytochemicals than modern subsistence agricultural populations, and the Inca and other ancient societies that practiced open infection-free brain surgery may have had dietary phytochemical protection. Phytochemically-based hunting poisons, wild fruit intake and other potential sources of phytochemicals were probably widespread in Inca populations despite their agricultural base. Open skull brain surgery without any attempt at sterility would be almost impossible in the modern medical world, as death by staphylococcus aureus infection would be a virtual certainty. If staphylococcus was present, but asymptomatic in ancient Inca brain surgery patients, as in the case of the inflectionless Kawymeno Waorani wounds, something was preventing massive microbial infection. This dissertation makes the case that indigenous societies of the past such as the Inca

and today's Kawymeno Waorani did not and do not get infected wounds due to phytochemically based dietary mechanisms of protection. Clearly the Kawymeno Waorani have been exposed to staphylococcus in 2010 and at least some if not all of the population are asymptomatic carriers, yet the Kawymeno Waorani still do not get signs of staphylococcus infections in severe wounds. The Inca, as with the Kawymeno Waorani, probably had staphylococcus aureus presence in their body that also did not manifest itself in wounds in a disease form, but rather remained asymptomatic residents of their human bodies due to a preventative microbial regulating varied wild phytochemical rich diet. Many ancient indigenous civilizations besides the Inca practiced apparently infection free trepanation and brain surgery including other central and South American civilizations.

The scientists that studied the Waorani in the 1980s assumed the reason that the Waorani did not get infections, even when severely wounded, was due to the complete Waorani isolation from the modern world diseases (Kaplan et al 1980, Larrick et al 1983). Thus, these researchers suspected that as soon as the Waorani were exposed to staphylococcus by contact with the outside world, the protection against staphylococcus and streptococcus disease manifestation would disappear. This dissertation demonstrates that 30 years later after sustained contact with the outside world including hospitals with nosocomial infections, those Waorani that maintain a hunter-gatherer lifestyle still have protection against staphylococcus infections.

Hunting and fishing phytochemical poison intake are particularly good candidates for providing a boost of anti-microbial anti-staphylococci and

streptococci phytochemicals. Davis and Yost have noted the anti-microbial properties of the Waorani curare hunting poison (Curarea Tecunarum) (Davis and Yost 1983). There are other individual plants with strong antimicrobial effects that we are aware of but most likely it is the combined arsenal of anti-microbial effect of all 88 regular Waorani wild plant foods, each of which is constantly modifying its arsenal of anti-microbial phytochemicals to keep up the race against microbes that would otherwise have long ago eliminated the plant kingdom.

Yet another absent bacterial killer: historical lack of streptococcal bacteria infection in Kawymeno Waorani. Streptococcus bacteria have infected and killed millions of people. Like staphylococcus bacterial infections streptococcus bacteria appear to be absent as a disease in the Kawymeno Waorani. For instance, the disease rheumatic fever is caused by streptococcus infection and typically manifests itself a while after a person has already had a virulent streptococcal related infection such as strep throat or scarlet fever. Rheumatic fever is very common in Ecuador, yet rheumatic fever is completely absent in the Kawymeno Waorani population, as the dissertation study found, and has always been historically absent in the entire Kawymeno Waorani community as yearly visits by the Franklyn Tello Hospital to Kawymeno confirm.

Larrick, Kaplan and other researchers in the early expeditions that examined the Waorani also documented a complete lack of Rheumatic fever in the entire Waorani population (Kaplan et al 1980). The Waorani have not had one single case of Rheumatic fever, which is caused by streptococcus bacteria. Rheumatic fever is very common in neighboring indigenous and Latin

populations in the communities nearest the Kawymeno Waorani. The Waorani antibody serology tests were positive for streptococcus in 1979, yet no disease manifested itself, something was preventing infection (Kaplan et al 1980).

There is evidence that streptococcus infections pre-dated the arrival of Western colonists as conditions such as sinusitis and mastioditis have been documented as occurring in pre-Columbian times (Weiner et al 1976) and streptococcus was probably long present in the Waorani population. Like staphylococci bacteria, streptococci bacteria can also be carried asymptomatically in host humans however it is not the norm for entire populations to be asymptomatic (Peter and Smith 1977).

Doctors and staff at the local Franklyn Tello hospital, have commented to me that one of most remarkable things about the Kawymeno Waorani community is there has never been a case of rheumatic fever in Kawymeno Waorani in the entire 10 years they have been coming to vaccinate the Kawymeno Waorani. On the other hand, these Franklyn Tello hospital doctors commented that rheumatic fever was common in the neighboring Santa Teresita Kichwa and other riverine Kichwa communities. Further investigation, such as the medical exam and history of this dissertation, confirmed a historical absence of streptococcal related diseases in the Kawymeno Waorani and the active presence of streptococcal infections in the neighboring Santa Teresita Kichwa. The study medical exams and history indicated strep throat, rheumatic fever or rheumatic heart disease or other manifestations of streptococcus have not historically, nor at the time of the medical exam, been present in any of the Kawymeno Waorani population.

The Kawymeno Waorani have the streptococcus bacteria, but not the diseases associated with the bacteria. Back in the early 1980s Kaplan commented on his serotype antibody examination of the Waorani, "If streptococcal infection had indeed been endemic among the Waorani the complete lack of rheumatic heart disease is this population is noteworthy." (Kaplan, et al., 1980, p. 307). The Kawymeno Waorani also have staphylococcus aureus bacteria, but none of the diseases associated with staph bacteria.

The Time Wounds Take to Heal: Kawymeno Waorani Hunter-Gatherers Versus Santa Teresita Kichwa Farmers.

A comparison of the speed with which wounds heal between Kawymeno Waorani and Santa Teresita Kichwa suggests Kawymeno Waorani hunter-gatherer wound healing is rapid compared to surrounding non-hunter-gatherer populations in this same rain microbe and pathogen rich rain forest environment.

Participants from the Santa Teresita Kichwa farmers and Kawymeno Waorani hunter-gatherers were surveyed about their most recent severe skin lesion (wound/cut). The question was: how long after receiving the wound (skin lesion) did it take the participant to get well enough to get out of the bed/hammock/ground and house? There were 30 Santa Teresita Kichwa respondents who described the following unprompted wound categories when they responded: Machete/axe wound, spear wounds, severe cuts, sting ray puncture, puncture (other types), burns, and animal bite (principally peccary). The survey question specified that all the answers were descriptions of wounds that were skin lesions. The same survey of wound types acquired, all of which had to be major skin lesions, was conducted across Waorani hunter-gatherers and the

Kichwa farmers. Wound cases involved falls, sprains, broken bones or other types of trauma that might lead to prolonged convalescence did not meet the criteria of the question asked.

Severe long-term morbidly from serious wounds was the norm in the Santa Teresita Kichwa population. There was 1 case where the person was bedridden for 1 week, 11 cases where the person was bedridden for 2 weeks, 4 cases where the person was bedridden for one month, 4 cases where the person was bedridden for 2 months, 4 cases where the person was bedridden for 3 months bedridden, 2 cases where the person was bedridden for 5 months bedridden, 2 cases where the person was bedridden for 8 months and 2 cases for 1-year convalescence.

Average time of convalescence for Kawymeno Waorani from severe wounds was less than 1 week on a survey of 12 Kawymeno Waorani including 6 cases I oversaw personally during the year. Several Kawymeno Waorani cases took a convalescence of 2-3 weeks including: stingray punctures, animal bites (peccary) and spear wounds (which probably involved trauma but nevertheless involved a remarkably short time for convalescence).

The exact figures from both populations must be viewed cautiously with all the bias that comes with humans remembering back in time. The generality and openness of the question and the difference in types of wounds in the responses from both populations also affect the data. In addition, the wounds I saw at the moment they occurred with the Kawymeno Waorani may have been less serious than wounds that are long-remembered by Santa Teresita Kichwa.

Finally the age of the participants may have affected recovery times as the Santa Teresita Kichwa population has an older average age by two decades. Study results have been age stratified to compare comparable age groups within the two populations. Since the answers were rounded numbers due to the difficulty in remembering exact dates of a bygone event, a statistical analysis was not performed and the numbers can be viewed as descriptive rather than quantitative.

While there are confounding factors to consider when making any conclusions from this type of open descriptive survey question, nevertheless the convalescent times were so notably different between the Kichwa farmer and Waorani hunter-gathering population, that a general statement can be made, namely there appears to be a trend to much faster recovery from wounds by the Kawymeno Waorani compared to the Kichwa farmers.

Anti-Inflammatory Effects of Phytochemicals on Waorani Wounds and Other Physiological Processes.

The question this dissertation poses regarding humans in general is whether all these defensive reactions such as swelling and redness, typically found in wounds, are actually normal helpful protective measures of the body to heal or a demonstration of an excessive inflammatory process caused by a lack of anti-inflammatory compounds normally present in the human body throughout human evolution. There are at least several processes going on in a wound besides just the microbial factors. Inflammation and redness are signs of a defensive reaction by the human body, and needs to be considered separately from the microbial infection itself. Pathogens cause infection but the human body causes the inflammation, swelling, redness and fever. Anti-inflammatory

phytochemicals, including antioxidant phytochemicals, are readily present in many dietary plants and these plant-based phytochemicals such as flavonoids and anthrocyanins reduce inflammatory responses in humans (Chun et al 2008, Galland 2010). All the lacerations, punctures, cuts and burns I saw in Kawymeno in 2010 had no sign of inflammation or redness. Inflammation is now widely believed to be a contributing cause of many or most chronic diseases. The Kawymeno Waorani may have a reduced inflammatory response to allergens, auto-immune disorders and other inflammatory disease processes due to phytochemical intake, which is visible in the wounds we saw, but more difficult to see with processes that take place within the human body. This dissertation makes the case that the high and varied antioxidant and other phytochemical mechanisms in the content of wild fruit in the Kawymeno Waorani diet reduce inflammatory reactions to the extent they are not visible even in major burns and lesion wounds.

Phytochemicals from fruit have the anti-inflammatory and antioxidant properties that can alleviate inflammation, reduce oxidative stress and lower blood pressure (Chun et al 2008, Eruland 2008, Galland 2010). A study with 1,950 men followed up over 12 years demonstrated that eating berries containing flavonoids and anthocyanins phytochemicals reduced inflammation and cardiovascular disease (Rissanen et al 2003). Another 16-year study of 34,489 women showed that once a week strawberry and blueberry dietary intake reduced cardio-vascular disease (O'Keefe et al 2008).

Thus, the high and varied antioxidant and other phytochemical content of the Kawymeno Waorani hunter-gatherers diet may prevent inflammatory processes in superficial wounds as demonstrated earlier, as well as inflammatory reactions deep inside the human body caused by allergic reactions and auto-immune disorders.

A year of experience working with the Kawymeno Waorani, as well as medical exams and histories, demonstrated the Kawymeno Waorani do not exhibit allergic inflammatory reactions to the many plant allergens and other allergens in their environment. Larrick et al noticed this apparent lack of allergic reactivity in the Waorani population and were intrigued enough to test for it (Larrick et al 1983). However, Larrick while found an allergic response by Waorani participants to unfamiliar foreign allergens he also observed that paradoxically inflammatory reactions to endemic allergens were not present in the Waorani in spite of many allergy provoking plants in their rain forest environment (Larrick et al 1983).

Biomedical science frequently assumes that major wounds do not heal in humans without an inflammation process. Kawymeno Waorani wounds consistently healed rapidly in very unhygienic setting, rich with bacteria, with no inflammation, redness or irritation.

The Kawymeno Waorani cases demonstrate that inflammation is not an inevitable process of healing as Waorani wounds do heal perfectly normally and more rapidly than Kichwa farmer wounds without any visible inflammation, irritation or redness. While inflammation in acute wounds is considered a normal part of

the healing process by biomedical science, a case can be made that even inflammation of acute wounds is actually not particularly helpful to the healing process. In any case the supposedly essential beneficial inflammatory process is actually not essential in the healing process of Kawymeno Waorani wounds.

Biomedical science divides inflammatory responses into two distinct categories, supposedly beneficial for acute inflammation found in wound healing, but long-term inflammation is conversely considered damaging in many chronic disease processes. In actuality, one could argue there may be little difference between "good" and "bad" inflammation and both types of inflammation may be the same abnormal phenomena from an evolutionary perspective if Kawymeno Waorani case is representative of a normal physiological reaction. In any case, it is reasonable to assume that the large and varied quantity of anti-inflammatories found in the Kawymeno Waorani dietary phytochemical intake does have an impact on both "good" acute external and "bad" internal body categories of inflammatory processes regardless of value assignments made by biomedical scientists. The Waorani exhibit no sign of any chronic diseases that have been linked to inflammatory responses, although it is more difficult to directly observe internal inflammatory processes than the absence of inflammatory processes in wounds in the Waorani. The next chapter demonstrates that phytochemicals have powerful anti-inflammatory properties in reducing the inflammatory process in the Kawymeno Waorani hunter-gatherers.

Kawymeno Waorani Lack of Inflammatory Reaction to Endemic Allergens.

As mentioned in another section of this chapter, beyond an absence of swelling or redness around wounds, the Kawymeno Waorani rarely have any allergic reactions such as swelling, redness or itching to the many allergens that are present in the rain forest. While the Kawymeno Waorani obviously come in contact with allergens, the reaction found in Westerners to allergens namely swelling, irritation and redness were not present in any of the Kawymeno Waorani medical examinations. The Kawymeno Waorani community also has no history of autoimmune disease or other partially inflammatory-based diseases. Lack of visible allergic reaction does not mean the Kawymeno Waorani do not react to allergens, but rather there is no inflammatory response typical in agricultural food systems such as the Santa Teresita Kichwa or Westerners. There are many anti-inflammatory phytochemicals found in plant food such as fruit, which the sections on vision and blood pressure discuss. Again this dissertation makes the case that a high and varied amount of dietary intake of anti-inflammatory phytochemicals prevents inflammatory responses both to allergens and internalized autoimmune disease.

Phytochemical Anti-Microbial Control of Endemic Microbes in the Human Intestine.

This dissertation makes the case that the evolutionary norm was regular, preventative dietary plant anti-microbial intake that regulated, controlled and prevented outbreaks and imbalances in the normally present microbial populations in human intestinal bacteria. As referred to briefly above, imbalance

of the microbe population in human intestinal tract is associated with chronic diseases such as obesity, inflammatory bowel disease and intestinal inflammation (Candela et al 2010). Human body populations of intestinal microbes represent a tremendous variety of species, over 1,800 genera and 16,000 phenotypes of microbes have been identified in the human body (Hattori and Taylor 2009, Gill et al 2006, Ley et al 2008). Microbes provide and execute metabolic functions for humans such that humans have not evolved the ability to conduct these metabolic processes on their own and are dependent on microbes to complete these human body physiological activities for human survival (Turnbough et al 2007). Thus, intestinal microbes play a major role in human health to the extent that alteration of these microbe populations is dangerous to human health and continued physiological functioning (Egert et al 2006, Neish 2009). It is known that many human physiological functions depend on mutualistic relationships with intestinal microbes, including nutrient processing, pathogen resistance, development and maintenance of human immune system (Round and Mazimanian 2009). Researchers now are beginning to perceive the intestinal microbial population as an essential organ of the human body, like that of a kidney or liver. Human microbe co-evolution has left the intestinal microbe population responsible for many critical human physiological processes to the extent that humans cannot easily survive without these intestinal microbes, which almost act as a human organ (Peterson et al 2008).

For instance human obesity is associated with a general reduction in human body bacterial diversity (Turnbough et al 2006, 2009). Human obesity is

also associated with alterations of ratios of bacteria, such as higher ratio of a combination of *Firmicutes* bacteria and *Actinobacteria* in relation to *Bacteroidetes* bacteria (Turnbough et al 2006, 2009). In another example, Inflammatory Bowel Disease and Intestinal Inflammation are associated with a reduction in human body bacterial diversity and again a change in the ratio of resident colonies of microbes in the human body (Frank 2007, Sokol et al 2008, Stecher et al 2007, Pedron and Sansonnetti 2008). So beyond just staphylococcus, streptococcus and other of the more famous microbial residents of the human body, there are thousands of microbial species in the intestines and elsewhere that are sensitive to anti-microbial intake. This dissertation makes the case that lack of dietary anti-microbial intake to regulate and control microbes essential to the human body creates types and balances of microbial populations in the human intestines and body which did not exist before the coming of agriculture and the downfall of the evolutionary normal rich and varied intake of anti-microbial phytochemicals. This leads to disease and dysfunction of the human body.

Social Implications of Human Physiological Specialization for Phytochemicals Targeting Endemic Microbial Disease at the Expense of Historically Rarer Outside Pathogens.

In sum phytochemical anti-microbial protection protects helpful bacteria and microbes and regulates bacteria that in excessive numbers cause diseases. First, this dissertation has made the case that phytochemicals are most effective in protecting the body's own beneficial microbial flora and fauna such as resident intestinal microbes from population explosions of non-beneficial bacteria and microbes. These intestinal microbes that make up the invisible extra organ of the

human body are responsible for the running of many biological processes essential to human physiological function and their loss causes chronic disease. Second, regular dietary intake of anti-microbial phytochemicals control bacteria such as streptococcus and staphylococcus that unchecked can quickly swell in numbers and kill the human body. The human immune system appears to be ineffective in dealing with these dangerous permanent resident staphylococcus aureus and streptococcus bacteria, as evidenced by the ability of these bacteria to survive for the entire life of a human even with human antibodies actively targeted against and designed to combat these bacteria.

On the other hand low level, daily dietary phytochemical antimicrobial/anti-parasite intake may not be sufficient to deal effectively with the rapid spread of novel virulent new pathogens that were probably rarely encountered throughout human evolutionary history. Evolutionary adaptation of physiological capacity to process dietary phytochemicals that deal with maintenance of everyday microbial problems of resident bacteria probably took priority over developing physiological capacity to capture plant anti-microbials useful only for diseases rarely encountered by hunter-gatherer groups that are a product of the advent of large interconnected agricultural populations such as the virulent plagues that spread easily in agricultural societies and the modern world.

Social Implications of the Plant Kingdom's Trademark Ability to Rapidly and Constantly Create Brand New Antimicrobials.

Plants are constantly evolving new antibiotics, much faster than pharmaceutical corporations can patent synthetic antibiotic versions. Thus, microbial mutations and resulting resistance to antibiotics is not an issue for

plants who vary their anti-microbial arsenal to match the microbe mutations. Plants millions of years ago would have succumbed to microbes without the ability to rapidly modify an existing antibiotic in their arsenal quickly into another equally effective antibiotic. Ethnopharmacologists rather than searching for unique biochemical substances might employ their time more profitably trying to understand the process, rather than seeking a single chemical entity, by which plants modify their antibiotics to beat microbial mutation - a successful biochemical model for millions of years that pharmaceutical corporations could learn from. Hunter-gatherers benefit from this antibiotic protection without any work merely by eating a wide variety of wild phytochemically producing plant foods. As discussed earlier, modern pharmaceutical merely utilize physiological receptors adapted to capture wild plant phytochemicals and would not function otherwise.

The modern world agriculturalists such as the United States rely more and more on human-made antibiotics as the natural dietary plant origin antibiotics are removed from the diet even more effectively with each new “improvement” in processing and purifying foods.

Thus, this dissertation predicts a return to varied wild dietary intake of phytochemical antimicrobials will allow the body to once again regulate resident staphylococci, streptococci, intestinal microbes and other diseases caused by the body’s own microbial population and restore anti-microbial populations balances to evolutionarily normal levels.

It is less likely a return to an evolutionary normal dietary intake of antimicrobial phytochemicals will prevent the more rapid virulent diseases spawned by agriculture's influence on reorganizing social structures to benefit these virulent microbes. However, these invading microbes are more amenable to vaccines and human-based solutions. Resident microbial based disease processes cannot be vaccinated against because these microbes are already an intimate part of the physiological functioning of the human body. Diet protects against diseases common in human evolutionary history, while diseases that are part the rise of agricultural civilizations require these civilizations to resolve diseases their own technology has inadvertently produced.

CHAPTER 14

HEALTH OUTCOMES III: EYE DISEASES AND PHYTOCHEMICALS

Eye Disease and Visual Acuity in Kawymeno Waorani Hunter-Gatherers Versus Santa Teresita Kichwa Farmers.

The age stratified vision charts comparing the visual acuity of the Santa Teresita Kichwa and Kawymeno Waorani demonstrate that as they grow older the Santa Teresita Kichwa vision deteriorates, while the older Kawymeno Waorani have the same visual acuity as when they were younger. A version of a Snell chart utilizing an "E" shaped figure that changes direction was used to capture visual acuity in these populations so that literate and illiterate participants could take the same eye exam.

A look at the vision figures that compare the Kawymeno Waorani with the Santa Teresita Kichwa shows that at the beginning of life visual acuity remained similar for both groups. The exception in the 18 to 29 year old comparison group are a couple of Kawymeno Waorani and Santa Teresita Kichwa that suffered eye trauma unrelated to eye disease processes, including one Kichwa person who lost an eye.

Other than these eye trauma cases, both Santa Teresita Kichwa and Kawymeno Waorani start life with excellent eyesight. In the 30 to 39 year old group both the Santa Teresita Kichwa and the Kawymeno Waorani maintain good visual acuity. Neither the Santa Teresita Kichwa nor the Kawymeno Waorani read, watch TV, use the computer, or other close vision work that may be associated with visual acuity deterioration earlier in life in Westerners (Morgan &

Monroe 1973). In addition, neither study group is exposed to the lifestyle and modern chemicals that westerners use that may affect vision earlier in life.

It is in the charts of visual acuity in the 40 to 49 year old age categories that we begin to see a large difference between the Santa Teresita Kichwa and the Kawymeno Waorani, as Santa Teresita Kichwa vision starts to deteriorate significantly and eye diseases begin to occur in a manner similar to Western populations. On the other hand, Kawymeno Waorani vision remains largely unchanged with some to slight visual loss shifting to 20/25 or 20/30 in some individuals. In the fifth decade of life most Santa Teresita Kichwa have poor vision that would require glasses in Western society, while the Kawymeno Waorani population have close to perfect vision.

In addition to the visual acuity exam the study medical exam and health history demonstrates cataracts, growths in the eyes and other ocular diseases appear in the Santa Teresita Kichwa with advancing years. However, the Kawymeno Waorani medical exams and history demonstrate that all members of this hunter-gatherer group remain free of any notable ocular disease during their lifetime such as cataracts and macular degeneration.

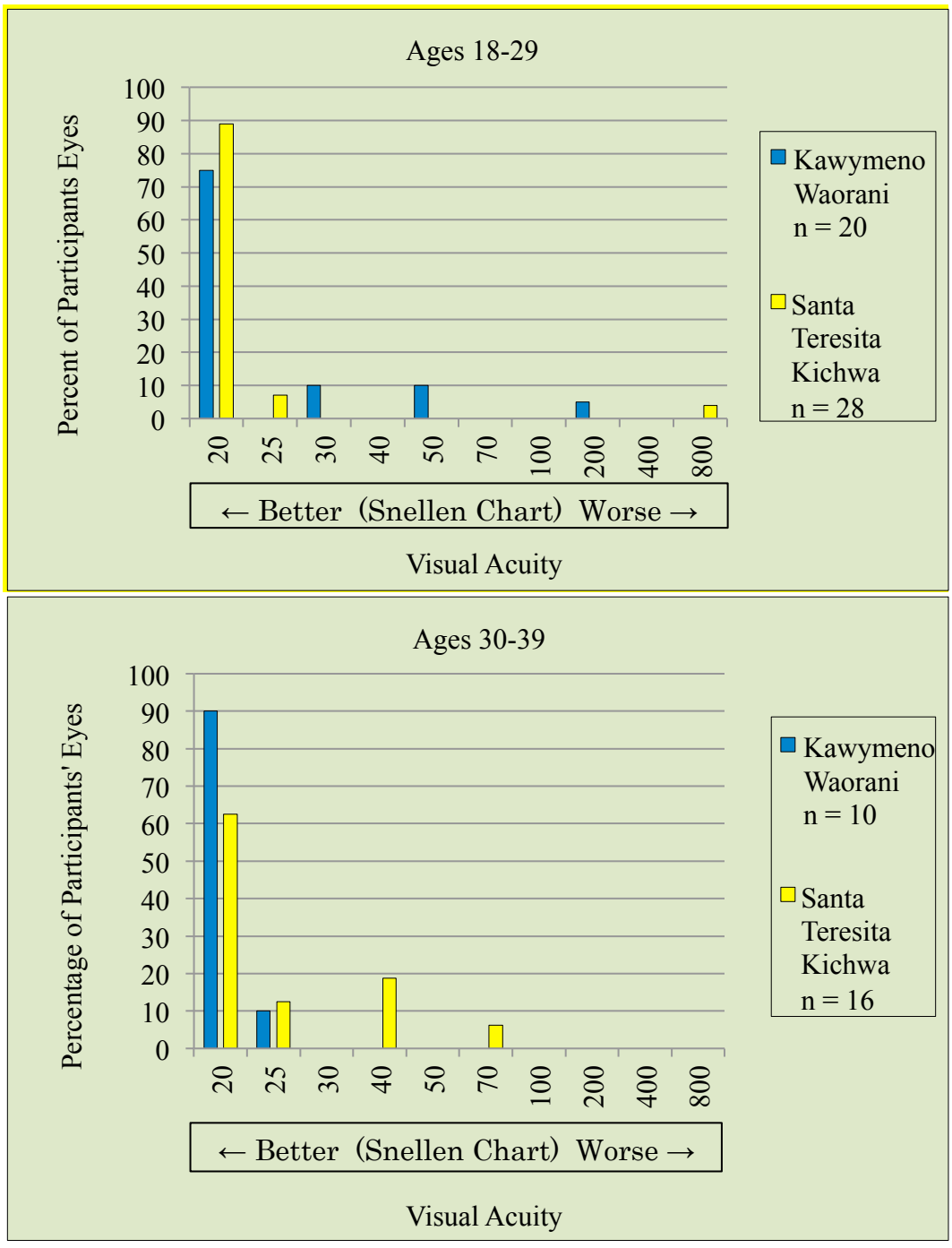


Figure 36. Age-Stratified Snell Scale Vision Exam Results for Age Groups 18 to 29 Years of Age and 30 to 39 Years of Age: Kawymeno Waorani vs. Santa Teresita Kichwa. 2010.

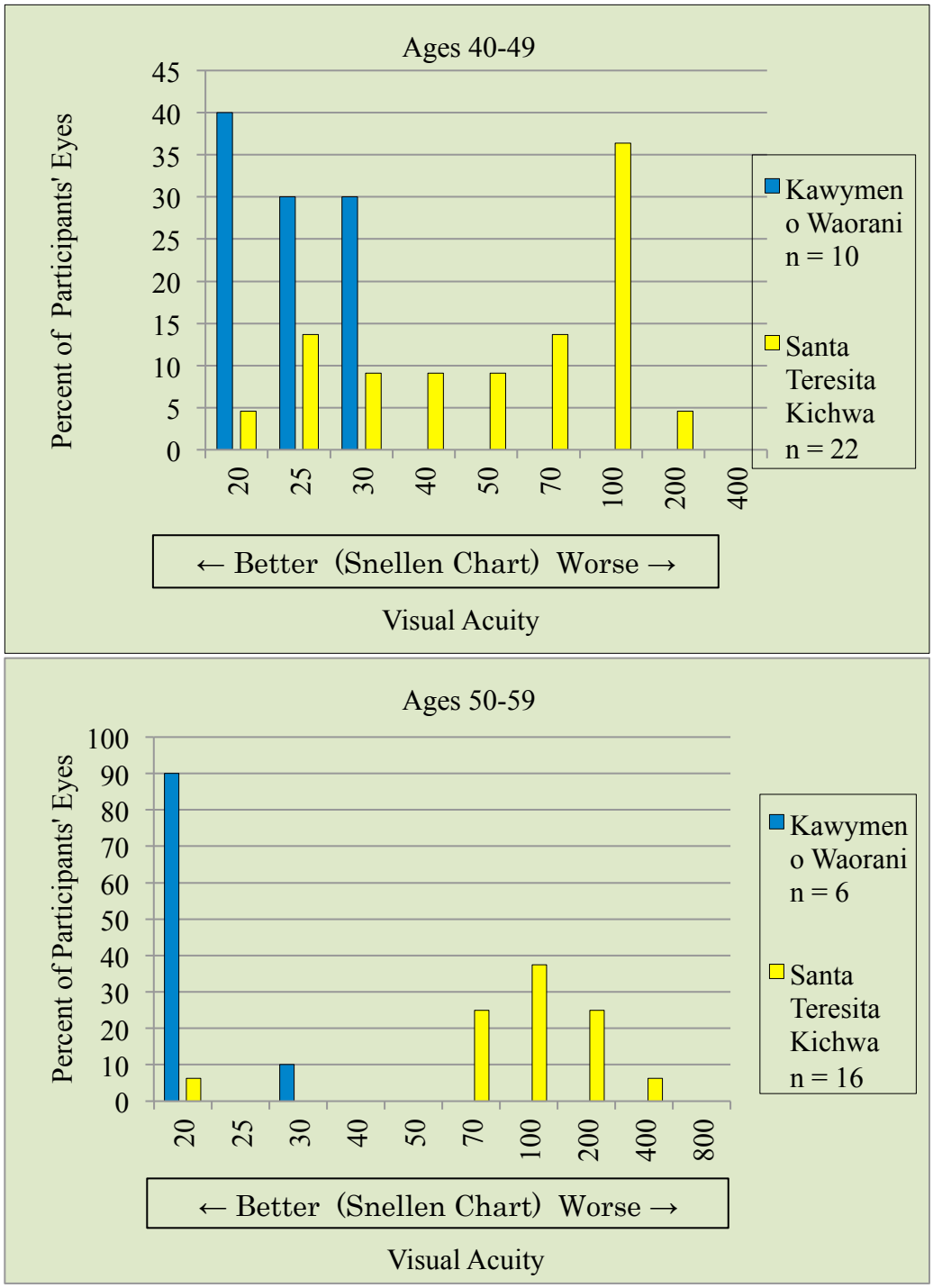


Figure 37. Weighted Age-Stratified Snell Scale Vision Exam Results for Age Groups 40 to 49 Years of Age and 50 to 59 Years of Age: Kawymeno Waorani vs. Santa Teresita Kichwa. 2010.

Phytochemical Intake and Improvement in Eye Disease: The Evidence.

Kalt et al and other researchers demonstrated, by identifying the passage of anthocynins from a dietary intake of blueberries, that phytochemicals acquired from dietary fruit intake are absorbed and moved into other parts of the human body, including the eye as well as the liver and brains of mammals (Andres-Lacueva et al 2005, Kalt et al 2008, Matsumoto et al 2006). Increasing evidence demonstrates that these phytochemicals that pass into the eye are involved in prevention and even reversal of age-related eye diseases such as glaucoma, cataracts and age-related macular degeneration (Rhone and Basu 2008). Inflammation and oxidative stress are intimately involved in the disease process of age-related ocular disorders, such as macular degeneration, cataracts and glaucoma and probably most other eye disorders that affect visual acuity (Rhone and Basu 2008). High blood levels of phytochemical antioxidants and other phytochemical mechanisms protect against oxidative stress and other factors in and aid in improving these chronic eye disorders (Ohira et al 2008 [ocular disease]; Beaty 2000 [macular degeneration] Ko et al 2005 [glaucoma]; Head 2001 [cataracts and glaucoma]; Beit-Yannai 2007 [glaucoma]; Fernandez and Ashari 2008 [cataracts]).

While this dissertation emphasizes a variety of phytochemicals as necessary for preventing eye disease and other chronic disorders, even nutritional studies of single phytochemical dietary intake increases have found some benefits from phytochemical intake in prevention and improvement of chronic eye diseases. A large study, the Women's Health Study with 35,551 participants,

found the group with the highest intake of the phytochemicals lutein/zeaxanthin had the largest reduction in risk of developing cataracts compared to women taking minimal amounts of lutein/zeaxanthin (Christen et al 2008). Another study called the ARED study with 4,519 participants found a reduced risk of Age Related Macular Disorder with dietary intake of lutein/zeaxanthin phytochemicals (San Giovanni et al 2007). The protective effects of lutein and zeaxanthin were greater with a stable intake over many years as demonstrated in the CAREDS study (Moeller et al 2006) similar to the steady phytochemical dietary intake of hunter-gatherers like the Kawymeno Waorani, rather than Westerners trying a new diet out for a short time. Other phytochemicals such as those found in berries (anthocyanins), and grapes (resveratrol) also help prevent eye disease (Rhone and Basu 2008).

The improvement in eye health in participants in these studies is likely to be partly related to the fact that people who eat foods with these particular study phytochemicals are more likely in general to eat a diet rich a variety of phytochemicals and while those participants that avoid these particular study phytochemicals may also avoid many other phytochemical rich plant foods. Thus variety of phytochemical intake may be the underlying factor. Lutein or zeaxantin phytochemicals are found together with many other phytochemicals with properties that affect human physiologically.

A wide variety of dietary intake of wild plant phytochemicals over the long-term is a safer more effective way of controlling disease than magic bullet one phytochemical-only treatments. The point of listing these magic bullet studies

is to show that dietary intake of phytochemicals does have an impact on eye health. However this dissertation has made the case that toxin build-up of long-term intake of some single phytochemicals often has deleterious health effects.

Phytochemical intake and its impact on study groups' eye health. The Santa Teresita Kichwa do consume a lot of vegetables that are recommended by nutritionists as healthy eye foods. However, as the years go by the Santa Teresita Kichwa vision deteriorates, indicating a diet rich in organic, agriculturally produced vegetables is not enough to preserve eye health. Many vegetarians in Western nations also do not have good visual acuity similar to the rest of the population. However, the majority of Santa Teresita Kichwa adults whose eyes were examined in this dissertation study do not read, use the computer, watch television or do other activities that involve close up vision that are believed to deteriorate the visual acuity of modern populations regardless of a vegetarian diet (Young 1969, Morgan & Monroe 1973).

In terms of phytochemical dietary intake, the problem is that not just the plants the population eats matter but the food system from which these plants come from matters. As the food system chapters demonstrate, the phytochemical intake from domesticated vegetables and fruit provide a very different dietary intake of phytochemical than wild plant foods in terms of variety, quantity, balance, level of toxicity and many other factors discussed in the chapter at length. Agriculturally-based vegetables such as those the Santa Teresita Kichwa eat, may also be paradoxically toxic as well as helpful to eye health. A wild ecosystem stimulates a rich variety of phytochemical output, while events such as

seasonal rotation to reduce monotonous intake of certain phytochemicals whose accumulation may eventually be toxic.

Food System-based Changes in Visual Acuity in Modern Hunter-Gatherer Groups.

Dissertation results suggest a dietary explanation rather than an increase in close visual work is responsible for deterioration of visual acuity, as hunter-gatherers become farmers as is discussed below. Survival in most animals and hunter-gatherer humans depends on excellent vision, thus lack of good long distant vision is unlikely to be naturally selected for in humans. Human visual acuity deteriorates with a change in food systems and lifestyle from hunter-gathering to agricultural. In the early 20th century a number of hunter-gatherer groups had their visual acuity checked. Holm refracted 3,624 African hunter-gatherer eyes in Gabon and only 14 were classified as myopic (Holm 1937). Skeller found similar figures in 1937 with 775 Angmagssalik Eskimo of which only a few of these hunter-gathers had myopia (Skeller 1954).

There is evidence in other hunter-gatherer studies that the change from hunter-gathering to a modern food system has impacted visual acuity and eye disease. Young et al in an interesting study on 415 acculturated Eskimos and found that the older, over age 41, part of this population that had grown up as hunter-gatherers eating a hunter-gatherer diet and living a hunter-gatherer lifestyle, actually had better eyesight than the younger population of 11 to 40 year olds. The younger Eskimos had grown up using an agriculturally-based diet with minimal wild foods while the older group was connected to a food chain reaching down from meat and fish to phytochemical producing plant life (Young et al

1969). Morgan and Monroe conducted a similar myopia study on 3,677 Yukon and Northwest Territory acculturating Eskimos and also found that younger subjects had similar rates of myopia as the United States while older Eskimos had close to perfect vision (Morgan & Monroe 1973). Several authors have suggested the difference in myopia in these Eskimo myopia studies is related to transition from a hunter-gatherer diet to a large-scale agricultural food system (Cass 1966, 1973).

In sum, there is abundant evidence that vision deteriorates as hunter-gatherers enter a modern lifestyle, but what aspects contribute to it? The results of this Waorani hunter-gatherer to Kichwa subsistence farming study are particularly interesting because the Santa Teresita Kichwa do not read, use the computer or do any close visual work that many researchers believe might cause deterioration of visual acuity in modern humans. Controlling for close visual work is an advantage of this dissertation study design that avoids confounding variables that may affect vision present in modern societies.

Dissertation study results suggest a dietary rather than a lifestyle change may be the key factor in vision deterioration by controlling for close visual work, such as reading and computer work, which many researchers feel underlies a deterioration in visual acuity.

CHAPTER 15

HEALTH OUTCOMES IV: BLOOD PRESSURE AND PHYTOCHEMICALS

What Is the Norm for Human Blood Pressure?

The American Heart Association states in 2011 that ideal blood pressures for humans are 90-119 mmHg systolic blood pressure and 60-79 mmHg diastolic blood pressure. Below 90 mmHg systolic and below 60 mmHg diastolic is considered hypotension, too low for ideal human health (American Heart Association 2011). The average blood pressure for the Kawymeno Waorani is hypotensive by AHA standards, while the Santa Teresita Kichwa average population blood pressure would be described as in the ideal range. However, hunter-gatherers studies have consistently demonstrated that the human evolutionary norm is blood pressure below the norms and guidelines of modern biomedicine (Barnicot 1972, Casley-Smith 1959, Donnison 1929, Kaminer 1960, Mann 1964).

Both the systolic and diastolic average blood pressure rises steadily throughout life for the population in the United States and for almost all of the world's population. Of course all of these people with rising blood pressure come from an agriculturally-based food system. In spite of the vast majority of the world having rising blood pressure throughout life, steadily rising blood pressure with advancing age may be a human abnormality and humans for 99% of human evolutionary history probably had slightly rising or stable blood pressure

throughout life. There are still indigenous cultures eating a wide variety of wild food whose blood pressures remains similar, or rises only slightly throughout life (Barnicot 1972, Casley-Smith 1959, Donnison 1929, Kaminer 1960, Mann 1964).

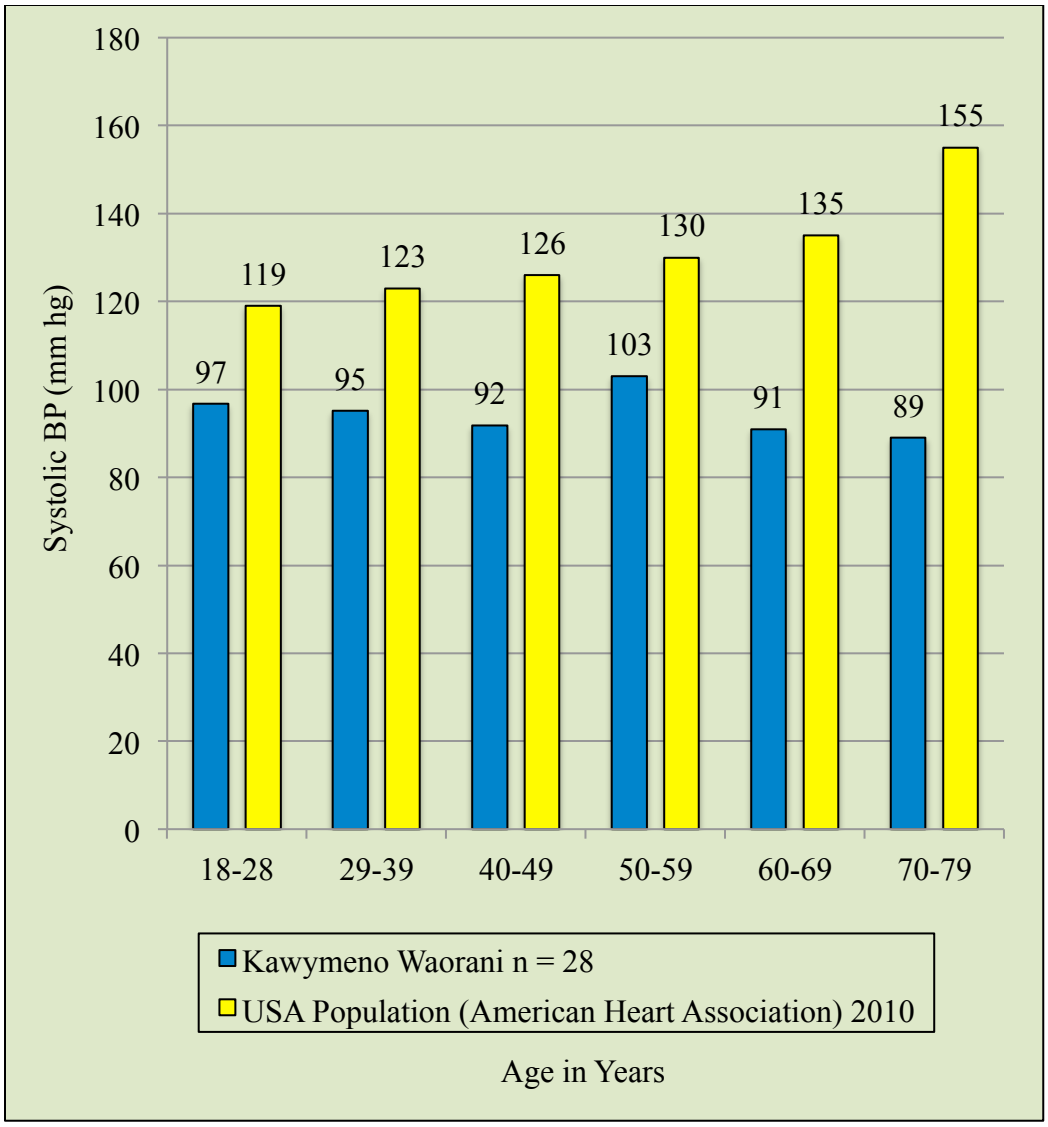


Figure 38. Mean Age-Stratified Systolic Blood Pressure: Kawymeno Waorani vs. United States Population. (statistical analysis in Appendix H) 2010.

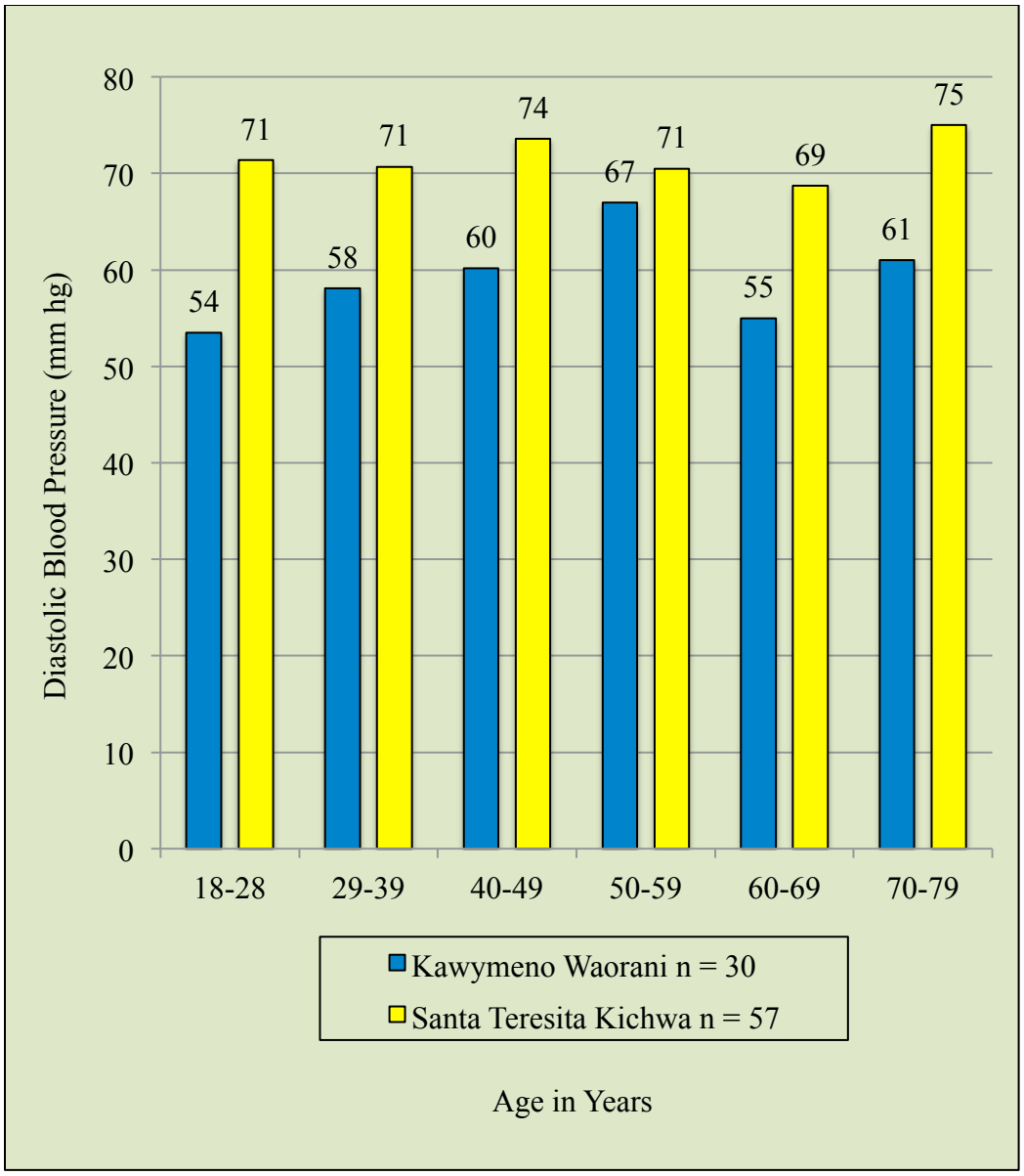


Figure 39. Mean Age-Stratified Diastolic Blood Pressure: Kawymeno Waorani vs. Santa Teresita Kichwa. (statistical analysis in Appendix H) 2010.

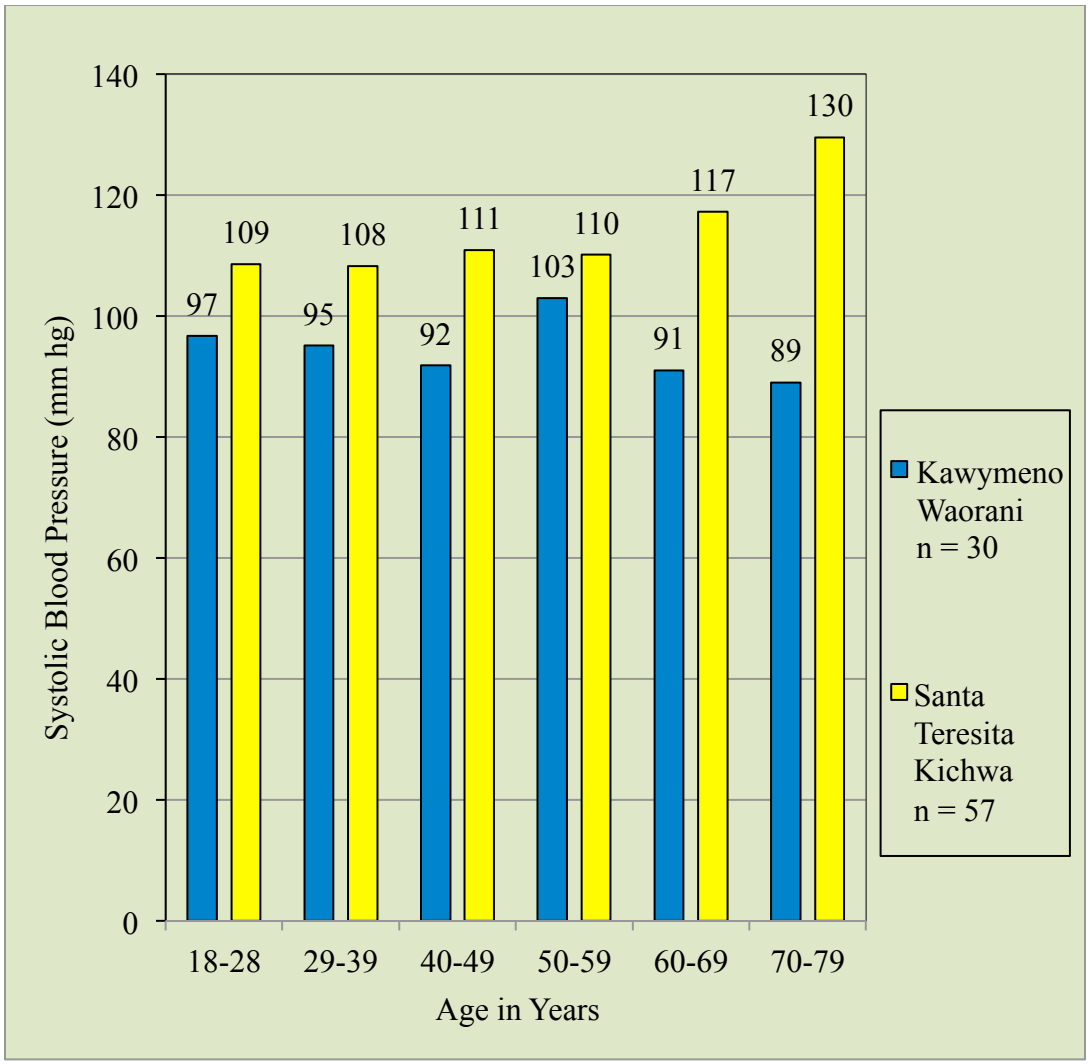


Figure 40. Mean Systolic Blood Pressure: Kawymeno Waorani vs. Santa Teresita Kichwa. (statistical analysis in Appendix H) 2010.

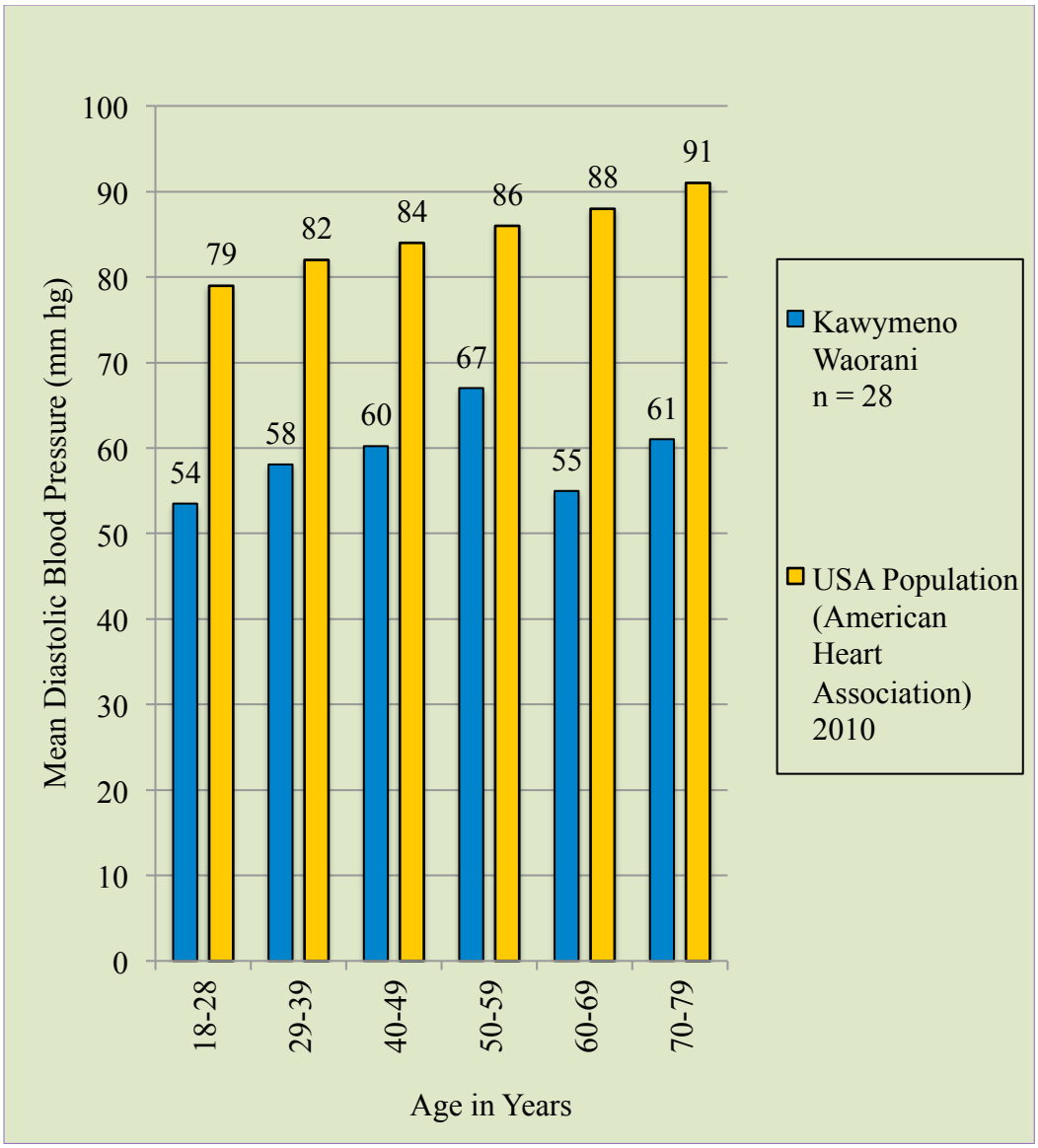


Figure 41. Mean Age-Stratified Diastolic Blood Pressure: Kawymeno Waorani vs. United States Population. (statistical analysis in Appendix H) 2010.

Waorani Hunter-Gatherer: Stable Low Blood Pressure Through Lifespan and No Cardiovascular Disease.

Blood pressure was taken on 30 Kawymeno Waorani hunter-gatherers and 57 Santa Teresita Kichwa farmers. I have run a medical clinic for 5 years with Harvard medical school and in addition medical personnel assistants have

expertise in taking blood pressure. Sitting blood pressures were taken twice to confirm accuracy and instruments were always checked using investigator and other team member's blood pressure. The same instruments were used across both populations.



Figure 42. Author Conducting a Medical Exam on a Santa Teresita Kichwa Man.

Kawymeno Waorani blood pressures in this dissertation study are among the lowest recorded in the world. Santa Teresita Kichwa blood pressure while in a healthy range by Western standards is high compared to the Kawymeno Waorani hunter-gatherers. Four percent of the Santa Teresita Kichwa farming population has what would be classified by the American Heart Association definition above as high blood pressure, while no Kawymeno Waorani had anything approaching high blood pressure.

The Hadza hunter-gatherers of Tanzania were the only African hunter-gatherers isolated from agricultural societies to survive into the late 20th century. They are often used in this dissertation for comparison for the reason that there were few other hunter-gatherers groups besides the Waorani that were living an almost totally isolated traditional hunter-gatherer life by the time Western scientists got to them in recent times. Barnicot took Hadza blood pressure in 1972 and found that the blood pressure was very low compared to Westerners. However, the Hadza blood pressure was not as low as the study Kawymeno Waorani hunter-gatherers' blood pressure. Hadza hunter-gatherers' blood pressure rose slightly with age, as does Kawymeno Waorani diastolic blood pressure (Barnicot 1972). As the blood pressure figures show the Kawymeno Waorani have systolic blood pressure that remains stable throughout their life span. The Kawymeno Waorani diastolic blood pressure rises slightly to middle age and then drops down again. Again the average Kawymeno Waorani systolic and diastolic blood pressure even at its height is hypotensive, meaning the measures of much of the Kawymeno Waorani population systolic and diastolic blood pressure fall below what would be considered normal by biomedical science. However, the Kawymeno Waorani are in excellent health up to advanced age and have no cardiovascular diseases. The Santa Teresita Kichwa have systolic blood pressure that rises throughout life especially in advanced age. The Santa Teresita Kichwa have diastolic blood pressure that remains stable throughout the life span. From the point of view of Western averages, the Santa Teresita Kichwa have excellent

blood pressure. Nevertheless, Kawymeno Waorani blood pressure is much lower than Santa Teresita Kichwa blood pressure.

High blood pressure is both a sign of cardiovascular disease and a silent killer in and of itself. The Kawymeno Waorani have no cardiovascular diseases and hunter-gatherers in general probably had little or no cardiovascular diseases. Cardiovascular diseases are largely products of modern life and agricultural diet.

The critical point is the average Kawymeno Waorani blood pressure is so much lower than the Santa Teresita blood pressure, and the Kichwa have not yet reached Western standards of very high blood pressure with advancing age. The Santa Teresita Kichwa population does have individuals with high blood pressure and heart conditions (one of the study participants died in hospital of a heart condition during the study) although the general population has blood pressure that is low by Western standards. Four percent of the Santa Teresita Kichwa population, when measured, had high blood pressure, high by Waorani standards where no Waorani of any age had high blood pressure. It is not surprising that the Kichwa blood pressure is lower than Western blood pressure with an organic agricultural diet and the absence of other lifestyle factors common in the West.

The real question is what is maintaining such a low average blood pressure across the entire Kawymeno Waorani population compared to the Kichwa? Judging from similar low blood pressure averages found by researchers in other hunter-gatherer groups (Barnicot 1972, Casley-Smith 1959, Donnison 1929, Kaminer 1960, Mann 1964) a further generalized question is what is it in our

ancestral diet and lifestyle that kept blood pressure so low throughout the human lifespan?

Plant-based Phytochemicals in the Kawymeno Waorani Diet Known to Clinically Lower Blood Pressure.

Many phytochemicals in the Kawymeno Waorani diet have the potential to lower blood pressure. Regular consumption of *(Curarea Tecunarum)* blowgun poison is an example of Waorani hunter-gatherer ingestion of phytochemicals with proven and well-established ability to lower blood pressure. Alkaloid phytochemicals found in the curare group of poisons, of which the Waorani blowgun poison *(Curarea Tecunarum)* is a member, have been shown clinically to regularly lower human blood pressure a fact established by medical research many years ago (Bennet 1968).

At least four species of cacao fruit are regularly eaten raw by the Kawymeno Waorani (*Theobroma cacao l., Theobroma subincanum, Grias neuberthii, Herrania nitida).* Ingestion of chocolate and cocoa from the fruit of cacao trees has been shown to reduce blood pressure in humans (Taubert et al 2003, Grassi et al 2005).

In terms of fruit in the Kawymeno Waorani diet, several interventional studies have shown that dietary intake of phytochemicals found in fruit, particularly berries, reduces blood pressure (Erlund 2008, Ruel 2008). The Kawymeno Waorani also eat several species of wild grapes. Domesticated red grapes have been shown to reduce blood pressure as well (Peng et al 2005). Phytochemicals have known ability to lower blood pressure and indeed a number of the actual plants the Kawymeno Waorani eat have proven blood pressure

lowering properties, as is discussed in the next section. This dissertation makes the case that the jump from the very low average population Kawymeno Waorani blood pressure to the moderate average population blood pressure of the Santa Teresita Kichwa is a property of dietary intake of phytochemicals some already known to have blood pressure lowering properties.



Figure 43. The Author's Wife, Smelling Wild Cacao from Kawymeno.

However, the jump from the moderate average population blood pressure of the Santa Teresita Kichwa to the higher blood pressure averages of Western

societies may be phenomena of other lifestyle changes beyond diet. Again, what is useful about this dissertation study is the ability to reduce confounding variables so that diet (particularly phytochemicals) is isolated from exercise or other lifestyle changes and appears to play a significant role in low blood pressure. However, when other lifestyle factors begin to occur as a population enters modern life, blood pressure rises further. In a study comparing hunter-gatherers to modern populations underlying causes of average blood pressure increases would be more difficult to untangle. Phytochemicals, while not the only factor in lowering high blood pressure in humans, may lower blood pressure in modern humans that return to diets high in wild varied phytochemical intake. This dissertation provides evidence of the blood pressure lowering properties of wild varied phytochemical rich diet, which Westerners with cardiovascular diseases might want to consider.

CHAPTER 16

HEALTH OUTCOMES V: LIESHMANASIS, MALARIA, VENOMOUS SNAKEBITE AND OTHER DISEASES

Absence of Leishmaniasis in the Waorani Hunter-Gatherers versus Serious Health Problems for Kichwa Farmers.

Leishmaniasis is a disease caused by a parasite from the genus Leishmaniasis that is very common in all populations throughout the study region of the Amazon rain forest, with the lone exception of the Kawymeno Waorani. This protozoan parasite is transmitted by a species of biting sand fly (subfamily Phlebotominae). Leishmaniasis manifests itself as skin sores weeks or months after being bitten by the sand fly that transmits the disease. Leishmaniasis can be fatal after many years as it damages the liver and spleen.

The complete absence of Leishmaniasis in the Kawymeno Waorani hunter-gatherer population at the time of the dissertation and historically in the community of Kawymeno is in stark contrast to the 33% of the Santa Teresita Kichwa interviewed on the medical exam who reported having Leishmaniasis at least once. In addition, Leishmaniasis causes anemia, which may explain why there are cases of anemia among the Santa Teresita Kichwa, although the Santa Teresita Kichwa farming diet provides enough iron and other minerals.

Leishmaniasis is endemic to the entire study region, so the complete absence of Leishmaniasis in Kawymeno Waorani indicates some factor is completely preventing the disease from manifesting itself in the Kawymeno Waorani. Since Protectorate Waorani get Leishmaniasis, the protecting factor

does not appear to be genetic. Leishmaniasis may in fact be transmitted to the Kawymeno Waorani. However, similar to the dissertation supposition about staphylococcus and streptococcus, while the Leishmaniasis protozoan may be present in the body of the Kawymeno Waorani, at least initially, the disease from this protozoon parasite may never manifest itself due to protection of dietary intake of anti-parasitic phytochemicals to which Leishmaniasis protozoan are sensitive to.

In sum, Leishmaniasis is a major public health issue with the Kichwa farmers, but completely absent in the Waorani hunter-gatherers even though Leishmaniasis is endemic to the entire region. Again, dietary intake of anti-parasitic phytochemicals may keep the disease from manifesting itself in the Kawymeno Waorani whether or not the actual initial infection of the Leishmaniasis protozoan is prevented from entering the Kawymeno Waorani body.

Malaria Prevalence across Study Groups.

The Kawymeno Waorani diet contains anti-parasitic phytochemicals. The phytochemical Quinine is made from the bark of a particular tree (*fam. Rubiaceae genus Cinchona*) found in regional Amazon rain forests. Quinine effectively kills the parasites that cause malaria and has been used by Westerners for centuries to control malaria. The existence of quinine demonstrates that anti-parasitic phytochemicals exist in plants in the eco-system in the Kawymeno region that can eliminate protozoan parasites in general and malaria in particular.

The Kawymeno Waorani at least recently do get malaria, another endemic protozoan parasitic disease similar in some aspects to Leishmaniasis. I have treated Kawymeno Waorani for malaria when they had no way of getting to a clinic. These Waorani responded to standard chloroquine treatment. There are 3 types of malaria now in the region P. Vivax, P. Malariae and P. Falciparum. When Kaplan et al tested for titers of malaria in 1979 they found Vivax and Malariae, but not Falciparum malaria, in the recently contacted Waorani which indicates along with other evidence from South American indigenous groups that Falciparum malaria may have been introduced to the Americas from the Old World (Kaplan et al 1979).

Historically, there have been no recorded deaths from malaria or long-standing malaria cases in Kawymeno Waorani, which is interesting as the Vivax variety of malaria tends to stay in the body long-term and recurs in episodes every so often. The medical history did not pick up any long-term historically repeating cases of malaria in the Kawymeno Waorani in spite of receiving no human-made anti-malarial pharmaceuticals until recently. As mentioned, wild rain forest trees that contain the widely-used (but now synthesized) Quinine anti-malarial phytochemical are found in the Amazon rain forest and there are most likely other versions of anti-malarial phytochemicals similar to Quinine in other local plants that the Kawymeno Waorani may ingest.

In the Santa Teresita Kichwa medical histories there are many cases where malaria reappeared in the same person up to 6 times indicating Vivax is present long-term in local population. More recently, many in the Santa Teresita Kichwa

got some anti-malarial drugs from the Franklyn Tello hospital although not all of the population can afford the medicine. Ironically, the test for malaria is free from the Ministry of Health, but the medication to treat malaria is not.

Difference in Fungal Infection Rates across Study Groups.

There were a number of cases of Tinea fungus infection among the children, perhaps the most common disease here in Kawymeno. My wife observed that 5 out of the 9 children she had taught had Tinea infection frequently in the scalp. These Kawymeno Waorani children's age roughly corresponded to first through fourth graders in the United States. The dissertation study makes the case that an absence of a large presence of endemic bacteria such as staphylococcus on the skin due to anti-bacterial properties of diet may actually make the Kawymeno Waorani more prone to certain fungus infections because it is known that fungus and bacteria compete with each other. Thus, control of staphylococcus and other bacteria on the skin, while preventing wound infections, leaves the Kawymeno Waorani open to more fungal infections, which are perhaps the most common disease in Kawymeno. The absence of competing microbes, which have been reduced by phytochemical intake leave the fungal infections with less competition. The only case of pneumonia-like disease during the year we spent with the Kawymeno Waorani also turned out to be a fungal infection. The Santa Teresita Kichwa have less fungal diseases of the Tinea type than the Kawymeno Waorani, an exception to the general observation of reduced disease in the hunter-gatherer population. In addition, the Kawymeno Waorani often sleep on the ground more, which may bring them into closer contact with endemic

fungal growths, while the Santa Teresita Kichwa almost always use hammocks or sometimes beds.

Dental Issues with the Kawymeno Waorani.

The Tello Hospital medical team has pulled some Kawymeno Waorani teeth every year and the Waorani have traditional methods of pulling teeth. The Waorani have had problems with their teeth even proceeding first contact with outsiders and even Waorani myths mention the origin of bad dentition (Davis and Yost 1983). I suspect there may be something traditional in the Waorani diet that causes poor dental heath, although I have no plant candidates at the moment, it may be something the Waorani chew on. The Kawymeno Waorani do not practice any dental hygiene, which might prevent some dental problems. Dental pain and the practice of pulling teeth is a common problem with the Kawymeno Waorani and dental issues have even been noted by researchers in 1979, at first sustained contact with the outside world (Larrick et al 1979). The Waorani have a medicinal plant that is actually fairly effective in dealing with tooth pain and I have seen it used. In spite of the complaints of dental problems historically, all the Kawymeno Waorani seem to have most of their teeth. My wife tried to teach Waorani children to brush their teeth. However, the Kawymeno Waorani do not teach their children to brush their teeth or really any preventative dental care thus, adult Kawymeno Waorani also do not brush their teeth.

Kai, the Kawymeno Waorani chief, and many Waorani in the past conducted their own dental operations to remove painful teeth. The operation was described to me. No attempt at any hygienic measures, or any sterile procedure is

used, neither are any antibiotics or pain-killers used. First, the nerve connecting the tooth to the jaw is cut. Later when the tooth was dead it was pulled out and recovery is immediate. It is interesting that an operation of this kind never caused any kind of infectious or inflammatory response.

Notable Difference in Reaction to Venomous Snakebites Across the Study Populations.

Snake venom is the animal equivalent of plant phytochemicals and in fact many medicinal products have come from derivations of snake venom.



Figure 44. Kawymeno Waorani Boy Handling Venomous Snake - Fer-de-Lance (*Bothrops atrox asper*).

In this dissertation study, 33% percent of Kawymeno Waorani reported being bit by venomous snakes including children. (Venomous snakebite is even an occupational risk for medical anthropologists working with the Kawymeno Waorani). Larrick in 1979 reported that historically 4.9% of all Waorani deaths

were due to venomous snakebite (Larrick et al 1978, 1979). In a study of 223 blood serum samples of Waorani, Theakston et al found 78% tested positive in Elisa tests for snake venom antibody, with no real difference in prevalence between men and women (Theakston et al 1981). Seventy-eight % is probably an underestimate of Waorani lifetime rate of snakebite as in other studies only 35% of those who were actually bitten had detectable venom antibody (Pugh and Theakston 1980). Venom antibodies included responses to the Fer-de-Lance (*Bothrops atrox asper*) the Hog-Nose Pit Viper (*B. nastusis*), the Eyelash Viper (*B. schlegeli*), the Bushmaster (*Lachesis muta*) and the Black-Banded Coral Snake (*Micrurus nigrocinctus*).

The Waorani incidence for venomous snakebite, as well as fatality rate for snakebite, is the highest recorded in humans (Theakston et al 1981). Ninety-five % of Waorani males reported being bit by venomous snakes more than once (Larrick et al 1978, 1979). Most of the Waorani reacted positively to multiple different venom antibodies indicating bites by a variety of different types of venomous snakes (Theakston et al 1981).

I had to use anti-venom myself on one of my Kawymeno Waorani health promoters KT when he was bitten by a Fer-de-Lance 10 yards from my doorway. KT brought the stunned snake he thought he had killed up from the river before he passed out. His sister killed the snake with a machete. The snake was identified as a Fer-de-Lance (*Bothrops atrox asper).* I administered anti-venom twice and KT recovered enough to be able to go out and hunt in 3 days, an amazing recovery. I went to check in on KT several times a day and take his blood

pressure. I watched the swelling on his very swollen leg recede rapidly day by day until only his toe where he was bitten was swollen.

The fact there is such low morbidity and fatality rate for venomous snakebite is even more remarkable than the high Waorani fatality rate, which actually is very low if considered per snakebite. In fact, no Kawymeno Waorani has died from venomous snakebites, yet these same venomous snakebites kill and cripple neighboring Santa Teresita Kichwa individuals in spite of more ready access to anti-venom. The low average body temperature of the Kawymeno Waorani may have some relation to the high level of venomous snakebites as well as high level of plant defense chemicals and will be discussed in a future publication.

In the dissertation medical history 22% of the Santa Teresita Kichwa population reported being bit by a venomous snakebite and all were evacuated within a few hours to the Franklyn Tello hospital where they received anti-venom. Unlike the Kawymeno Waorani recovery from a venomous snakebite, in Santa Teresita recovery took place over many months and several individuals were permanently crippled. This is in contrast to my health promotor KT's rapid few-day recovery. Kawymeno Waorani clearly have some type of physiological resistance to snake venom, since a 95% rate of venomous snakebite would long ago have wiped out the Waorani culture and population. If some natural selection has occurred to provide resistance to snake venom this is a strong indication of the longevity of the Kawymeno Waorani culture in this region of Ecuador.

This dissertation will not go into length in comparing any other diseases of the Kawymeno Waorani hunter-gatherers and Santa Teresita Kichwa farmers. The overall comparison of all disease outcomes, both differences and similarities, between the Santa Teresita Kichwa and the Kawymeno Waorani, is summarized in the Summary Table in the beginning of this chapter.

CHAPTER 17

HELMINTHS I: PHYTOCHEMICALS AND IMMUNE FUNCTIONING - FLAWS IN THE HELMINTH HYPOTHESIS

An Alternative Point of View to the Helminth Hypothesis

The Helminth Hypothesis

Researchers typically use the term helminth to describe a variety of parasitic multi-cellular worm-like organisms that live part or all of their lifecycle in human or animal hosts. Some helminth species are visible to the naked eye. Helminths are transmitted into human hosts through mosquito bites, infected food, contaminated water, walking on infected soil and other means. Helminths live in and feed off their host by absorbing nutrients while receiving protection from the outside environment. Helminthic infestation in humans is of great interest to the medical community, as well as medical anthropologists, because a pillar of medical science and clinical practice revolves around theories about the co-evolutionary role of these worms and their human hosts. Proponents of the Helminth Hypothesis suggest that the development of the co-existence between the helminth parasites and human hosts through the millennia has shaped our immune system and that natural selection has given humanity a helminth antibody called IgE. These proponents suggest that helminths, while parasitic, now play a necessary role in human physiology (Hurtado, et al., 2008). They propose that helminth elimination from the host human body, via modern public health measures, has negative as well as positive effects on their human host's health.

On the surface, this double-edged sword approach to understanding helminth-human co-evolution appears to coincide with one of this dissertation's central themes – that co-evolutionary relationships with other organisms have simultaneously a beneficial and negative effect on human health. However, upon closer examination, there are major differences between what this dissertation suggests about a more inclusive co-evolution involving entire food chains and ecosystems and the more standard bilateral medical pathogen-host co-evolutionary relationships that are the theoretical backbone of the Helminth Hypothesis.

The Helminth Hypothesis is directly tied to the Hygiene Hypothesis, a theory more widely known even in lay circles, both of which provide theoretical support in the biomedical field to elaborate clinical interventions and direct preventive healthcare education. Despite its name, the Helminth Hypothesis is considered almost an unquestionable medical fact rather than a hypothesis, perhaps due to the theory's longevity, which spans half a century. Medical anthropologists are particularly interested in the Helminth Hypothesis as it considers the broad theory of evolution and natural selection as they relate to disease processes. A succinct description of the Helminth Hypothesis and related Hygiene Hypothesis are found in the excellent introductory medical anthropology textbook *Medical Anthropology: A Biocultural Approach* (Wiley and Allan, 2009, p. 243-5). These theories are taught as standard introductory knowledge to medical students and medical anthropologists alike.

Arguments against the Helminth Hypothesis and in Favor of a Plant Phytochemical Explanation for Immune Functioning

This chapter is a fact-based argument against aspects of the Helminth Hypothesis, based on laboratory evidence from this dissertation study combined with archeological evidence and studies of modern living human populations practicing hunter-gathering. This study uses a comparative nutritional approach across two entire food systems followed by a comparison of a broad range of health outcomes across these food systems. There are several principal arguments in this chapter, which are outlined below.

Plant phytochemicals – not helminths –stimulated creation of IgE antibodies through natural selection. First, this dissertation asserts that the most serious biochemical threat to humans is the chemical warfare going on between plants and humans. Rather than IgE antibody development being a product of helminth-human co-evolution as the Helminth Hypothesis suggests, this dissertation proposes that the regular dietary intake of toxic plant phytochemicals throughout human evolution necessitated the development of IgE. Humans and other herbivorous mammals that cannot tolerate strong plant defense chemical toxins would be left with very limited food sources to survive on. A generalist antibody such as IgE was required to help neutralize the huge range of dietary plant toxins consumed daily by humans. Without the ability to adapt to and ingest a broad diet full of phytochemical toxins, humans would have lost their survival edge. Profet (1991) outlined a plant toxin alternative to the Helminth Hypothesis to explain existence of IgE but relegated phytochemicals to a role of natural poisons (Profet, 1991), while this dissertation makes a case that

phytochemicals are an essential and beneficial part of the human diet. Moving beyond armchair theorizing, this dissertation has actually tested for helminth presence in living hunter-gatherers. To test for evidence that there was a difference of helminth presence when hunter-gathering systems gave way to subsistence agriculture, the dissertation design involved comparing otherwise similar neighboring groups of hunter-gatherers and subsistence farmers for helminth infestation presence. The fact that the dissertation Kawymeno Waorani hunter-gatherer population has virtually no helminths, use no anthelmintic plants as medicines and yet hold the world's highest recorded IgE antibody levels provides evidence that high helminth levels in human bodies do not cause high IgE levels (Kron, 2000). NIH-sponsored researchers began looking for a connection between helminth load status and IgE levels in early studies of the Waorani, particularly because of the Waorani record-breaking high IgE levels. However, no correlation was found between high IgE levels and high helminth levels, which contradicts the Helminth Hypothesis but is consistent with this dissertation's Waorani results. However, authors of that day and age did not yet have a plant phytochemical model to contrast with the Helminth Hypothesis, as it was not suggested until almost ten years later and still used aspects of the Helminth Hypothesis to account for their findings.

Unlike this present dissertation study, earlier NIH researchers did not use a comparison group when they investigated a remarkably healthy Waorani hunter-gatherer population (Larrick, 1983; Kaplan, 1980). This dissertation study design involved the selection of two study groups that are very comparable in most

respects (except food system) to make a straight comparison of food systems while minimizing confounding factors that would influence helminth presence as discussed in this and other chapters. The lack of helminths in the Kawymeno Waorani hunter-gatherers was especially notable when contrasted with the presence of helminths in 82.5% of the Kichwa subsistence farmer comparison group. Dissertation results also demonstrated a difference of over 600 % in regular dietary intake of wild plant foods and animals (Etkin, 2006) rich in phytochemicals in the Kawymeno Waorani hunter-gatherer diet compared to the Santa Teresita Kichwa farmed food diet (see food system chapter). Disparity in phytochemical intake coupled with the vast difference in helminth presence across food systems in the dissertation results give enough comparative evidence to warrant re-evaluating the validity of the Helminth Hypothesis and making a case for a phytochemical alternative explanation to IgE function and origin, brought on by a switch in food systems from hunter-gathering to agriculture.

There is actually no convincing evidence that IgE antibodies kill or harm helminths in the human body and any IgE antibody long-term effects of slowly preventing helminth re-infection is speculative and unknown (MacDonald, et al., 2002). Furthermore, as any lab technician that works with parasites knows, many helminths such as tapeworms and Enterobius do not solicit a large IgE reaction but rather an IgM or IgG antibody reaction.

Dietary phytochemicals kept helminth levels low in prehistoric hunter-gatherers

Agriculture created a favorable environment for helminth infestation of human bodies. Second, this chapter asserts that the prehistoric hunter-gatherers, like the Kawymeno Waorani hunter-gatherers today, never had evolutionary path-altering levels of interaction with helminths, principally because a regular ingestion of plant defense anthelmintic chemicals prevented helminth infestations. Phytochemical control of helminths worked in combination with the hunter-gatherer lifestyle involving small, isolated mobile groups, a lifestyle that was also not conducive to maintaining parasitic helminthic populations in human bodies. Both lifestyle and preventative phytochemical intake changed drastically with humanity's move to an agricultural system from a hunter-gathering food system. However, the change to an agricultural food system facilitated the transmission of helminth species across populations and augmented the ability of helminths, now without any dietary plant-based bio-chemical obstacles, to more successfully infest human populations.

This chapter then turns to studies of modern hunter-gatherers and demonstrates that by separating helminth and/or IgE studies on modern indigenous groups along a spectrum from strict hunter-gatherers to acculturating farmers, a relationship begins to emerge between the change in the food system wild phytochemical intake and the degree to which helminths are encountered in the particular population. The closer to a hunter-gathering food system and the further from subsistence farming, the fewer helminths are found in these

indigenous groups. Daily dietary anti-helminth phytochemical intake may have prevented the growth of native species of helminths in many hunter-gatherer populations and the isolated nature of hunter-gatherer life may have slowed down any outside introduction of helminths.

Beyond the Waorani and modern hunter-gatherer evidence, this chapter looks at archeological studies that compare Neolithic farmers and contemporary prehistoric hunter-gatherers. These comparative, cross food system archeological studies came to a similar conclusion as this dissertation study. These archeologists emphasized that one of the most import reasons for the increase of helminths in humans was the adoption of agriculture over hunter-gathering (Reinhard, 1986, 1988). There was evidence of daily dietary phytochemical anthelmintic food intake in prehistoric hunter-gatherers coupled with a lack of helminth worms in hunter-gatherer feces. In contrast, archeological evidence from neighboring Neolithic farmers found no evidence of regular dietary phytochemical intake but did find feces that are positive for helminth infestations.

Arguments Supporting This Chapter's Phytochemical Hypothesis

Beyond helminths there is another explanation for the existence of IgE antibodies – the chemical warfare between humans and plants. The Hygiene Hypothesis revolves around the human antibody isotope Immunoglobulin E (abbreviated IgE). The other human antibodies have known mechanisms for preventing and curing disease, but the mechanism and purpose of IgE has never been determined definitively. It is well known that IgE activation in populations with minimal baseline IgE antibody levels appears to actually cause rather than

prevent disease, such as allergic responses to environmental materials that cause IgE to stimulate inflammation, redness and allergic reactions and is linked to autoimmune disease. One example is the reaction humans have after touching a Poison Ivy (Toxicodendron radicans) plant leaf, which releases IgE-stimulating anti-herbivore plant defense toxins into the skin of the perceived human threat.

Antibodies are proteins produced by the human immune system when foreign objects enter the human body. Antibodies identify and tag invading foreign organisms and objects such as bacterial and viral pathogens for destruction by other immune system bio-chemical guardians. Some antibodies go beyond tagging and actually attack and neutralize foreign organisms themselves. There are five major antibody isotopes in mammals IgA, IgD, IgE, IgG, and IgM.

The fact that other antibodies beyond IgE such as IgG, IgM and IgA also target helminths (Moreau and Chauvin, 2009) casts additional doubt as to whether there was really a pressing evolutionary survival need for the creation through natural selection of a separate IgE antibody just for helminths when other antibodies are also activated by helminth infestations. In fact, a number of helminth species commonly found in humans such as tapeworms and Enterobius vermicularis do not even stimulate much IgE antibody reaction but do stimulate IgG and IgM antibodies in humans, as is well known to all medical lab technicians working with diagnosing tapeworm and Enterobius infestations.

Anthropological studies of modern indigenous groups: do they really support the Helminth Hypothesis?. Some of the strongest proponents of the Helminth Hypothesis are anthropologists studying modern hunter-gatherer

populations. Magdalena Hurtado is one of the foremost proponents in suggesting there is evidence in support of the Helminth Hypothesis found in modern acculturating indigenous populations. Hurtado argues that modern indigenous groups represent the closest link to hunter-gatherer lifestyles available now, including prehistoric helminth-human relationships. Hurtado and a number of other researchers believe these modern indigenous studies suggest that parasites are a selective force in the immune system (Fumagalli and Pozzoli, 2009).

Hurtado, et al. (2005) in a review paper on indigenous groups, try to link the level of "indigenousness" of a population as a measuring device for population helminth levels. Hurtado lists as evidence a number of indigenous groups with high helminth levels and compares them to non-indigenous groups with lower helminth levels.

Whether indigenous groups have more helminths than non-indigenous groups is not the relevant question to test the Helminth Hypothesis. Indigenousness itself is not the issue when it comes to helminth loads; the food system is the underlying factor.

After a careful look at each of the indigenous groups and studies Hurtado references to support her point, it is evident that most of the indigenous groups that Hurtado selected were practicing subsistence farming, although some groups were supplementing their diet through hunter-gathering and fishing. Hurtado's former hunter-gatherer populations have high helminth loads due to their present farming activities and contact with outsiders who harbor a reservoir of parasites, not as a vestige of their previous life as hunter-gatherers (McKeown, 1976; Dunn,

1972). These former hunter-gatherer groups were well on the road to acculturation, mostly settled, and entering into modern agricultural practices. In other words, most of the groups selected by Hurtado were not hunter-gatherers but indigenous people who are acculturating into a mix of subsistence agriculture and Western food systems with occasional part-time hunting and gathering.

The Helminth Hypothesis is so firmly rooted among most anthropologists studying modern hunter-gatherers as to be considered "fact". Thus, it is necessary to make a very strong case with multiple examples to even cause doubt. This chapter provides these additional case studies at the end of the chapter to make an even stronger case. Namely that the closer a food system is to actual hunter-gathering the fewer the helminths found in indigenous groups.

Explaining falling IgE levels in modern populations: reduction of dietary wild phytochemicals or elimination of helminths? Proponents of the helminth hypothesis believe the purpose of IgE is to serve as the "helminth antibody" and the normal fluctuation and rise of human IgE in our hunter-gatherer ancestors is due to the presence of helminth worm parasite residence in the human body. The Helminth Hypothesis suggests that IgE antibodies run amok in humans without helminths to serve as moderators of human physiology. The Helminth Hypothesis suggests humans without helminths also lose immunity to microbial infections. This loss of immunity to microbes is accounted for by a complicated theory of imbalance of immune system T1 and T2 helper cells, provoked by a decrease in IgE levels due to a lack of helminth parasites in the human body. Put simply, the Helminth Hypothesis says that IgE levels are regulated by the amount

of helminths in the body, with more helminths leading to more IgE production, and through the process of creating biochemicals through helminth-human interaction enhanced immunity to microbial infections is also maintained.

This dissertation puts forward a case for taking a step back from the bio-medical preconception that human antibody's principal function is to protect against foreign microbes, larger pathogens and bi-products of both microbes and pathogens and considers that there may be other reasons for antibody existence. Specifically, human antibodies may have developed to also deal with chemical threats from the plant kingdom, rather than to only wage chemical warfare with pathogens from the animal kingdom. The enormous variety of toxic dietary plant defense chemicals humans must consume every day to survive requires antibodies that can be generalists –like IgE – that deal with many toxins and augment less inclusive targeted detoxification that escapes other antibodies, enzymes and intestinal bacteria designed to fight specific toxins and pathogens. Hunter-gatherers that could not tolerate strong plant defense chemical content would have a very limited number of food sources. A generalist antibody that creates an ability to eat a wider variety of foods by processing more toxins from previously inedible plants gives a survival edge to possessors of this IgE antibody.

High wild phytochemicals = high IgE / low wild phytochemicals = low IgE. A hunter-gatherer diet usually includes a variety of wild plants some of which contain anthelmintic, prophylactic and purgative plant defense compounds against helminths and other parasites (Moerman, 1986; Fry and Hall, 1975). In subsistence agriculture these wild plant foods are replaced by domesticated foods

lacking such compounds (Moerman, 1986; Fry and Hall, 1975). Most researchers generally agree that a reduction in dietary plant phytochemical intake occurs when switching from a wild plant hunter-gatherer diet to agricultural plants (Strassmann, 2008).

Phytochemicals are already well-known to stimulate high IgE levels (Profet, 1991). Although IgE may respond to helminth allergens, a case is made here that IgE is not solely, or even principally, designed to deal with these helminth chemical byproducts produced in their human hosts. This dissertation suggests that IgE principally enabled humans to survive by reducing chemical toxicity to the many foods hominoids adapted to eating throughout their existence on earth, particularly plant food phytochemical toxins such as anti-herbivore defense chemicals.

I hypothesize the actual purpose of IgE in the Kawymeno Waorani hunter-gatherers of this study may be to control the high levels of plant toxins present in many prehistoric human diets, particularly the high ingestion rate of plant-based poisons used to hunt and fish. In this chapter, I argue that the extremely high IgE level in the Kawymeno Waorani hunter-gatherers of this study and other hunter-gatherer groups are largely unrelated to helminthic parasites because most hunter-gatherers did not have IgE producing parasites in sufficient quantities to affect immune functioning.

Daily plant phytochemical consumption while boosting IgE levels to detoxify aspects of phytochemical intake may also improve immune function. By constantly stimulating IgE antibodies, phytochemicals may keep the body

antibody and immune system alert and activated to deal with other disease causing entities that enter the human body. Steady high IgE levels such as those present in Kawymeno Waorani hunter-gatherers may be a biomarker for normal immune functioning that deteriorated with the advent of agriculture. The much lower IgE level present in modern humans may be abnormal for humanity and a biomarker for an immune system no longer stimulated by plant phytochemical intake that is now vulnerable to disease.

Plant phytochemical dietary intake has been modified greatly since hunter-gatherers began to switch to farming. Modern agriculture has eliminated many phytochemicals toxins/allergens from the diet that require IgE antibodies. Thus, IgE is less useful to agrarians than hunter-gatherers if its principal purpose is controlling toxic reactions from phytochemicals. This dissertation proposes that while agriculture did not eliminate plant toxins from the diet, the variety of particularly strong plant-based allergens that required generalist antibodies like IgE is greatly reduced in agricultural diets.

Were high helminth levels present in prehistoric hunter-gatherers?

The Helminth Hypothesis suggests that helminths have always had a powerful influence on human physiology and IgE levels throughout human history and pre-history, which on the surface seems reasonable considering how widespread helminthic infections are in human populations today. However, this dissertation suggests when a more long-term perspective be applied to counterbalance the dominant short-term agricultural perspective, which is the only living reality most

researchers study, it is less clear that helminth presence was always as high in humans as it is today.

This dissertation suggests that helminths are not as widespread or numerous in hunter-gatherers as they are in the subsistence farmers that followed them. Dissertation evidence of a lack of helminth presence in Kawymeno Waorani hunter-gatherers, coupled with Kawymeno Waorani historically ultra high IgE levels, suggest helminths are not responsible for the high IgE levels present in other hunter-gatherers. The Santa Teresita Kichwa farmers have abundant helminth infestations while the Kawymeno Waorani have virtually no helminths. This dissertation study has documented that Kawymeno Waorani hunter-gatherers do not consume anthelmintic remedies while their neighboring Kichwa subsistence farmers do consume powerful anthelmintic natural remedies, such as a squash seed *Cucurbita maxima* called Sapallo, and a tree sap called Hila Wiki (*Ficus insipida)*.

Thus, hunter-gatherers and modern societies with public health systems have something in common; low helminth loads. Modern industrial societies with adequate public health systems that came after subsistence farming do not have the high helminth loads found today in the developing world and this dissertation suggests hunter-gatherers that proceeded subsistence farming also did not have high helminth loads. However, evidence from this chapter makes a case that this middle group of subsistence farmers like the comparison Santa Teresita Kichwa study group did have high helminth loads, which is the focus of so much biomedical research. However, this biomedical research may not be looking at the

human norm regarding the extent to which helminths have affected humans historically.

This dissertation puts forward the case that when the modern public health system began to compensate for the vulnerability to helminths brought about by an agricultural lifestyle by introducing sanitation and hygiene measures, helminth populations merely fell closer to hunter-gatherer levels. This dissertation further argues that the human norm is a low helminth load, and that only relatively recently with the advent of agriculture that supported large sedentary populations (originally without adequate sanitation facilities) have helminths became more numerous. As the chapter progresses several lines of evidence are presented to support the hypothesis that diet and lifestyle of hunter-gatherers are not conducive to a strong helminth-human relationship while the diet and lifestyle of subsistence farming is ideal for promoting helminth infestation in humans. In the spectrum from hunter-gathering to subsistence farming, fewer helminths are found when the food systems approach the norm for human history, namely high phytochemical dietary intake acquired though hunter-gathering coming from a wild ecosystem food chain.

Beyond phytochemicals: other hunter-gatherer lifestyle factors that affect helminth-human co-existence. Dietary intake of phytochemicals did not act alone in discouraging helminth infestations in hunter-gathering populations. Isolation prevented exposure and transmission of helminths across human groups to start with as hunter-gatherer bands such as the Waorani had infrequent contact with other groups of humans including other Waorani groups.

While the helminths discovered in this study do not have an animal reservoir or animal participant in their lifecycle, further lack of domesticated animals in pre-hunter-gatherer groups over the millennia precluded the type of close animal-human contact that would eventually facilitate the spread and survival of helminth mutations capable of crossing host species. In addition, the small group size and mobility of hunter-gatherer bands may have disrupted some helminth-human lifecycles that depend on oral-fecal transmission by more suitable to human agrarian hosts with a sedentary lifestyle and large population pools with poor sanitation.

Humans and helminths relationship: co-evolutionary or co-existence?

Most common helminths that co-exist in human hosts exhibit little or no pathogenesis in moderate loads and few cause outright anemia at all in humans and thus seem unlikely forces of natural selection in humans. Geographically restricted less common helminths such as *Schistosoma mansoni, Trichinella spiralis, Fasciola hepatica, Onchocerca volvulus, Dracunculus medinensis* and the filarial nematodes can sometimes cause more serious disease in humans. However, there is no archeological evidence of these more problematic helminths' widespread existence in prehistoric hunter-gathering societies (Gonclaves 2003; Sianto 2009). Hurtado, et al. (2005) suggest that while helminths themselves may not be forces of natural selection, helminths in combination with other diseases can cause enough health problems to affect natural selection. However, this type of argument can be made with any disease, since many diseases interact with each other and can multiply/augment the

disease capacity of each other, especially if one disease weakens the person's physical condition or immune status, thus reducing resistance to the second disease, such as combinations of tuberculosis and AIDS or obesity and heart disease. If the Helminth Hypothesis proponents are correct, the creation through natural selection of a new immunoglobulin antibody, IgE, just for helminth prevention is a feat no other disease threat to humans has accomplished. Not even malaria, which is well-known as a selective force in humans, can account for the creation of a completely new human immunoglobulin (Kwiatkowski, 2005).

Moreover, IgE does not kill the high helminth loads that can cause anemia and other nutritional helminth-related disorders (MacDonald, et al., 2002). IgE

ctually has surprisingly little effect in eliminating helminths in human bodies (MacDonald, et al., 2002), which is another reason one could argue the Helminth Hypothesis may be theoretically unsound. There is no convincing evidence that IgE antibodies kill or remove helminths living in humans themselves or even indirectly. In fact, the physiological mechanism, if any, that IgE uses to reduce helminth load over the long-term is speculative and unknown (MacDonald, et al., 2002). Thus, helminth resident parasites may remain largely undisturbed regardless of human IgE status for many years.

Evidence is presented on two more topics as the chapter progresses. First, many common helminths, such as Enterobius and tapeworms do not even stimulate IgE production, but rather raise levels of other human antibodies as is well known in parasite laboratory science. Thus, IgE is not the only helminth-related antibody. Further, this dissertation argues that helminths that do cause

disease in humans and raise IgE levels may not have been widespread globally and were actually absent in entire continents until recently (Faust, 1949; Faust, 1955; Jelliffe, et al., 1962; Jones, 1980; Moller, et al., 2007; Salzano, et al., 1988). This dissertation argues that the complete absence of major helminths over vast regions may be due to long-term phytochemical anthelmintic preventive aspects of diet as well as lack of contact and cross-exposure to helminths by disparate hunter-gatherer groups on different continents.

Conclusions

This dissertation chapter suggests that a reasonable evidence-based case can be made to reject the Helminth Hypothesis based on evidence from dissertation helminth stool examinations combined with previous Waorani studies, which is then confirmed through a wider look at helminth-human co-existence in hunter-gatherer groups geographically around the world and going back in time temporally and archeologically to the Paleolithic Era.

The potentially damaging effects that helminthic infestations have on today's human population, particularly the poor in the developing world, may lead researchers to conclude that today's rate of helminth disease burden has always been the human norm. Thus, it's important for evolutionary-minded researchers to question present human norms as reality throughout human existence. It is tempting to use present day data on the impact of helminth parasites in the developing world as evidence of Paleolithic norms but this chapter suggests there is not enough convincing evidence from modern indigenous studies to support a co-evolutionary helminth-human relationship as the entire framework

for understanding IgE antibody functioning. Subsistence agriculture is very far from the evolutionary norm, and today's farming societies and acculturating indigenous groups– no matter what the culture – did not have helminthic loads typical of humanity's long-term evolutionary past.

The dissertation hypothesis regarding IgE origin is that while some types of helminths, in large enough loads, may stimulate human IgE antibody levels, helminths were only one of a number of factors that affected IgE levels, and not the principal factor, which we hypothesized came predominantly from the food system.

This dissertation suggests that the true purpose of IgE antibodies is more likely to combat a wide variety of toxic plant phytochemicals in the hunter-gatherer diet rather than for reducing certain helminth by-products released into the human body, as suggested by the Helminth Hypothesis. Plants always had defense chemicals that were toxic to humans and humans always had to find a way to make their plant food edible. Ultra high IgE levels (hyperimmunoglobulinemia) such as that of the Kawymeno Waorani may actually have been a human norm in hunter-gatherer populations to deal with a high phytochemical-based diet. Agricultural societies' relatively minimal average level of 100 IU/ml may be a historical abnormality caused by entering into agriculture.

In the dawn of agriculture, when humanity gave up a disease protective, phytochemical-rich and varied hunter-gatherer diet, helminths and other diseases rose since there was no longer a natural system to control them, causing increased

helminth infestations across broader populations as well as microbe-based plagues, pestilence and population-decimating diseases. This middle time between hunter-gathering and modern food systems needs to be analyzed separately in regards to helminths and other diseases. The change from hunter-gathering to subsistence farming created a more favorable human-made environment for helminths and greater facility for helminth transfer worldwide.

Recommendations for Future Investigations on Hunter-Gatherers, IgE, Helminths and Phytochemical Intake

This dissertation chapter proposes there is a general trend in the literature for a lower helminthic parasite presence to be found in studies on modern indigenous groups with the following characteristics:

1) Studies done on groups at a time closer to a hunter-gathering group's first contact with outsiders from modern agricultural cultures.

2) Studies done on more isolated populations.

3) Studies done on groups consuming wild foods rather than beginning to rely on domesticated animals and plants.

5) Studies done on groups embedded in a pristine natural ecosystem with a completely wild food chain and ecology.

6) Studies done on groups with the largest variety of wild dietary plant defense phytochemical intake as well as wild animal intake. Animals also consume or produce bioactive animal constituents similar to phytochemicals but are rarely studied (Etkin, 2006).

In addition, more attention should be given to comparative studies rather than uni-population studies typical of anthropological work. Comparing food systems can be more fruitful than simply documenting a single food system. Unfortunately, there are few comparative modern indigenous studies done with practicing complete hunter-gatherers across other types of food systems. Most of the comparative studies across food systems involving true hunter-gatherers are archeological and these archeological studies should receive more importance in the helminth-human argument (Armelagos, 2005; Reinhard, 1986, 1988).

Further, rather than grouping all species of helminths together as is the custom in most modern anthropological indigenous studies on helminths, it would be more useful to compare individual helminth organisms species by species across studies. Many helminth species do not even affect IgE and should be eliminated from consideration in any argument relating to the Helminth Hypothesis. Other common helminths may have been introduced to these indigenous groups across the world in the colonial era and therefore should also be eliminated from consideration in any argument relating to the Helminth Hypothesis. In the end, there are few helminths species left as candidates to have altered or created antibodies in the human immune system through the process of evolution and natural selection and these helminths may never have been widespread or common, leaving proponents of the Helminth Hypothesis with little proof that helminths were part of a major human co-evolutionary force.

Largely uncontacted, unacculturated hunter-gatherer groups in Peru and Brazil still exist. Checking both the stool helminth count and IgE blood level of

the remaining true hunter-gatherers left in the world might be far more valuable than any continued work with acculturating indigenous groups.

Unfortunately, the increased level of outside contact the Kawymeno Waorani hunter-gatherers are beginning to experience in 2012 with oil company sponsored expeditions interested in exploiting the ITT (Ishpingo, Tambococha, Tiputini) oil wells 25 minutes from Kawymeno, will make meaningful stool specimens that represent an isolated hunter-gatherer food system increasingly difficult to get from Kawymeno Waorani, so our study may represent the last opportunity to have done so.

When researchers do test for both IgE and helminths the results can be surprising, as demonstrated by Moller's Greenland study which found a population with elevated IgE but an absence of helminths (Moller, 2007). This Kawymeno Waorani dissertation study is another surprising example that defies the Helminth Hypothesis: the world's IgE record holders have no helminths. More primary studies with the last remaining hunter-gatherers should test both IgE levels and helminth levels, and not assume these two factors are interchangeable.

In a recent study of the Shuar, an indigenous group not far from the Waorani in Amazonian Ecuador, researchers used IgE levels as a proxy for actual stool examination for helminth load (Blackwell, et al., 2010). The authors admit in their article that no one has ever conducted stool examinations to see if the Shuar actually have helminths (Blackwell, et al., 2010). Blackwell stated that stool testing was inconvenient and unnecessary because high IgE levels indicated the population had helminths (Blackwell, et al., 2010). While Blackwell

conducted a useful and interesting study, this example is typical of indigenous studies today that do not analyze IgE levels against helminth levels.

Many things are known to cause elevated IgE besides helminths; e.g., atopic disease, viruses, neoplasms and even smoking (Dumerez, 1996). But none of these are as omnipresent as human food entering the human body. A key point mentioned in this chapter is that one simply has to remove the bio-medical preconception that all antibodies are there to eliminate the effect of animal kingdom pathogens. IgE antibodies may be designed to deal with chemical threats from the plant kingdom as well as parasitic animal kingdom threats. The need to detoxify and control dietary plant kingdom defense chemicals in food is a stronger evolutionary force than helminth-human co-existence.

CHAPTER 18

HELMINTHS II: DISSERTATION COMPARATIVE STUDY OF HELMINTH PRESENCE IN HUNTER-GATHERERS AND AGRARIANS

Subject and Methods

Dissertation Study Populations. The Kawymeno Waorani, the study hunter-gatherer group, have close to the world's highest recorded IgE blood antibody level – 11,850 IU/ml average in 2000 (Kron, 2000). The Waorani culture as a whole has the highest recorded IgE rates in a human population at an average of 11,975 IU/ml, (Larrick, 1983; Kaplan, 1980). Since the protectorate Waorani population is being absorbed into the modern food system and lifestyle, their IgE rates have dropped considerably, while Kawymeno IgE rates have remained at levels comparable to the first introduction to Westerners (Kron, 2000). The Riverine Kichwa of whom the Santa Teresita Kichwa study group belong, are made up of several villages on the banks of the lower Napo River. (Kawymeno is also in a similar riverine environment living on the banks of the Yasuni River). The Riverine Kichwa have an intermediate IgE level of 2,964 IU/ml (Kron, 2000). Modern populations in large-scale agricultural systems such as residents of the USA have a relatively minimal IgE level of less than 100 IU/ml. High helminth levels are believed to be caused by high IgE levels. This dissertation study examined Kawymeno Waorani hunter-gatherer and Santa Teresita Kichwa stool helminth levels to see if the helminth level matched that expectation, which

would mean higher helminth levels in the Waorani group compared to the Kichwa study group.

Laboratory analysis was conducted on stool samples from sixteen adult Kawymeno Waorani hunter-gatherers; eight males and eight females**.** Laboratory analysis was also conducted on stool samples from sixty-three Santa Teresita Kichwa subsistence farmers, thirty-three males and thirty females. Stool samples were obtained within a two-week period for both groups.

Sixteen out of 121 people living in Kawymeno in 2010 (7.56 % of the population) produced stool samples for the dissertation study. During oil drilling negotiations with the Waorani nation in 2010, stool specimens were obtained from the Kawymeno Waorani immediately after Waorani arrival in the provincial capital of Coca for meetings using an Ecuadorian government oil company boat. The Kawymeno Waorani were being housed only a few blocks from the laboratory where the specimens were analyzed. Thus, the study selection of the Waorani group was made based on willingness to make the trip to Coca on the oil company boat. One Kawymeno Waorani member sampled had already been in Coca for several weeks and was the only Waorani member to produce a stool positive for helminths. Two members of the Kawymeno Waorani group in Coca were unable to produce stool specimens.

All the Kichwa families in the Santa Teresita study group produced at least one stool sample for the dissertation study; at least one member in each household participated in giving a stool sample. A total of sixty-three out of a total Santa Teresita Kichwa population of the 312 Kichwa living in Santa Teresita

participated in the dissertation study, meaning 20.1% of the population was sampled.

Laboratory analysis for helminth levels in Waorani and Kichwa stool samples. The investigation collected one round of stool samples from all participants. A single stool sample identifies about 75% of the parasitic infections that would be detected over time using three different stool samples from the same subject (Cartwright, 1999). Thus, a single stool sample is reasonable evidence of helminth history in a human participant. An exception would be Enterobius helminth, which due to their life cycle are not usually found in stools, but may appear in a stool sample if they are clinging to perianal folds and are pushed in (Faust, 1947). Enterobius were not found in either group.

Both Kawymeno Waorani and Santa Teresita Kichwa specimens reached the laboratory within several hours of collection. Santa Teresita Kichwa stool specimens were transported by high-speed motorboat to the laboratory for analysis. Fewer Waorani stool samples were obtained than Kichwa because the oil company brought a limited number of Waorani into the city where the laboratory was located. Kawymeno is too far away from any laboratory and difficult to access (only via canoe) to get stool samples transported in sufficient time to avoid deterioration of the specimens. Urine samples were captured and analyzed from both groups at the same time as stool specimens; the results of the urine samples are discussed elsewhere.

All stool samples were placed into standard, sealed, sterile stool laboratory plastic stool collection containers using the sterile spoons provided, and then

packed in chemical ice in a thermos for transport. I personally supervised the complete stool collection process of all Waorani and Kichwa samples, staying with the samples from the moment of collection in the field onward, personally identifying and labeling the stool specimens for identification, and personally transporting and delivering specimens to the laboratory.

Results

Helminth Presence in Stool Samples of Study Populations. Stool samples collected in March 2010 yielded the following helminth species load information for Santa Teresita Kichwa subsistence farming population living on the banks of the Napo River:

- 82.5% (52 out of 63 tested) had some kind of helminth parasite.
- 76.1% (48 out of 63 tested) had Ascaris lumbricoides.
- Hookworm (Ancylostoma duodenal) was present in 11.1% of the samples.
- Trichuris was present in 1.5% (one person). This individual also had Ascaris lumbricoides helminths.
- Three individuals, 4.74% of the population, had hookworm helminths (Ancylostoma duodenal) in addition to Ascaris lumbricoides.
- Laboratory results indicated the average Kichwa worm load infestations were moderate: 1 to 2 eggs/larvae per low-powered microscope magnification field slide (10x).

Absence of helminths in Kawymeno Waorani stool samples. In contrast, sixteen stool samples were collected in March 2010 from the Kawymeno Waorani hunter-gatherer group. The results were remarkable.

- These sixteen stool samples revealed an absence of all species of helminths in all members of the Kawymeno Waorani group tested, with the single exception of one woman (6.25% of the population tested) with a light load of Ascaris lumbricoides (one egg per 5-10 low-powered microscopic magnification fields) who had been staying several weeks in the provincial capital of Francisco de Orellana, an Amazonian city inhabited primarily by Kichwa and Latinos with a constant influx of oil company personnel.
- The difference between the population helminth infestation levels of the Kawymeno Waorani and Santa Teresita Kichwa is very large – 6.25% of the Kawymeno Waorani population (one person) compared to 82.5% of the Santa Teresita Kichwa population. The only Kawymeno Waorani positive for helminths had been outside the Kawymeno community and in the city for several weeks.

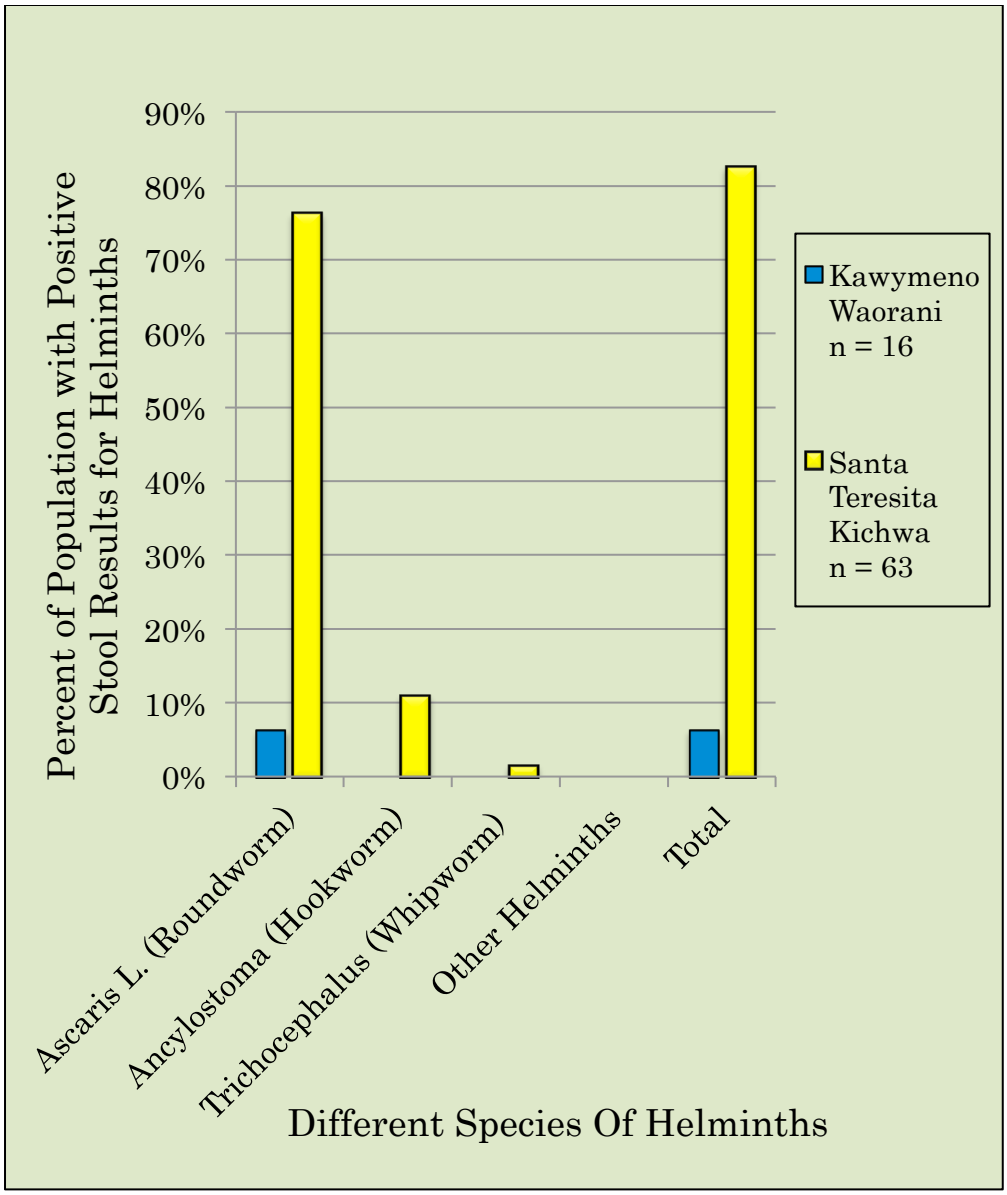


Figure 45. Parasitic Helminth Worm Incidence: Kawymeno Waorani vs. Santa Teresita Kichwa. (statistical analysis in Appendix H) 2010

Types of helminths found. Scholars estimate that over a quarter of the world's population today is infected with an intestinal helminthic worm of some sort, principally roundworm (Ascaris lumbricoides) (Chan, 1997; Crompton, 1999; Watkins and Pollitt, 1997). Ascaris lumbricoides was the most commonly

found helminth in the dissertation study. Ascaris lumbricoides infects the digestive tracts of over 1.4 billion people worldwide (Chan, et al, 1997; Crompton, 1999). Ascaris lumbricoides has a specialized lifecycle for human bodies and is not found in domesticated animals.

Table 10. Principal Helminth Parasitic Worms Found in Human Beings

Phylum/Class	**Species 1**	**Common names**
Nemotode/Ascarididae	Ascaris lumbricoides	Giant Roundworm
Nemotode/Strongylidae	Necator americanus	Hookworm
Nemotode/Strongylidae	Ancylostoma duodenale/brazilense	Hookworm
Nemotode/Oxyuridae	Enterobius vermicularis	Pinworm (UK) Threadworm (USA)
Nemotode/Adenophorea	Trichuris trichiura or Trichuriasis	Whipworm
Nemotode/Secernentea	Strongyloides stercoralis	also called Threadworm (above)
Cestoda/Platyhelminths	Taenia Solium/saginata/asiatica	Tapeworm

The Ascaris lombricoides helminth lifecycle can be direct, which means no intermediate hosts are required although typically eggs shed in human feces re-infect humans via oral fecal transmission. Eggs of Ascaris lumbricoides take 10-

30 days to embryonate outside the human body and become infective. These eggs are resistant to heat and, to some extent, dryness for short periods. Helminths with a short lifespan such as Ascaris lumbricoides (often under a year but up to two years) require constant infestation. More permanent sedentary community lifestyle promotes re-infection of Ascaris lumbricoides and hookworm species through feces to oral contact (Chernela and Thatcher, 1993; Dunn, 1972). Although the Kawymeno Waorani are more mobile than the Santa Teresita Kichwa, trekking throughout the rainforest frequently, both Kawymeno and Santa Teresita communities have been in existence in the same physical location for several decades and are capable of maintaining the Ascaris lumbricoides, Trichuris and hookworm species lifecycle.

Hookworms (*Ancylostoma duadenale*) and whipworms (*Trichuris trichiura*) were also present in the Santa Teresita Kichwa population and represent two of the most common helminth species found worldwide in humans. Direct human to human transmission can occur with Ascaris and Trichuris, while hookworms have an external lifecycle that requires time outside the human body in soil.

A few hookworms of the *Ancylostoma duodenale* species were found in the dissertation study in the Santa Teresita Kichwa. The open moist soil of Kichwa gardens may promote the hookworm transmission slightly more than the Kawymeno Waorani semi-cultivated plots of manioc where open moist soil is typically not present. However, the Kawymeno Waorani are more likely to walk

barefoot than the Santa Teresita Kichwa and hookworm often enter the human body by making a hole in the foot when contacted in the soil.

The only other helminth found in the stool exams, *Trichuris trichiura,* was present in only one Kichwa participant stool and not in any Waorani samples.

Lack of exposure to potentially infectious outsiders with helminths on the part of the Kawymeno Waorani is unlikely to explain the dramatic difference in helminth levels between the hunter-gatherers and farmers in this study as Kawymeno Waorani frequently visit Protectorate Waorani who have high levels of helminth infestations.

Outside the laboratory: additional evidence to confirm laboratory findings. The absence of helminths in stool examinations of Kawymeno Waorani and the presence of helminths in Santa Teresita Kichwa stool samples coincided with observations about helminth incidence and prevalence found in dissertation medical histories and informal conversations and observations over nine months of living daily with both groups, by alternating sites during the data collecting time period. These observations, interviews and conversations showed little evidence of helminth infestation in Kawymeno and an abundance of evidence of helminth infestation in Santa Teresita. All Kawymeno participants denied having problems with helminths when living in Kawymeno and are familiar with helminths from their contacts with protectorate Waorani families who have major problems with helminths. (Thus, since protectorate Waorani have helminths, a genetic resistance to helminths on the part of the Kawymeno Waorani seems unlikely). In contrast, the entire Kichwa population who participated in the

medical exam and history, minus several individuals with neurological handicaps, who may not have understood the questions well, complained of helminth infestations. Santa Teresita participants cited helminths as a major ongoing health concern. Ascaris lumbricoides, the most commonly encountered helminth in the dissertation study, is clearly visible in feces to the naked eye, so it is unlikely Waorani would not be aware if they had a helminth infestation.

Most Santa Teresita Kichwa participants reported using the anthelmintic natural plant remedies a squash seed (*Cucurbita maxima*) called Sapallo, and a tree sap called Hila Wiki *(Ficus insipida)* both of which are discussed in other chapters. Some Kichwa also reported using synthetic anthelmintic medications at some time in their lives. No Kawymeno participants reported any use of anthelmintic plant or synthetic medications.

Participant observation, medical exams and histories: more evidence of helminth absence in the Waorani population. Participant observation over 210 days, medical histories, and medical exams also failed to reveal complaints or observations of helminths in the entire Kawymeno Waorani population, other than the few occasions a member spent an extended time outside the community. Conversations with the Kawymeno Waorani about helminth worm parasites were extensive, including identification of species in my daily classes with the four Waorani health promoters I was training. I also conducted routine health visits to Waorani households with our health promoter trainees. Helminths, particularly the Ascaris lumbricoides worms prevalent in the Kichwa population, are clearly visible in feces. Helminths were never mentioned or observed as a disease or

nuisance in any Kawymeno household. The Kawymeno Waorani frequently complained of other minor infections and infestations such as botflies and mite infestations and Tinea capitis scalp fungus infections. In fact, seven of the ten Kawymeno Waorani children my wife, Taxa, was teaching had Tinea scalp infections.

Absence of helminth infestation among the Kawymeno Waorani hunter-gatherers was not a stand-alone feature in the dissertation results, but rather part of a pattern of absence of local Amazonian diseases common in other Amazonian indigenous and Latino populations. The dissertation medical exam and history, as well as examinations by doctors at Franklyn Tello Hospital we invited to visit, showed there was also a dearth of many viral and bacterial diseases in the Waorani group that are common among the neighboring agricultural Kichwa, and indeed in the rest of Ecuador.

Since there is enough contact with the outside world to pass transmissible diseases such as helminths to the Kawymeno Waorani, the notable absence of disease found in our study is more likely related to diet and environment, rather than solely isolation from the outside world. The fact that acculturating Waorani in the protectorate have these diseases that Kawymeno Waorani do not have also suggests an environmental and dietary factor rather than a genetic explanation. A common factor – large and varied intake of plant defense chemicals that defend plants against microbes and larger parasites like helminths – may account for the widespread absence of most native infectious diseases including helminths in the Kawymeno Waorani.

Controlling for Confounding Factor of Intake of Anthelmintic Medicinal Plants

The first common argument that emerges as an alternative explanation for the absence of helminths in Kawymeno Waorani study stool samples is that ingestion of medicinal plant species with anthelmintic properties specifically designed as a treatment for helminths prior to stool sampling, occurred just prior to Waorani stool sampling (especially since lifestyle factors for helminth propagation are comparable across the hunter-gatherer and farming study communities). While it would be tempting to suggest intake of anthelmintic medicinal plants as the explanation for Kawymeno Waorani absence of helminths in study stool samples, this is not the case. The Kawymeno Waorani have no past history of, and do not have at present, any medicinal plants or other treatments for helminths. As mentioned in the introduction, Harvard's 1983 extensive study of Waorani medicinal plant intake demonstrated that the Waorani culture used no medicinal plants at all against helminths nor were they using anthelmintic medicinal plants when first contacted (Davis and Yost, 1983). Yost also traced disease symptoms back over a number of generations of Waorani and while other fungi and insect parasites were frequently mentioned, no Waorani acknowledged worm parasites as existing (Yost, 1981).

In the case of the Santa Teresita Kichwa, our study interviews show the Kichwa sporadically consume large amounts of anthelmintic medicinal plants, to such an extent that there have been several fatalities from natural anthelmintic

medicinal plant overdoses. The Santa Teresita Kichwa have a medicinal plant arsenal and regularly use recognized plant remedies for helminths. We documented the wide use of two natural medicinal remedies designed for helminth elimination by the Kichwa study population in Santa Teresita. The first is a natural mild plant phytochemical from a squash seed (*Cucurbita maxima*) toasted without oil, ground into a powder and drunk with water to control helminths. A more powerful plant anthelmintic medicine used by the Santa Teresita Kichwa to kill helminths parasites is called Hila Wiki, which comes from the tree sap from the *higueron* tree (*Ficus insipida*). Hila Wiki is much stronger and more dangerous to use than *Cucurbita maxima*, and the active ingredients per milligram of plant material vary widely depending on environment stimulants that provoke toxin production in this tree. This is a disadvantage of medicinal plants compared to human synthetic pharmaceuticals; the active chemical dosage varies widely even though actual milligrams of remedy are the same. The study has documented deaths by overdose from Hila Wiki by Santa Teresita Kichwa.

A hunter-gatherer diet usually includes a variety of wild plants, some of which contain anthelmintics, prophylactic and purgative plant defense compounds. In subsistence agriculture these wild plants foods are replaced by domesticated foods lacking such compounds (Moerman, 1986; Reinhard, 1986, 1988; Fry and Hall, 1975). Part of the dissertation study explanatory model suggests that the Kawymeno Waorani diet and most other hunter-gatherers' daily diets already contain preventive levels of plant secondary chemical toxins with pharmaceutical properties that controlled helminth occupation of the human body.

If dietary plant defense pharmaceuticals already control these helminth parasites, doses of medicinal anthelmintic plants are unnecessary. Medicinal plant remedies utilizing phytochemicals are more toxic than food phytochemical pharmaceuticals and typically made from different parts of plants that are unsuitable for daily dietary intake.

Judging from their stool samples, in spite of their reported sporadic intake of anthelmintic medicinal plants, the Santa Teresita Kichwa were still not able to control helminth parasite infections in their population. Medicinal plant anthelmintic pharmaceuticals may provide, at best, very limited short-term parasite protection, judging from the Kichwa prevalence of helminths. In fact, during the dissertation study many Kichwa requested Western anthelmintic medications.

To summarize, it is unlikely that Kawymeno Waorani hunter-gatherers took anthelmintic plants specifically to rid themselves of helminths before study sampling or in general. On the other hand, Santa Teresita Kichwa regularly take medicinal plants designed to eliminate helminths and may have consumed them prior to the study. Based on this, one would expect the opposite of the stool sample results; low numbers of helminths in the Kichwa and high numbers of helminths in the Waorani, but this was not the case.

Controlling for Other Confounding Variables

Comparable sanitation and hygiene practices across study groups. Both Kawymeno Waorani and Santa Teresita Kichwa have comparable levels of exposure to helminths from outsiders, sanitary practices and fixed geographical

community locations that would facilitate helminth-human disease cycles. The difference in helminth presence across the study hunter-gatherer and farming communities cannot be accounted by these factors, which are discussed below.

Human infection with Trichuris trichiura, hookworm and Ascaris is often due to poor sanitation practices. Humans ingest infective eggs by mouth via contaminated hands, food or insects (flies, cockroaches, etc.). Kawymeno Waorani typically do not wash their hands, protect their food from insects nor utilize toilets, while Santa Teresita Kichwa frequently wash their hands, cover their food to protect against insects and utilize latrines. Thus, if anything, sanitation issues should result in more Kawymeno Waorani helminth infestations than Santa Teresita Kichwa.

Both Kawymeno Waorani and Santa Teresita Kichwa have the opportunity to bring back helminth parasitic infections acquired from other human groups outside their community. Both populations are exposed to outsiders when they leave their community. For instance, the Kawymeno Waorani visit Protectorate Waorani who have helminthic parasites and the Santa Teresita Kichwa visit other Kichwa communities and nearby towns. The opportunity to start a helminth-human disease cycle from outside disease transmission is present in both communities.

Comparable drinking water sources. Drinking water sources, which could spread disease, are comparable across populations. The Kawymeno Waorani hunter-gatherers do not boil their drinking water, but rather scoop it directly from the river to drink. The Kichwa study population also often drinks

water straight from the river without boiling, although they may boil the water when preparing other beverages. The two main water sources used by both the Kawymeno Waorani and the Santa Teresita Kichwa are larger rivers (the Yasuni River and Napo River, respectively) upon whose banks both riverine communities live, and to a lesser extent feeder streams that start far away within the pristine rain forest. Both rivers and streams, like most Amazon waterways team with life, and are likely to have some microbial and larger parasitic organisms. The Kawymeno Waorani also occasionally drink rainwater, as do the Kichwa on rare occasions. In sum, risks of helminth infection via drinking water are comparable across populations.

Kawymeno Waorani make some effort to defecate in the forest away from their traditional sources of drinking water. Every night one can see Waorani walking a good ways into the jungle with a burning torch to defecate. Feces are rarely seen near the community or on trails in the rainforest. The Kichwa have access to latrines next to a number of their houses, while the Waorani rarely use the sanitary facilities left by the Brazilian oil corporation Petrobras, apparently to appease the Kawymeno Waorani when they conducted seismic drilling a few years ago in the region.

Comparable long-term permanent community location. In sum, sedentary lifestyle and the lack of sanitary practices that facilitate Ascaris, Trichuris and hookworm helminth-human co-existence are present in both communities. Kawymeno has been occupied continuously for 15 years. Kawymeno is a sedentary population in the sense that they occupy the same land

continually, but not in the sense that they spend as much time in their community as the Santa Teresita farming population does, which gardens daily. However, Kawymeno hunter-gatherers do not need to move far to find food; I have been on hunting trips that are less than 15 minutes from Kawymeno, which attests to the abundance of natural food resources near Kawymeno, even after almost two decades of occupation. The Kawymeno Waorani are people of the forest and constantly on the move as they trek through the rain forest. They just return to the same site when their trip is over.

Sedentary lifestyles are likely to increase helminth infestation. In both Kawymeno and Santa Teresita, human defecation occurs repeatedly over years in the homestead area. Both Kawymeno and Santa Teresita populations live in a fixed sedentary village site, thus both sites potentially facilitate oral-fecal infection routes of helminths, such as *Ascaris lumbricoides, Trichuris* and hookworm species, in a way living in a less fixed community might not.

Unlike hunter-gatherer populations in Africa who wander widely through enormous barren territories, the Waorani live in such a rich bio-diverse Amazonian ecosystem with such a wealth of food resources that a small population of people can live for decades in the same spot without diminishing the game, fish and fruit. The Kawymeno Waorani in the past remained nomadic mostly to avoid raids from other Waorani and outsiders. They kept alternative living sites ready for a quick move in case enemies discovered them, but not because the area became exhausted of wild game, fish, fruit or land for semi-cultivation (Yost, 1981).

Comparable personal hygiene. If anything, the personal hygiene of the Santa Teresita Kichwa may be more preventative of the spread of helminths via fecal oral transmission than that of the Kawymeno Waorani. I have not observed the Kawymeno Waorani practicing hand washing, or brushing or cleaning their teeth. On the other hand, the Santa Teresita Kichwa wash their hands, and clean their teeth and sometimes use toothbrushes.

The Kawymeno Waorani sleep on the ground usually huddled in a group, as household hammocks often only accommodate the household leader. We observed the Protectorate Waorani in Bataburo and Tiwino, make greater use of hammocks than Kawymeno Waorani when we visited in 2010. The Kichwa typically use hammocks and sometimes beds.

Both groups wash themselves and items needing cleaning in the river. Kawymeno Waorani wear few clothes and are often naked. The Kichwa group wears a similar set of clothes as Westerners.

Comparable extended contact with animals. The exposure to animals on a regular basis is comparable between the Kawymeno Waorani and Santa Teresita Kichwa. From personally living in household in both study groups, I have observed the exposure to wild animals and their feces is roughly equal in both groups, while only the Santa Teresita Kichwa have domestic animals. Helminth parasites captured in the study stool samples, Ascaris lumbricoides, Trichuris and hookworms do not use animal intermediates as part of their lifecycle, and are typically transferred directly from human feces to human bodies. However, hygiene and sanitation can be affected by the presence of

animals and provide more opportunities for fecal oral transmission of helminths. Both the Waorani and Kichwa have a wide variety of wild pets, including many species of monkeys, which constantly co-inhabit almost all of their living structures in both communities. A few of the better-off Kichwa have a few pigs and cows and many have chickens. The Waorani have no domestic animals.

Westernizing Waorani versus hunter-gatherer Waorani: the relationship of helminth levels to IgE is the inverse of Helminth Hypothesis predictions. Finally, comparing hunter-gathering Kawymeno Waorani with acculturating Protectorate Waorani entering the modern food system in Tiwino and Bataburo, this dissertation study noted that while the Kawymeno group had no helminths, protectorate Waorani often had large helminth loads of various species. Based on our conversations with public health officials in the Waorani Protectorate it is widely known that acculturating Waorani have a large helminth load. Yet when acculturating Protectorate Waorani and Kawymeno Waorani were measured together for IgE levels, the Kawymeno Waorani had a much higher IgE rates than protectorate Waorani (Kron, 2000). This is the opposite of what the Helminth Hypothesis predicts; Waorani IgE should go up as helminth load goes up. But in fact, the opposite occurs in the Waorani case – a declining IgE level accompanies a steadily rising helminth load in the protectorate. This makes sense if a diet rich in phytochemical toxins (not helminths) raises IgE in Kawymeno, while dwindling sources of wild rain forest phytochemicals drags down IgE levels among the Protectorate Waorani.

Controlling for interaction between the two study groups that would confound data results. These two study groups do not trade or mix food systems or have contact with each other despite their proximity. Both the Kawymeno Waorani and their Kichwa neighbors live in the same environment, but use different food systems and rarely mix due to hostilities. The Kichwa fear the Waorani due to confrontations in which Waorani speared Kichwa, and Kichwa rarely enter Waorani territory without being paid by corporations to illegally cut timber and harvest rain forest products. However, this is changing rapidly, as the younger generations of Waorani are not the aggressive warriors their parents were. Kawymeno social contact with outsiders comes from occasional visits to the Protectorate and outside cities such as Coca and Tiputini.

CHAPTER 19

HELMINTHS III: EARLY INVESTIGATIONS OF WAORANI IgE AND HELMINTH PRESENCE

Record High IgE in the Kawymeno Waorani – Kron, et al., 2000

In 2000, Kron collected 31 blood IgE levels from the same study Kawymeno Waorani, Riverine Kichwa and Protectorate Waorani as this present dissertation study is investigating (Kron, et al., 2000). His is the only existing study on the Kawymeno Waorani population on any scientific topic published in a Western peer-reviewed journal that I know of, and was conducted with a collaborator of this dissertation, as Dr. Ammunariz, a long-time Ministry of Health medical director for the region that both Kawymeno and Santa Teresita are part of. For those that read the article, Kron referred to the Kawymeno Waorani as Dicaran, the name outsiders called Kawymeno at that time.

In these serology tests on the Kawymeno Waorani, Kron recorded the second highest known average IgE level ever found in a single culture, a population mean of 11,850 IU/ml (Kron, et al., 2000) similar to the ultra high average level of 11,950 IU/ml obtained from Waorani shortly after first sustained contact with the outside world decades earlier (Kaplan, 1980; Larrick, 1983). Kawymeno Waorani practice the same type of hunter-gathering lifestyle today that these earlier researchers encountered in the Protectorate Waorani in the late 1970s. While Kron demonstrated that the Kawymeno Waorani had the highest

IgE rate in the world in 2000, he didn't test for helminths to confirm the Hygiene Hypothesis that helminths were causing these high IgE levels.

Most researchers that have cited Kron's study since then have assumed that the ultra high IgE of the Kawymeno Waorani came from high helminth prevalence, but Kron never tested for helminths (aside from the regionally rare *Onchocerca volvulus* species, which was not present anyways). Kron's IgE evidence, together with the dissertation findings of no helminths in the Kawymeno Waorani population, in retrospect adds evidence for a plant-based explanation for the high average IgE levels of the Kawymeno Waorani. Kron's study was particularly valuable to this dissertation study because he compared the same populations as this dissertation so Kron's IgE levels could be contrasted with this study's helminth levels. The addition of Kron's data to dissertation helminth data suggests a non-helminth factor for the ultra high Kawymeno IgE levels and opens the door to a dietary plant phytochemical toxin-based explanation.

The original high average IgE level of 11,950 IU/ml recorded from the Protectorate Waorani, just after leaving their traditional pristine rain forest environment and wild phytochemical-rich hunter-gathering lifestyle for the first time in the early 1980s, contrasts with the declining average IgE level of the protectorate Waorani of 4,854 IU/ml recorded by Kron when hunter-gathering was now only sporadically practiced and dietary phytochemical intake from wild rain forest food was greatly diminished (Kaplan, 1980; Kron, 2000; Larrick, 1983).

Kron recorded the Santa Teresita Kichwa IgE level at 2,964 IU/ml, which while lower than Waorani IgE levels was still much higher than the USA at 100 IU/ml. The diminishing but continuing dietary intake of wild phytochemicals by both Santa Teresita Kichwa agrarians and acculturating Protectorate Waorani, through occasional hunting and gathering and medicinal plant use, may account for both their average IgE levels still being higher than populations like the USA but much lower than the Kawymeno Waorani.

Absence of Helminths in Waorani at First Contact with Western Outsiders

As discussed elsewhere in the dissertation, the Waorani were the closest facsimile to original prehistoric hunter-gatherers that modern researchers have encountered in the Americas – and together with the Hadza in Africa, perhaps in the world – in terms of health characteristics and biomarkers, diet and lifestyle (Davis and Yost, 1983; Jelliffe, et al., 1962; Kaplan, et al., 1980; Larrick, et al., 1983). Early Waorani investigations provide evidence that pre-contact Waorani did not have helminths.

A study of Waorani health problems prior to contact with European origin outsiders, based on interviews collected over a five-year period of residence with the Waorani, suggests significant helminth infestations were not present in Waorani prior to outside contact (Larrick and Yost, 1979; Yost, 1981). However, soon after first contact with outsiders, such as Summer Institute of Linguistics missionaries, the Waorani began to complain of helminth infections.

Doctors who first examined the Waorani soon after initial peaceful contact with the outside world, found no intestinal parasites in any of the Waorani, but

within three years of contact helminth loads were light but comparable to neighboring acculturating indigenous groups (Davis & Yost, 1983; Kaplan, et al., 1979). These researchers attributed the lack of helminthic parasites in the Waorani to the Waorani lifestyle prior to contact with outsiders, which included a hunter-gatherer diet high in wild phytochemicals (Davis and Yost, 1983; Kaplan, et al., 1979). Dietary plant anthelmintic phytochemical protection is incremental, and stimulating human physiological usage, adaptation and processing of anthelmintic phytochemicals is probably related to repeated exposure to disease. Thus an infusion of new disease organisms such as helminths, just like the introduction of new microbial diseases to isolated hunter-gatherers, is unlikely to be stemmed immediately with an already declining intake of wild rainforest phytochemicals.

This dissertation reinterprets Larrick, Kaplan and Kron studies as none of these groups of researchers had considered plant phytochemical toxins as an explanation for IgE. There was no debate about plant phytochemical versus helminth explanations for IgE antibodies at the time of these Waorani studies because Profet (1991) had not yet suggested a plant toxin explanation for high IgE levels. In fact, these researchers were probably at least marginally (if not fully) in the Helminth Hypothesis camp. There is a difference between the actual findings and the theoretical framework that authors have chosen to use to explain their findings. This dissertation argues that a plant phytochemical explanation for these early Waorani researchers' findings is a much better fit with the facts. In fact, when Larrick tried to confirm the Helminth Hypothesis through a study of allergic

affects of various substances on Waorani, his study refuted his own explanation and was his last article on the subject.

Changes in Waorani Helminth and IgE Levels after a Few Years of Acculturation

Waorani incidence of helminths changed within just a few years from virtually nothing at first contact with the outside world, to light hookworm infections in almost half the population. Stool samples of sixty-five Waorani tested after just a few years of acculturation in a missionary camp showed a 46% incidence of hookworm, *Necator americanus* (Kaplan, 1979; Larrick, 1979). While NIH/Duke authors suspected that outsiders had recently introduced these hookworm infestations to the Waorani, they nevertheless invoked the Helminth Hypothesis as an explanation, which in retrospect seems contradictory since their data suggested that helminths were absent in original pre-contact Waorani (Kaplan, 1979; Larrick, 1979). Besides hookworm, there was a very low incidence of Ascaris, Trichuris and Enterobius helminths. These same researchers conducted immune system blood work on 293 Protectorate Waorani individuals and encountered the world's highest IgE antibody levels recorded in a single ethnic human population, a population average of 11,975 IU/ml (Larrick, 1983; Kaplan, 1980). At that time all Waorani helminthic burdens (including the hookworm) were "light" with only a few worms per individual infected (Larrick, 1979); not enough helminth load to begin to account for the ultra high IgE levels encountered in the Waorani at the time. Absence of helminths in Waorani at first

contact also suggests an alternative to a helminth-based explanation for the ultra high average population IgE levels of the Waorani in the late 1970s.[1]

In summary, for a Waorani population that had virtually no helminths to have the world's highest recorded IgE level provides more evidence that high helminth levels in human bodies do not cause high IgE levels. On the contrary there seems to be no connection between helminth load status and IgE levels in early studies of the Waorani, which contradicts the Helminth Hypothesis. This data supports the dissertation thesis that there is little physiological connection between ultra high IgE and helminth load. The comparison over time of the drop in average IgE in Protectorate Waorani, with a corresponding rise in helminth loads in the Protectorate Waorani, also contradicts the Helminth Hypothesis. On the other hand, the gradual loss of IgE levels matched the gradual loss of wild plant defense pharmaceuticals in the Protectorate Waorani diet, as wild plant food sources dried up further with environmental destruction and the Waorani switched over to a modern food system, abandoning their traditional diet. In other words, IgE antibody loss and gain correlate with food system change whereas helminth levels do not seem to have a correlation to IgE levels.

If one looks at Waorani hunter-gatherer IgE levels of almost 12,000 IU/ml as the human norm throughout 99% of human history, then IgE levels of 100 IU/ml for the US population, or about .0083 % of the average Waorani IgE level, are far below the historical human norm. Even though they have repeated

[1] The only recorded IgE level that surpassed those of the Waorani was one Amazonian Venezuelan study of 274 persons from a mix of ethnic indigenous populations with an IgE level of 13,088 IU/ml (Lynch, 1983). Unfortunately,Lynch took no stool samples to examine for helminths.

exposures, modern societies may be more vulnerable to helminth infestations and microbial disease in part due to reduced photochemical stimulation to maintain a high presence of IgE antibody capacity at all times. It is possible that IgE levels may also serve as a biomarker for other as yet unknown immune system functioning factors. Ultra low modern IgE levels may comprise immune functioning at least compared to our ancestral hunter-gatherers who, like the Kawymeno Waorani hunter-gatherers, maintained high IgE and immune functioning in the absence of helminth stimulation while consuming a daily diet rich in wild rain forest phytochemicals that stimulate IgE levels. The Kawymeno Waorani Hunter-gatherers, in spite of exposure to diseases that plague modern societies that have a history in their Amazon region, have an absence of many of them that plague their neighbors in the Santa Teresita Kichwa and IgE immunity may be one important factor why this occurs.

Human medical norms established by the medical community need to be questioned by evolutionists. Bio-medical conclusions regarding what is considered "standard" blood pressure, body temperature and IgE level may in reality be physiological averages in modern populations, but not necessarily normal human reactions. This re-evaluation of human physiological norms may result in revised clinical treatment goals and dietary recommendations to improve the health of the modern population

Plant Phytochemicals versus Helminths: The Waorani Allergy Litmus Test

The Helminth Hypothesis suggests that the reason modern humans have a lot of allergies and autoimmune disease is because they no longer have helminth

parasites in their body to stimulate regular high IgE levels (Hurtado, et al., 2008). Larrick and colleagues (1983) conducted an allergy skin test on Waorani to test the relation that these high IgE levels might have to allergic reactions, in part to try to prove the Helminth Hypothesis, which still remained a hypothesis rather than a fact. Larrick's thesis seemed promising since, upon previous medical examinations by these investigators, all the Waorani displayed no sign of allergies. This led him to propose that perhaps helminths were protecting the Waorani from allergies through stimulation of high IgE levels. Conversely, under a plant phytochemical toxin model, allergic stimulation should cause allergies in the presence of helminth infestations because helminths do not cause high IgE levels or prevent allergic reactions. As it turned out, the Waorani reacted physiologically and tested positive to the skin allergens that came from material sources native to the United States and Europe that Larrick exposed them to (Larrick, et al. 1983). Thus, these investigators refuted their own Helminth Hypothesis explanation and published the results in a rather technical journal article in 1983 (Larrick, et al., 1983).

CHAPTER 21

HELMINTHS IV: ARCHEOLOGICAL EVIDENCE THAT SUGGESTS A CENTRAL ROLE FOR PHYTOCHEMICALS IN HELMINTH CONTROL IN HUMAN EVOLUTION

Somewhat surprisingly, our dissertation study results line up more with what archeologists have concluded and less with what anthropologists working with acculturating hunter-gatherers have proposed. It is frequently argued that modern hunter-gatherers are different from prehistoric hunter-gatherers. Archeological evidence suggests, at least in the role of phytochemicals to helminths, modern hunter-gatherers such as the Waorani using phytochemically rich diets similar to the rich and varied wild plant intake of prehistoric diets have the same phytochemical to helminth dynamics and results as prehistoric hunter-gatherers — absence or low level of helminths.

Phytochemicals serve as a double edged sword in this chapter's argument, as they not only stimulate IgE but also eliminate helminths. The material evidence presented below that dietary phytochemicals eliminate helminths in prehistoric hunter-gatherers, not just humans living in a modern times, means both a sustained presence of helminths is doubtful in humans of the Paleolithic Era and that helminth presence and wild phytochemically rich dietary intake are incompatible. It can only be one or the other and there is little doubt hunter-gatherer diets were rich in phytochemicals with anthelmintic properties as the study below demonstrates.

Archeologists like Armelagos and Reinhard have compared and contrasted the diet and health of ancient hunter-gatherers versus ancient farmers using material remains as clues to humanity's past. Our Waorani-Kichwa comparative food system study is a modern hunter-gatherer versus subsistence farmers' version of those archeological studies, but with living subjects rather than material evidence. However, our results and conclusions are more similar to the archeologists than other anthropologists such as Hurtado and Hill, which this dissertation suggests are trying to make the modern hunter-gatherer evidence fit the long-held but still unproven Helminth Hypothesis rather than let the evidence speak for itself (Hurtado, et al., 2008). The bottom line is: food systems matter.

Reinhard's study – helminths and phytochemical intake: prehistoric farmers versus hunter-gatherers on the Colorado Plateau. Reinhard's paleopathology study on helminthic parasite coprolites (fossilized feces) in Neolithic farmers and contemporary hunter-gatherers parallels this dissertation's design comparing hunter-gatherer and agricultural populations living at the same time in the same region (Reinhard, 1985, 1988). Reinhard states that the common daily intake of anthelmintic phytochemicals in the diet of prehistoric Native American hunter-gatherers on the Colorado plateau prevented helminth manifestation in these groups.

Reinhard conducted archeological excavations of prehistoric Neolithic subsistence farmers and compared their food system and helminth load to the contemporary prehistoric hunter-gatherers in the same general Colorado plateau region. Helminths were common in feces found in excavations of the Neolithic

farmer groups, while helminths were non-existent in the feces of contemporary hunter-gatherer groups (Reinhard, 1985, 1988). Archeological evidence drew Reinhard to the conclusion that dietary intake was effecting helminth presence in the prehistoric hunter-gatherer groups.

Archeological evidence of anthelmintic plant phytochemicals was found in these prehistoric hunter-gatherer feces samples. Sixty-three of one hundred feces samples examined at Dust Devil Cave hunter-gatherer site had *Chenopodium* seeds, which have anthelmintic properties. *Chenopodium* seeds cure infections of hookworm, Ascaris and Enterobius helminths (Hegner, 1938; Millspaugh, 1972; Schery, 1972; Wahl, 1954). Prehistoric hunter-gatherer groups of the Colorado plateau consumed *Chenopodium* as part of their dietary regime, thus limiting infection of helminth parasites (Reinhard, 1985, 1988). Reinhard indicates this prehistoric hunter-gatherer dietary plant anthelmintic consumption was unconscious and not intentionally designed to eliminate helminths. Lack of helminths and large quantities of *Chenopodium* indicate *Chenopodium* anthelmintic plant defense chemicals had been part of the normal diet of these hunter-gatherers rather than sporadic medicinal plant intake. Similar findings of anthelmintic phytochemicals consumed as part of daily diet have been noted in Anasazi hunter-gatherer archeological sites (Fry and Hall, 1975).

Reinhard emphasized one of the most important reasons for the increase of helminth parasites in humans was the adoption of agriculture. Reinhard concludes that reduction of intake of these plant phytochemicals that followed the

introduction of agriculture may explain increased helminth load in post–hunter-gatherer humans (Reinhard, 1986,1988).

In the dissertation study parallel, Kawymeno hunter-gatherers are also unaware of the plant based pharmaceutical properties of their diet, but have no helminths in their feces. Nearby contemporaries, the Santa Teresita Kichwa, consume an agricultural diet and cannot get rid of their helminth parasites. The conclusion from both studies and their material evidence found in stools is that the food system and phytochemical intake is what matters most when it comes to controlling helminthic parasites.

Were pathogenic IgE-raising helminth species a menace to human health in the Paleolithic Era, as they appear to be in today's agricultural-based globally connected human populations? Archeological evidence shows that domestication of plants and animals in Neolithic farming cultures facilitated transmission of parasites that may have existed only sporadically in hunter-gatherers, leading to an increase in the number of parasite infections in humans (Gonclaves, 2003; Sianto, 2009). Most helminth findings in archeological material date to after the beginnings of the extensive use of agriculture as a means of subsistence (Sianto, 2009). Eleven types of parasites from the New World – including Trichuris, Ascaris, Enterobius and Strongyloides – have been identified in coprolites (fossilized feces) at post-agricultural archeological sites (Dittmar, 2000). A hookworm (Ancylostoma duodenale) has been found in a Peruvian Mummy (Sianto 2009; Reinhard, 2005). Helminth findings should be just as common in pre-agricultural archeological sites as they are in agricultural sites to

support the Helminth Hypothesis; namely, that helminths co-existed with most humans throughout the millennia in significant amounts. However, pre-agricultural helminth findings are very rare in the Paleolithic archeological sites that have been uncovered (Sianto, 2009).

However**,** there is supporting evidence that certain non-IgE stimulating helminths did co-exist in human bodies in the Paleolithic era, specifically certain species of tapeworms (Taenia) and Enterobius vermicularis (Armelagos, 2005; Hoberg, 2000). However, Taenia and Enterobius and other helminths appear to stimulate other antibodies such as IgG and IgM with little stimulation of the IgE antibody, as is well known to lab technicians diagnosing parasitic infections. Therefore, it is unlikely that either of these long-term helminth inhabitants of hominoid bodies exerted influence over the formation of IgE, because other antibodies were already dealing with Taenia and Enterobius helminth defense/by-product chemicals released into the human body. In summary, so far there is little evidence that the helminths that are pathogenic, cause disease and raise IgE levels were present in humans in the Paleolithic era.

CHAPTER 21

HELMINTHS V: MODERN EVIDENCE THAT HELMINTHS WERE A LOCAL, SCATTERED AND OFTEN ABSENT PHENOMENA IN HUMANS OF THE PALEOLITHIC ERA

Most of the species of helminths that plague mankind and effect IgE levels today may have been confined to small, isolated local geographic human hunter-gatherer pockets during the Paleolithic Era and only very recently became common across many cultures with the spread of agricultural populations. Evidence from four continents is provided below.

Helminth and human co-existence in South America. Preventative anthelmintic properties may have slowed or prevented any native helminth species from dominating on the South American continent. Only with the entrance of foreign helminths from other continents carried by colonists, coupled with the introduction of agriculture, did helminth infestation begin to seriously affect the former South American hunter-gatherers who transitioned into poor subsistence farmers.

Salzano, et al., (1988) compiled a table on the results of twenty-two separate studies done on helminth-human co-existence in former hunter-gatherers with a cumulative 2,145 South American indigenous individuals (Salzano, et al., 1988). According to Faust (1955), both types of hookworm helminths were not native to the Americas and were originally African diseases. In addition to the recently introduced African hookworms, the fact that many indigenous groups in

Salzano's review of all South American hunter-gatherer helminth studies were entirely missing one or two helminth species that the environment could otherwise support (Salzano, et al., 1988) suggests that Ascaris and Trichuris helminths, like hookworms were either introduced by European and African colonists to hunter-gatherer groups or factors such as dietary phytochemical anthelmintic intake created very restricted localized ranges of helminth occurrence. Salzano, et al. concluded that this pattern of helminth infection shed doubt as to whether these South American hunter-gatherers had any of these helminths prior to contact with outsiders (Salzano, et al., 1988).

The Waorani had the lowest rate of helminthic infestation of all South American groups in Salzano's table (Salzano, et al., 1988). Serology anti-body tests indicated the Waorani had not had contact with any Old World diseases up to as recently as the late 1970s (Kaplan, 1979). The Waorani represented the most undisturbed prehistoric hunter-gatherers, making them of particular interest in understanding the pre-agricultural state of helminth-human relationships. Anthelmintic properties of diet may have led to isolated helminth occurrence dependent on the variation of anthelmintic phytochemicals in different indigenous South American diets and among other factors. Contact with foreign helminths, coupled with a switch to agriculture that cut off the intake of rainforest phytochemicals changed the Waorani-helminth relationship, leaving Kawymeno as the last known vestige of prehistoric Waorani helminth and health status.

Complete absence of common pathogenic helminths in the prehistoric Australian Continent? A very large Australian study provides even stronger

evidence that hunter-gatherer wild dietary intake and isolated nomadic lifestyle prevented helminth occurrence across an entire continent. Stools from 2,080 participants, including a population of 1,683 aboriginals, were collected across a number of districts in Australia (Jones, 1980). Jones found a complete absence of Ascaris lumbricoides, and virtually complete absence of Trichuris trichiura in aboriginals in the entire tropical Kimberley district, an ideal humid, hot climate for helminths (Jones, 1980). What was even harder to explain was that both Ascaris and Trichuris parasites were common in Australian aboriginals in the neighboring districts that had essentially the same ecosystem and environmental factors as Kimberley to support helminth lifecycles.

Jones noted a key difference between these two regions was the food system; in the region with no helminths the aboriginals still practiced an isolated, nomadic hunter-gathering lifestyle and dietary intake, which includes wild plant phytochemicals. On the other hand, the aboriginals were acculturating into the modern food system and lifestyle in the regions where these helminths were abundant (Jones, 1980).

Jones noted that the entire Australian continent originally probably did not have any Ascaris and Trichuris helminth parasites and these helminths were probably recently introduced by colonists to aboriginals. However, the hunter-gatherer lifestyle and diet coupled with dry barren environment that borders the Kimberley region may have buffered this geographical region longer against helminth infestations than other parts of Australia. Unfortunately, Jones took no IgE levels of his participants.

Higher IgE but No Helminths - Greenland Arctic Region. Parasitic helminth infestations were thought to be common in Greenland, since elevated serum IgE is found in Greenland children and there is a lack of allergic conditions to stimulate IgE levels (Moller, 2007). Fecal samples from 320 children in a town in Greenland were examined for intestinal parasites but not a single helminth parasite was found with the exception of one case of Enterobius helminths. Greenland may not have any common helminth species, yet other arctic indigenous regions using the modern food system do have helminths. Like the other regions with low or no helminths, Greenlanders practice little agriculture, rely on a natural food chain and are geographically isolated. This is yet another example that helminths were limited to certain populations and regions and not a worldwide phenomenon in the Paleolithic era before the advent of agriculture and reduction in wild food chains such as those that can move phytochemicals from marine plants to humans in arctic regions.

Helminth absence among the Hadza hunter-gatherers from Africa and other factors in common with the Waorani. By the 1960s, the Hadza were the last remaining isolated true hunter-gatherer group left in Africa, all other groups that hunted and gathered in Africa were by then acculturating, part-time hunter-gatherers with extensive contact with outsiders. Unfortunately, rigorous quantitative studies on helminths were not conducted prior to the 1960s in Africa when other isolated true hunter-gatherer groups besides the Hadza still existed (Faust, 1955). After 1960, moderate to high helminth burdens were found in all these other African former hunter-gatherers.

Both the Hadza hunter-gatherers and the Waorani hunter-gatherers had remained much more isolated than other indigenous groups in their respective continents up to the time when the first helminth stool exams were conducted. In a 1960 study, stools of fifty-six Hadza children, about 25% of the whole Hadza child population, were examined. The Hadza, like the Waorani, had an absence of helminths except for four tapeworm eggs (Taenia sp) when first contacted and were only contaminated with other helminth species after contact with Westerners (Jelliffe, et al., 1962). Tapeworms are one of the few helminths with evidence of a long-term relationship with humans in Africa. However, tapeworms do not influence IgE levels and only interact with IgG and IgM antibodies (Dunn, 1972). Thus, tapeworms are not relevant to the IgE argument. Africa, unlike other global regions discussed, most likely did have helminth species such as hookworms that raise IgE in humans in prehistory (Faust, 1955) but as the Hadza example indicates, hookworms in prehistoric Africa may have once had a very restricted region of occurrence, again probably due to isolation and dietary intake of anthelmintic phytochemicals.

To summarize, there is evidence from South America, Africa, Australia and the Arctic region that the most common helminths around the globe today that are pathogenic and raise IgE levels may not have existed in vast areas of the globe in the Paleolithic era. Daily dietary anthelmintic phytochemical intake may have prevented the growth of native species of helminths in many hunter-gatherer populations and the isolated nature of hunter-gatherer life may have hindered any outside introduction of helminths.

More advice to public health policy makers: Ancestral hunter-gatherer phytochemical rich diets may eliminate helminths that public health measures cannot. The caveat to the previous discussion of helminth presence in modern population is the large presence of parasitic worms such as Enterobius vermicularis in industrialized countries with public health systems. Most of the general public, and perhaps many readers of this dissertation, are not aware that helminth infections are common in industrialized societies, and that they themselves likely have parasitic worms without being aware of the infestations because doctors do not discuss these helminth infestations with their patients. For example, 10% -50% of the entire population in the USA and Europe has Enterobius parasitic worms (Cook, 1994; Warren, 1975; Burhart, 2005). Interestingly, Enterobius is believed to be rarer in hunter-gatherers than modern populations (Hienz, 1961). Modern sanitation and public health measures do not control Enterobius parasites because Enterobius is not transmitted through an oral-fecal cycle. In fact, hunter-gatherer anthelmintic phytochemical diet may actually be much more effective than modern sanitation in eliminating all helminths from the human body.

Relevance of this chapter's theme to real world public health issues. The arguments in this chapter have public health implications; the Enterobius helminth case is a good example. Following the line of argument in this chapter, Enterobius and other helminth infestations were not the human norm throughout human evolutionary history. If that is the case there is more reason to be concerned that Enterobius at best has unknown effects on the human body and at

worst is involved in some subtly disease processes. If Enterobius is an agricultural disease that modern public health has still not controlled, human hosts have had little time to adapt physiologically to their Enterobius parasites and any disease they may cause. Enterobius helminth parasite infestations are typically asymptomatic in humans. However, that can be said about light infections of most helminths. The lifelong association that is the new agricultural Enterobius pattern for modern humans may cause yet unrecognized chronic disease over the long-term.

From the point of view of those interested in ancestral diets and improved health, a look at ancestral phytochemical intake may be helpful in gaining better control over diseases such as Enterobius that slip through public health systems even in countries like the USA. Dissertation evidence suggests that the Santa Teresita Kichwa farmers, even with their heavy intake of powerful anti-helminth natural remedies (akin to modern populations taking human-made pharmaceuticals) cannot rid themselves of many diseases, including Enterobius, more than briefly. An ancestral diet undertaken by modern humans may help control Enterobius and other potential causes of chronic diseases that are increasingly common in modern populations but absent in hunter-gatherers like the Kawymeno Waorani.

Conclusions of Chapters 17 through 21

This dissertation chapter suggests that a reasonable evidence-based case can be made to reject the Helminth Hypothesis based on evidence from dissertation helminth stool examinations combined with previous Waorani

studies, which is then confirmed through a wider look at helminth-human co-existence in hunter-gatherer groups geographically around the world and going back in time temporally and archeologically to the Paleolithic Era.

The potentially damaging effects that helminthic infestations have on today's human population, particularly the poor in the developing world, may lead researchers to conclude that today's rate of helminth disease burden has always been the human norm. Thus, it's important for evolutionary-minded researchers to question present human norms as reality throughout human existence. It is tempting to use present day data on the impact of helminth parasites in the developing world as evidence of Paleolithic norms but this chapter suggests there is not enough convincing evidence from modern indigenous studies to support a co-evolutionary helminth-human relationship as the entire framework for understanding IgE antibody functioning. Subsistence agriculture is very far from the evolutionary norm, and today's farming societies and acculturating indigenous groups– no matter what the culture – did not have helminthic loads typical of humanity's long-term evolutionary past.

The dissertation hypothesis regarding IgE origin is that while some types of helminths, in large enough loads, may stimulate human IgE antibody levels, helminths were only one of a number of factors that affected IgE levels, and not the principal factor, which we hypothesized came predominantly from the food system.

This dissertation suggests that the true purpose of IgE antibodies is more likely to combat a wide variety of toxic plant phytochemicals in the hunter-

gatherer diet rather than for reducing certain helminth by-products released into the human body, as suggested by the Helminth Hypothesis. Plants always had defense chemicals that were toxic to humans and humans always had to find a way to make their plant food edible. Ultra high IgE levels (hyperimmunoglobulinemia) such as that of the Kawymeno Waorani may actually have been a human norm in hunter-gatherer populations to deal with a high phytochemical-based diet. Agricultural societies' relatively minimal average level of 100 IU/ml may be a historical abnormality caused by entering into agriculture.

In the dawn of agriculture, when humanity gave up a disease protective, phytochemical-rich and varied hunter-gatherer diet, helminths and other diseases rose since there was no longer a natural system to control them, causing increased helminth infestations across broader populations as well as microbe-based plagues, pestilence and population-decimating diseases. This middle time between hunter-gathering and modern food systems needs to be analyzed separately in regards to helminths and other diseases. The change from hunter-gathering to subsistence farming created a more favorable human-made environment for helminths and greater facility for helminth transfer worldwide.

Recommendations for Future Investigations on Hunter-Gatherers, IgE, Helminths and Phytochemical Intake

This dissertation chapter proposes there is a general trend in the literature for a lower helminthic parasite presence to be found in studies on modern indigenous groups with the following characteristics:

1) Studies done on groups at a time closer to a hunter-gathering group's first contact with outsiders from modern agricultural cultures.

2) Studies done on more isolated populations.

3) Studies done on groups consuming wild foods rather than beginning to rely on domesticated animals and plants.

5) Studies done on groups embedded in a pristine natural ecosystem with a completely wild food chain and ecology.

6) Studies done on groups with the largest variety of wild dietary plant defense phytochemical intake as well as wild animal intake. Animals also consume or produce bioactive animal constituents similar to phytochemicals but are rarely studied (Etkin, 2006).

In addition, more attention should be given to comparative studies rather than uni-population studies typical of anthropological work. Comparing food systems can be more fruitful than simply documenting a single food system. Unfortunately, there are few comparative modern indigenous studies done with practicing complete hunter-gatherers across other types of food systems. Most of the comparative studies across food systems involving true hunter-gatherers are archeological and these archeological studies should receive more importance in the helminth-human argument (Armelagos, 2005; Reinhard, 1986, 1988).

Further, rather than grouping all species of helminths together as is the custom in most modern anthropological indigenous studies on helminths, it would be more useful to compare individual helminth organisms species by species

across studies. Many helminth species do not even affect IgE and should be eliminated from consideration in any argument relating to the Helminth Hypothesis. Other common helminths may have been introduced to these indigenous groups across the world in the colonial era and therefore should also be eliminated from consideration in any argument relating to the Helminth Hypothesis. In the end, there are few helminths species left as candidates to have altered or created antibodies in the human immune system through the process of evolution and natural selection and these helminths may never have been widespread or common, leaving proponents of the Helminth Hypothesis with little proof that helminths were part of a major human co-evolutionary force.

Largely uncontacted, unacculturated hunter-gatherer groups in Peru and Brazil still exist. Checking both the stool helminth count and IgE blood level of the remaining true hunter-gatherers left in the world might be far more valuable than any continued work with acculturating indigenous groups.

Unfortunately, the increased level of outside contact the Kawymeno Waorani hunter-gatherers are beginning to experience in 2012 with oil company sponsored expeditions interested in exploiting the ITT (Ishpingo, Tambococha, Tiputini) oil wells 25 minutes from Kawymeno, will make meaningful stool specimens that represent an isolated hunter-gatherer food system increasingly difficult to get from Kawymeno Waorani, so our study may represent the last opportunity to have done so.

When researchers do test for both IgE and helminths the results can be surprising, as demonstrated by Moller's Greenland study which found a

population with elevated IgE but an absence of helminths (Moller, 2007). This Kawymeno Waorani dissertation study is another surprising example that defies the Helminth Hypothesis: the world's IgE record holders have no helminths. More primary studies with the last remaining hunter-gatherers should test both IgE levels and helminth levels, and not assume these two factors are interchangeable.

In a recent study of the Shuar, an indigenous group not far from the Waorani in Amazonian Ecuador, researchers used IgE levels as a proxy for actual stool examination for helminth load (Blackwell, et al., 2010). The authors admit in their article that no one has ever conducted stool examinations to see if the Shuar actually have helminths (Blackwell, et al., 2010). Blackwell stated that stool testing was inconvenient and unnecessary because high IgE levels indicated the population had helminths (Blackwell, et al., 2010). While Blackwell conducted a useful and interesting study, this example is typical of indigenous studies today that do not analyze IgE levels against helminth levels.

Many things are known to cause elevated IgE besides helminths; e.g., atopic disease, viruses, neoplasms and even smoking (Dumerez, 1996). But none of these are as omnipresent as human food entering the human body. A key point mentioned in this chapter is that one simply has to remove the bio-medical preconception that all antibodies are there to eliminate the effect of animal kingdom pathogens. IgE antibodies may be designed to deal with chemical threats from the plant kingdom as well as parasitic animal kingdom threats. The need to detoxify and control dietary plant kingdom defense chemicals in food is a stronger evolutionary force than helminth-human co-existence.

The contribution of evolutionary medicine to the medical field is questioning the more narrow (temporally speaking) ability of biomedical research results to generalize as to what is normal for human beings. Laboratory tests and physical exams only suggest human reality in the here and now, failing to reflect the fact that this is not how humans normally functioned throughout 99% of human existence. The relationship between helminths and humans in modern populations is just one example, evolutionary medicine has a role to play in all diseases. The Helminth Hypothesis is a bilateral, exclusive, parasite-human relationship right out of a medical textbook dressed in evolutionary clothing. I would argue that in the case of the Helminth Hypothesis, evolutionists have accepted biomedical hard evidence from the present as the truth, rather than relying on their strength, which is understanding evidence from the long-term perspective. The chemical wars, as well as chemical alliances, which constitute plant-human co-evolutionary history, have been ignored until recently by medical researchers, partly because it requires a long-term evolutionary perspective to understand its significance.

CHAPTER 22

POISON I: DESCRIPTION OF ANCESRTRAL FISHING AND HUNTING PHYTOCHEMICAL POISONS

Introduction

This chapter discusses all the hunting and fishing poisons used by the Kawymeno Waorani hunter-gatherers and Santa Teresita Kichwa subsistence farmer groups studied in this dissertation. However, this chapter's primary focus is a case study of the Kawymeno Waorani curare hunting poison from a rain forest vine (*Curarea tecunarum*) and the surprisingly significant effect it may have on the Kawymeno hunter-gathering community, particularly fertility cycles. *Curare tecunarum* phytochemicals from this vine may have antimicrobial properties as well and this aspect is discussed in the next chapter. The dietary intake of Kawymeno Waorani hunting poison (*Curarea tecunarum*) has been chosen to demonstrate what the effect of phytochemicals from a single dietary plant may have on the entire hunter-gathering group physiology as a group, as well as how hunting and fishing poisons may have shaped human evolution and plant-human co-evolution. In the next few chapters, after a description of the poisons use of the study groups, the interaction of phytochemical poisons on other physiological functions of the human body such a hormone cycles are discussed.

This dissertation is interested in items regularly ingested in the diet that affect human physiology and health. This dissertation avoids using categories such as "food" and "non-foods", which by implication direct one to standard

nutrients that are the mainstay of the nutrition profession, but only part of the dietary intake. Hunting and fishing poison are included in this dissertation study about diet because they are ingested on a daily basis by the study groups regularly and may have health value, as do traditional foods. This chapter argues that, aside from their necessity for hunting and fishing, these poisons may have been beneficial for human physiology and perhaps played a role in disease prevention as powerful phytochemical pharmaceuticals with antimicrobial and hormone regulating properties. Indigenous groups moving towards subsistence agriculture, like the dissertation study Kichwa, increasingly use less hunting and fishing poisons until they vanish completely in the modern food system.

This dissertation is interested in the whole plant in all its complexity that is beneficial in the diet. This is a dissertation about diet, not about single chemicals with medicinal properties such as alkaloids in hunting poisons. Most of the opportunity to understand plant-human co-evolution is lost when dietary plants are taken out of their ecological and food chain context and analyzed as chemical components.

The Use of Curare Hunting Poison in Western Medicine

As early as 1564, Western physicians recognized that poisons previously used by most indigenous groups and Western cultures around the world have medicinal value. The Western physician Paracelsus, who used poisons to treat patients, suggested in the fifteenth century that all biochemical physiology-altering substances are poisonous in excess but dosage determines if the biochemical effects are toxic or have potential medicinal effects. “Solely the dose determines

that which is not a poison" (Bisset, 1991). It is only with increased confidence in modern technology and synthetic medications that interest in natural substances, such as hunter-gather origin poisons, has faded and become medical history. However, hunter-gatherer hunting poisons are actually the basis for modern anesthesia and are still used in hospitals the world over for operations.

In theory, all of these Curare poisons have plant alkaloid phytochemicals that cause muscle paralysis. The proposed biochemical mechanism blocks impulse transmission through inhibiting acetylcholine neurotransmitters in the motor end plates, which in large enough doses should lead to complete paralysis of skeletal musculature including respiratory function. In the case of *Curarea tecunarum* the physiological mechanism and responsible phytochemicals are less clear, as discussed below.

In 1939, curare dart poisons were first introduced into 20th century clinical medicine to prevent side effects from Metrazol convulsive shock therapy and electric shock therapy. Many synthetic derivatives have been developed from the curare natural plant phytochemicals for use as one of the first types of anesthesia for operations. Since 1942, the synthesized pure alkaloid (+) -tubocurarine produced in curare plants has become a useful muscle relaxant in all forms of anesthesia and continues to be used up to the present (Bennet, 1968). Two other pure natural curare alkaloids called C-calebassine and C-toxiferine that have a longer duration of effect were developed for titanic convulsions. It is interesting to note that most alkaloids of the curare group of poisons aside from exercising muscle control in low doses and paralysis in high doses, also lower blood pressure

slightly and have many other physiological effects that have been little explored in humans.

The dissertation makes the case that these powerful plant poisons affected human physiology and as is elaborated later fertility, the hormone levels of pre-historic humans as well. With the advent of agriculture leading to the recent withdrawal of hunting and fishing poisons as well as other phytochemicals from the human diet, humanity has been left with a physiological legacy that is unfulfilled yet modifies the health and fertility of humans now enmeshed in agricultural systems in unexpected ways.

Scientific analysis of the Waorani Curare hunting poison

. *Curarea tecunarum* has been analyzed in the lab in the 20th century twice for medicinal purposes. The first chemical analysis in the 1930s was by Folkers and Unna who indicated there were no curare alkaloids typically found in other curare poisons in the *Curarea tecunarum* plant chemical make-up (Folkers & Unna, 1939). Another chemical analysis by Barltrop and Jeffreys fifteen years later further concluded the *Curarea tecunarum* plant chemical make-up did not have alkaloid chemicals capable of the paralysis observed (Barltrop & Jeffreys, 1954). Our dissertation observations indicate that *Curarea tecunarum* is curare-like if not actually curare, since the monkeys hunted with a blowgun using *Curarea tecunarum* become paralyzed and fall from the tree. It is unclear what chemicals, besides the particular curare alkaloids these early chemists looked for, might cause a reaction that resembles classic Curare poison paralysis. Other than a few animal laboratory tests for paralytic potency, *Curarea tecunarum* does not

appear to have been used or tested by scientists in the biomedical field (Nuewinger, 1998; Lewin, 1923; Pagozov, 2008).[2] There have been only a few ethnographic descriptions of *Curarea tecunarum* use in indigenous groups (Davis & Yost, 1983A and B; Prance, 1972; Krukoff & Smith, 1937).

Humanity's Long-Term Use of Hunting and Fishing Poisons

This dissertation argues that most humans consumed hunting and fishing poisons on a regular basis around the world during the Paleolithic Era. Humans throughout all the continents and parts of the world have long prepared poison for the use of arrows and darts as well as spears and javelins (Bisset, 1988; Perrot & Vogt, 1913; Lewin, 1923). Most hunter-gatherer poisons used in Paleolithic Era may have been simple but effective single ingredient poisons such as the *Curarea tecunarum* the Kawymeno Waorani still use. The vast majority of poisons encountered around the world over the past 150 years are mixtures of multiple ingredients, although the active ingredients come from a much narrower range of plant families (Bisset, 1988). The extent of the human use of poisons in the Paleolithic Era is largely unknown due to lack of material evidence. Spearheads, which were often poisoned, date back at least 300,000 years (Clark, 1971 and 1977). A spearhead that was at least 120,000 years old was found piercing the ribs of an elephant (Clark, 1971 and 1977). The present Maasai hunters of Kenya may have been using poisoned arrows as early as 18,000 BP (Gramly, 1976). Another hunter-gatherer group, the Hadza of Africa, along with the Waorani are both

[2] To avoid confusion, the reader should note that in these early lab tests researchers referred to *Curarea tecunarum* using the scientific name *Chondrondendron limaciifolium* which has been abandoned (Barltrop and Jeffreys, 1954; Folkers and Unna, 1939).

arguably two of the most isolated unchanged hunter-gatherer groups to have survived into modern times. The Hadza hunt using bows with arrows coated with plant poisons (Adenium sp. strophanthus), which are shot into animals' abdomens (Jelliffe, 1962).

Further, the dissertation argues that during the Paleolithic Era these mostly plant-based hunting and fishing poisons stimulated the development of receptors designed for processing and detoxification of phytochemicals in these poisons for potential use in hormonal regulation and antimicrobial protection. These poison receptors exist in humans or otherwise, humanity would have long ago succumbed to its own diet. Many phytochemical receptors have been located in the human body by medical science as described in the Plant-Human Co-evolution chapter. The question is why these bio-chemical receptors for plant phytochemicals developed and what purpose do these receptors serve in maintaining human health. Further, when the consumption of hunting, fishing and other powerful and varied phytochemicals stops, does this relieve the body of the burden of processing toxins? Or does the decrease in regular dietary intake of phytochemical poison, unprecedented in human evolutionary history: 1) lead to disease that these phytochemical substances were previously controlling or; 2) lead to a disease process caused by phytochemical receptors that no longer have a job and run amok chemically, creating unwanted bio-chemical changes that lead to chronic disease. 3) This dissertation also makes the case a little latter that human fertility and hormones make be linked physiological to phytochemical

intake particularly in the large regular doses such a poison from hunting and fishing provides.

Most hunter-gatherer hunting and fishing poisons are made from plant phytochemicals originally designed to protect the plant, particularly alkaloids, saponins and cardiac glycosiods (Neuwinger, 1998; Bisset, 1991) which are referred to in other parts of the dissertation as "plant defense chemicals" and are merely potent variations of mostly anti-herbivore chemicals found in most plants. However, the plant species that are used as hunting and fishing poisons may have phytochemical defense compounds more targeted to protection from, and chemical manipulation of, larger animals rather than just insects or parasites.

However, some hunting and fishing poisons are also made from animal defense chemicals produced by fish, insects, reptiles, and amphibians, although the origin of these compounds in the food chain may have come from plant life. Those that argue that arctic regions have few plants to promote a plant-human co-evolutionary relationship should know that animals also develop the equivalent of plant defense chemicals. Partly due to the almost exclusive focus of the natural foods industry on plant supplements, little research has been done on the animal equivalent to plant defense chemicals (Etkin, 2006). Finally, another less common poison used by indigenous groups is the intentional transfer of pathogenic microorganisms (Bisset, 1988).

Types of blowgun dart poisons

. Curare are a large group of poisons originally used by hunter-gather indigenous groups as arrow and dart poisons for hunting in the northern part of

the South American continent. These poisons come from two entirely different plant families, Loganiaceae from the genus Strychnos, and Menispermaceae. There are a few atypical hunting dart poisons that do not use Loganiaceae or Menispermaceae plants that have usually been described as "non-curare". These atypical dart poisons include the use of poisonous frogs from the *Dendrobatidae* family by the Chocó Indians in Columbia (Wassen, 1935), although the frog appears to have simply processed an insect poison for its own defense. Frog use of insect food poison is a good example of a defense chemical coming up the food chain, as discussed in the chapter on Plant-Human Co-evolution.

Use of curare poisons in Ecuador All current Amazonian and coastal Ecuador indigenous groups used blowguns and manufactured poisons from local plants for their blowgun darts, although some trade occurred in blowgun poisons (Karsten, 1935). Amazonian indigenous groups from Ecuador that manufactured dart poisons in the 20th century included the Cofan, Siona-Secoya, Yumbo, Quijo, Canelos, Kichwa, Waorani, Shuar, Achuar/Jibaroan, Zaparo and Teitete. Many of these groups, such as the Zaparo and Teitete, have all but vanished in the 21st century (Kvist, 1987). On the other side of the Andes mountains, the coastal rainforest indigenous groups that survived into the 20th century in Ecuador – the Colorado, Cayapa, and Coaiquer peoples – largely used the non-curare plant genus *Naucleopsis* for dart poison.

Most curare poisons are produced in the same manner by indigenous South American groups; by squeezing – or in the case of Oonta (*Curarea tecunarum*) shaving – the vine bark and dripping water through a plant leaf funnel

that is filled with the pulverized plant material. The resulting liquid extract is heated at a low temperature over a fire (Neuwinger, 1998). Photos of Kawymeno Waorani Oonta preparation are presented in this chapter.

Kawymeno Waorani Dietary Intake of Hunting and Fishing Poisons

. Hunting and fishing poisons are more frequently consumed by the Kawymeno Waorani than all other types of foods, in terms of frequency ingested, with the possible exception of manioc (*Manihot escuelente*), and a couple types of bananas. But the intake of poisons is through the regular consumption of animals and fish hunted and fished with poison. The Waorani refer to the vine and poison of *Curarea tecunarum* as "Oonta", which will be used as the proper name as there is no equivalent in Spanish or English. The core of the word "oo" has several meanings in the Waorani language including dart poison, blow, meat and hunt (Davis & Yost, 1983A). Oonta curare*,* the Waorani blowgun dart hunting poison, is consumed in the flesh of poisoned monkeys and birds, which are daily fare in their diet. Oonta curare alone is only exceeded in frequency ingested by three foods: manioc, bananas and the white-lipped peccary (*Tayassu Pecari*).

Plant phytochemical fish poisons are not far behind hunting poisons in frequency of Kawymeno hunter-gatherer consumption, ingested along with the fish they stun, especially during the dry season when streams and lagoons are shallow enough for the poison to be less diluted and therefore more effective.

Santa Teresita Kichwa subsistence farmers no longer use plant-based hunting poison although fishing poisons were used sporadically up until very recently.

Uniqueness of Waorani poison utilization due to their isolation from outside contact. The Waorani ethnobotany is notably different from the rest of the South American indigenous groups, which is evidence of their isolation from the outside world until very recently. Their dart poison (*Curarea tecunarum*) consists of a single ingredient, a rarity in South American dart poisons that usually have multiple ingredients (Kvist, 1987). Further evidence of Waorani isolation is the fact that until recently, the Waorani were unaware of a common powerful fish poison species used throughout the Amazon called *Clibadium asperum*. In addition, the *Banisteriopsis* species hallucinogen used by the Waorani shaman is different than the types of Banisteriopsis used in the rest of the Amazon. Even the role of the shaman is unusual. Kawymeno has no shaman, as shamanic practices are considered by the Waorani to be a cause of disease and any cure points the finger at the shaman as the instigator, thus life expectancy of practicing shamans is not great in Waorani culture (Rival, 2002; Davis & Yost, 1983A).

Types of Plant Poisons Used by Waorani and Kichwa in Hunting and Fishing

Below is a discussion of all the poisons used by both the Kawymeno Waorani hunter-gatherers and Santa Teresita Kichwa Agrarians followed by a brief history of poison use by indigenous groups in the region. The point is not to compare poisons use since the Kichwa no longer use poisons regularly enough to affect human physiology. This chapter documents the use and abandonment of phytochemical poison, a human evolutionary heritage, with a transition to agriculture.

Oonta (*Curarea tecunarum*) the hunting poison of the Waorani. The only hunting poison used by the Kawymeno Waorani is processed from a vine called *Curarea tecunarum*. This vine comes from the plant family of *Menispermaceae*. The species name *Tecunarum* refers to the Tecuna Indians who also used this plant as dart poison. Krukuff and Smith in 1937 first identified the Curarea tecunarum plant species (Krukuff & Smith, 1937). The scientific name of *Curarea tecunarum* has had a confusing history and has been referred to incorrectly in the literature as Chondrodendron limaciifolium and Chondrodendron iquitanum from 1930 through 1970. *Curarea tecunarum* has also has been mistaken for Curarea toxicofera and Abuta limaciifolia.



Figure 46. Curare (Curarea tecunarum) Vine Growing in Primary Rain Forest Near Kawymeno.

Very little has been written about or is known about *Curarea tecunarum* perhaps because it is only found in very remote regions and used by only a few

groups of indigenous in the Northwestern Amazon in the past, and is perhaps only used by the Waorani at present. Wade Davis cataloged Oonta *Curarea tecunarum* as being used by the Protectorate Waorani for hunting in 1983 (Davis & Yost, 1983A and B) and the Kawymeno Waorani still carry on this tradition.

I have observed the Oonta vine climbing large trees near Kawymeno. Oonta is found in dwindling primary rainforests such as Yasuni National Park. The vine is a flattened shape rather than round and grows where the water level never rises high enough to cover the ground. The altitude at which Oonta have been reported vary; they are usually below 350 meters but have been recorded as high as 1,000 meters. *Curarea tecunarum* vines have been found in Brazil, Columbia, Peru and Ecuador.

Ima, my Waorani assistant, mentioned that the Oonta vine is almost identical and easily confused with a plant the Waorani call Omenta, but the Oonta leaf is green on one side and whitish-green on the other side, whereas the Omenta leaf is green on both sides. Omenta may be relevant because even the Waorani – keen observers of nature – can mistake it for *Curarea tecunarum*. Omenta has no poison and thus, perhaps scientists made the same identification error, which might account for conflicting accounts.

The Santa Teresita Kichwa indicated that up until the mid-20th century they used a blowgun poison. These study Kichwa described their blowgun as being round and short, rather than flat and long as is the Waorani blowgun. According to dissertation interviews, the last remaining Santa Teresita Kichwa blowgun in the community had not been used in decades and was destroyed the

year before by playing children. Although no living residents in Santa Teresita knew how to make the poison, they had seen blowguns used to hunt as children. It is known that at least two other groups in Ecuador used *Curarea tecunarum* at one time, the Cofan indigenous (Kvist, 1987) and the lowland Kichwa (Krukoff & Smith, 1939). It is very likely that the Santa Teresita Kichwa of this study may have also used *Curarea tecunarum* poison since its use was documented in 1939 with Amazonian Kichwa groups in Ecuador. The Santa Teresita Kichwa no longer use significant amounts of any poison, thus the loss of another major source of dietary intake of wild plant phytochemicals as a result of a move away from hunting and fishing and towards agriculture.



Figure 47. Kawymeno Waorani and Author's Student Hunting with a Blowgun

Types of monkeys and birds hunted with a blowgun by the Kawymeno Waorani. The Kawymeno Waorani use Oonta for hunting animals often found high in rainforest trees, particularly a number of species of monkey.

The wood used to make blowguns in Kawymeno is called Tepawe/Tepa (undetermined scientific name), which is easier to find than more traditional Cayobera/Cayewebe wood (undetermined scientific name). Blowguns are made from two wood pieces cut in half and wrapped together with vines and are very long at over 9 feet. I have observed when hunting with the Kawymeno hunter-gatherers that it can take up to ten minutes after a monkey has been hit with a curare blowgun dart for it to get the full affect of the poison and fall from the tree. The principal monkey species I have observed being hunted using Oonta (*Curarea tecunarum*) dart poison are the Wooley Monkey (*Lagothrix lagotricha)*, White-Bellied Spider Monkey (*Ateles belzebeth)*, White-Fronted and Brown Capuchin Monkey (*Cebus albifrons, Cebus apella*), Red Howler Monkey (*Alouatta seniculus*), Squirrel Monkey (*Saimiri sciureus*), Dusky and Yellow-Handed Titi Monkey (*Callicebus discolor, Callicebus Lucifer*), as well as the Equatorial and Monk Saki Monkey (*Pithecia aequatorialis, Pithecia monachus)*. The Waorani frequently keep baby monkeys that are acquired during the hunt as pets when their parents are hunted, particularly Wooley and Spider monkeys. The type of spider monkey found near Kawymeno appears to be an exceptional tall subspecies that frequently walks bipedally and can be mistaken for a human at a distance. These pet monkeys are allowed to run free but return to the Kawymeno Waorani house for food.



Figure 48. Kawymeno Waorani Boy on Curare (Curarea tecunarum) Blowgun Dart Hunting Expedition with a Shot Wooley Monkey (Lagothrix Lagotricha)

The Kawymeno Waorani also hunt a number of bird species using Oonta blowgun poison, principally the Pavo Colorado *(Penelope jacquacu)*, various Amazon species of parrot *(Psittacidae)*, Blue and Yellow Macaw, Scarlet Macaw *(Ara ararauna, Ara macao),* Toucan *(Ramphastos tucanus)* and Pavo Negro

(*Pipile pipile)* none of which are seasonal and all of which are obtained in equal numbers throughout the year.

The Kawymeno Waorani are great conservers of their natural flora and fauna. Thus, monkeys, birds and other animals are still plentiful only a few minutes' walk from the community. The Kawymeno Waorani never take more food than they can eat from the rainforest the same day or the next. In addition, no animals or plants are sold or traded by the Kawymeno Waorani. Elsewhere, poaching and logging have contributed to loss of flora and fauna in Yasuni National Park but Kawymeno does not permit the entrance of intruders.

The Waorani production of *Curarea tecunarum* hunting poison alters phytochemical properties

. Ima has indicated that no other food, poison or medicinal remedy in the entire Kawymeno Waorani repertoire requires such elaborate preparation as the preparation of Oonta blowgun poison. This is perhaps a reflection of the simplicity of the food system rather than the complexity of making the dart poison, which is rather straightforward. Typically, with the few plants actually used to make medicine or poison by the Kawymeno Waorani, the preparation is limited to chopping, squeezing and application of a single ingredient from a single plant. Only a few plant remedies are even mixed with another plants, one being a remedy for snakebite using Gimatowe (undetermined scientific name) combined with Tentemowe (*Renealmia asplundii, Renealmia thyrsoidea*). Only Oonta goes through the more complicated process of filtering, boiling and drying. An illustrated section below shows Oonta blowgun poison being made.

There may be biochemical changes in Oonta/Ome (*Curarea tecunarum)* in the transition from the original chemical compounds in the raw plant to final chemical formula in cooked Waorani hunter-gatherer animal food in terms of the way it affects human physiology. The poison is in the animal killed with the poison, which the Waorani subsequently eat. Oonta undergoes a processing that causes many biochemical changes before finally being consumed by humans. First, the bark is shaved from the vine, the shavings are filtered into a container with water in a funnel, and the resulting liquid is then boiled. The boiled liquid is painted and dried on the darts. The dart stays attached to the prey long enough to enter the bloodstream due to piranha fish teeth attached to the dart tip. Oonta enters the blood stream of the hunted monkey or bird, which dies and is cooked and then consumed by the Waorani. This processing and preparing is typical of most Curare dart poisons by South American hunter-gatherers (Nuewenger, 1998).

The Kawymeno Waorani refer to the final elaborated Oonta poison by another name – Ome. My assistant, Ima, indicated that the Ome form is much more potent than raw Oonta (*Curarea tecunarum)* and inadvisable to drink. The dietary intake of Oonta is almost daily in many seasons of the year and poison preparation is frequent. However, Ima noted that he has never heard of any Waorani dying from ingestion of Oonta or Ome.



Figure 49. Ima, my Waorani Assistant with Poisoned Blowgun Hunting Darts he Made with “Ome” (Curarea Tecunarum).

There is evidence that that the muscle paralyzing effect is enhanced almost tenfold in some curares through the process of converting raw plant into the finished dart poison (Nuewinger, 1998). It is not clear what biochemical modifications occur to the alkaloid and other toxic phytochemicals (that are among the most active ingredients) during poison preparation.

Shelf life: Waorani Onta (Curarea tecunarum) vs. Kichwa Sangre de Drago

. In the dissertation survey of the shelf life of all plants used by the Kawymeno Waorani, ninety-four of the ingested plant species (including all the fish poisons) lasted less than two weeks after being cut from the living plant, and only four plant species lasted over a month. Only one plant ingested, Oonta (*Curarea tecunarum*) lasted many times longer and still retained its potency to kill animals. My assistant, Ima, noted that long after preparation, Ome poison (*Curarea tecunarum*) is still an effective poison for hunting, even after being stored over a year by the Kawymeno Waorani

The Santa Teresita Kichwa have only one commonly ingested medicinal or food plant product whose shelf life was over two months, namely "Sangre de Drago", which comes from the sap of the wild tree *Croton lechleri*. According to the Santa Teresita Kichwa, Sangre de Drago maintains its potency up to a year for medicinal purposes. In a recent study of the antioxidant content of foods and supplements, Sangre de Drago sap from the *Croton lechleri* tree had the highest antioxidant content of all 3,139 foods and supplements evaluated in the study – an ultra-high 2897.1 mmol/100g – while all supposedly high antioxidant foods paled in comparison (walnuts had 21.9 mmol/100g, strawberries 2.1 mmol/100g, whole wheat bread 1.0 mmol/100g) (Carlson, et al., 2010).

The Kawymeno Waorani know of, but do not utilize Sangre de Drago as a medicine or in any form. The Santa Teresita Kichwa make extensive use of Sangre de Drago, with many residents taking it daily, more often than most foods.

The high antioxidant content may account for its long shelf life, which is well over a year with no special storage care. Like all powerful substances, there may be negative as well as positive health aspects to Sangre de Drago ingestion.

Aging and potency of Curarea tecunarum: Good after 140 years on the shelf. *Curarea tecunarum* hunting poison potency greatly exceeds Sangre de Drago's longevity. *Curarea tecunarum* poison is remarkably stable once prepared. Specimens left in European museums remain very lethal with a potency to paralyze even after 140 years on a museum shelf. When a number of these museum poisons were tested, the more aged the *Curarea tecunarum* poison was, the more lethal the same dose proved to be, as poisons over 130 years old were more potent than less aged specimens (Nuewinger, 1998; Lewin, 1923). This may be due to the high antioxidant content of *Curarea tecunarum*, but it has yet to be tested for antioxidant capacity.



Figure 50. Sap from the Tree (Croton Lechleri) or Sangre De Drago. Used Medicinally by the Kichwa and One of the World's Highest Antioxidant Contents.

Personal consumption of Curare hunting poison by the investigator. Having no other way to survive in the remote rainforest while living with the Waorani hunter-gatherers and far from any other food sources, I consumed Oonta (*Curarea tecunarum)* in my food regularly for many months with no noticeable reaction; in fact, I never became ill during the entire year I spent with the Waorani.

In addition this investigator, at the insistence of his Waorani assistant, Ima, has also consumed Oonta poison drops in a raw form straight from a cut vine. When these drops caused immediate numbing of my tongue, but otherwise there was no noticeable generalized body reaction. My tongue and the upper front palate in my mouth felt a little numb for a day or so afterwards. Evidently, raw

Oonta *Curarea tecunarum* has minimal nervous system effect in small doses unless it enters the blood stream. In fact, the Kawymeno Waorani use Oonta medicinally as well as for hunting poison, which is discussed in more detail in the next chapter.

The investigator was told by the Kawymeno Waorani not to try poison consumption of raw plants used from fish poisons, as the reaction can be fatal. In conversations with Waorani from the protectorate it appears fish poisons are the leading material used to commit suicide, an increasing problem with Waorani that have left their rainforest and hunter-gathering way of life. There has never been a suicide in Kawymeno.



Figure 51. Akowe Tree Cedrelinga sp. family Fabaceae

"Yesterday, a group of Kawymeno Waorani went hunting peccary. They found a peccary with a strange spear shaft still lodged in the peccary, with the wound still bleeding, less than two kilometers from Kawymeno. They brought me the wooden spear tip lodged in the peccary made from Chonta. The spear wood is not the type used by the Waorani in Kawymeno. There

is no community for hundreds of miles as Kawymeno is extremely isolated. The Kawymeno Waorani suggested it might be a Tagaeri spearhead. In 2002, a Tagaeri house was found 2 days walk from Kawymeno when the oil company was performing seismic explosions and charting territory, according to the Waorani guides who were assisting. The Tagaeri are the last uncontacted group of hunter-gatherers left in Ecuador and all Waorani in Kawymeno admire them for still resisting the outside world all Waorani are being forced to enter. The spear point appears to have been painted with some kind of film. Twenty-five years ago, according to Yost, the Waorani still used poison on their spearheads. This custom has died out. However, the Tagaeri may still maintain this custom of applying poison to spearheads". (Douglas London, Field Journal Entry: May 4, 2010)



Figure 52. Very Large Fish Species Are Commonplace Near Kawymeno Even in Relatively Shallow water

Waorani and Kichwa Fishing Poisons

Fishing poisons used by the Kawymeno hunter-gatherers are fairly mild, only stunning rather than killing the fish. In this area of the Amazon, plant-based fish poisons are referred to as “barbasco”. When I have been barbasco fishing with the Kawymeno Waorani, only the fish that are to be eaten are harpooned when stunned, and the rest of the fish are allowed to recover. The Kawymeno Waorani never sell the fish and never take more than the community can eat. Thus, in 15 years they have not depleted the fish population. Even in front of the community in the Yasuni River where I swim, schools of piranha can be easily seen immediately. Nearby streams and lagoons are brimming with fish – many of them enormous for such shallow waters – as well as pink dolphins, anacondas,

caiman and a multitude of other animals. Thus, the Kawymeno Waorani hunter-gatherers protect their rain forest ecosystem and cause no more damage by the use of poison than when fishing with a net. Large fish have long since vanished from regions close to the oil wells where many Protectorate Waorani now live.



Figure 53. Preparing Meniko Fish Poison (Lonchocarpus nicou - variation Urca) for Use in the Shallow Feeder Stream

Waorani fishing poison – Meniko - Lonchocarpus nicou-variation Urca. The most frequently used "barbasco" fish poison in Kawymeno is *Lonchocarpus nicou - variation Urca*, which comes from the plant family Fabaceae. The Kawymeno Waorani refer to this plant as "Meniko" or "Meneco". Meniko fish poison is made by crushing the outer wood of *Lonchocarpus nicou - variation Urca* into sawdust and throwing it into the stream where the fish are.

This native barbasco poison is planted throughout the forest and is thus semi-cultivated. This poison effectively stuns the fish in shallow stream water, which are then harpooned by the Kawymeno Waorani.

In the dry season, the water level dries up feeder streams and leaves fish in shallow water. Water level in the Amazonian region where Kawymeno is located can fluctuate more than ten feet. Kawymeno Waorani report the water level fluctuations on the Yasuni River are less regular and seasonal in the last few years, due perhaps to the changing weather system worldwide.

Waorani fishing poison: Campago *Lonchocarpus nicou var. Languidus*

. Another poison that is occasionally used is *Lonchocarpus nicou var. Languidus*, another variant of the original species that comes from the plant family *Fabaceae,* and is named "Campago" by the Kawymeno Waorani. The root is ground to a pulp and put in shallow streams. Storage time is around two weeks before the roots lose their potency. In Kawymeno, Campago is not used often, because it needs to grow near the community and requires some human care and doesn't reproduce well when left to itself. This poison effectively stuns fish in shallow streams and is used only in seasons when the water level is low.



Figure 54. Placing Meniko Fishing Poison chopped roots in the Feeder Stream

Waorani fishing poison: Koonii. Another poison that is used seasonally in Kawymeno is called "Koonii" or "Cogni" (*scientific name unknown*). Koonii is a semi-cultivated rain forest shrub used for several months when the poisonous fruit is on the tree. Only the crushed fruit is used as a fish poison. Davis mentions a poison with a similar name, Coonei, (*Clibadium asperum)* from the plant family *Compositae* or *Asteracae* (Davis & Yost, 1983B) that he describes as powerful poison made from leaves that can kill fish a mile downriver (Davis & Yost, 1983). Davis's *Clibadium* is a poison borrowed from the Lowland Kichwa and not an

original Waorani poison (Kvist, 1987) while the Kawymeno Waorani poison called Koonii appears to be a new unreported poison.



Figure 55. Koonii a Plant Whose Fruit are used by Kawymeno Waorani to Make Fish Poison

The Kawymeno Waorani do not use powerful poisons because they are unnecessary in the small feeder streams and lagoons near their community. My assistant Ima indicated that Koonii is the weakest of all poisons, only useful in the immediate area where fruit is dropped, and does not discolor the water. Koonii is neither a leaf nor a powerful poison as is *Clibadium.* Thus, most likely Kawymeno's Koonii is not the same as Davis's Coonei and may be an unreported fish poison in the literature for the Waorani. Other indigenous groups in the Amazonian region used a fruit-based poison called *schoenobiblus peruvianus* from the Thymeleaceae family, which may be similar to Koonii. A repetition of the same name for different poisons may be the case here, as clearly these are not the same plants. I have heard about of the Protectorate Waorani using the same name for both a traditional plant and a new medicinal plant (traditional Toyoba for tooth problems versus newly-invented Toyoba B remedy for hepatitis).

Former Kawymeno Waorani fish poisons. There are a number of fishing poisons that were in use a decade ago that the Kawymeno Waorani no longer use. One is a *Cedrelinga* species from the plant family *Fabaceae,* which the Waorani call "Acowe". The Acowe bark was ground into sawdust and put in streams as fish poison. The huge 80-meter Acowe tree is found in dry primary forest. Davis reported the bark as being used as an antifungal (Davis & Yost, 1983A and B) and the Kawymeno Waorani still use Acowe as an antifungal in 2012. In the past, Acowe was used to disinfect traditional cloths made from tree bark that had scabies. In addition to Acowe, the Waorani used the bark of an Enterolobium species in the past both as a fishing poison and as an antifungal (Davis & Yost, 1983).



Figure 56. Most of the fruit, medicinal, poison plants of the Waorani are actually large trees not herbs or shrubs

Fishing Poisons Used by the Santa Teresita Kichwa. The Santa Teresita Kichwa report rarely using fish poisons because the shallow feeder streams are fished out, and there were complaints that the more powerful poisons used in the Napo River affect the livestock of their neighbors. At least until recently, several fish poisons were used sparingly in Santa Teresita. A positive identification as to the scientific name of the fish poison plant species used by the Santa Teresita Kichwa could not be made without specimens available to observe.

However, Kvist indicates that *Clibadium asperum* leaves, as well as *Lonchocarpus sp.* and *Minquartia guianensis* (cortex of plant) were frequently used as fishing poisons by the Amazonian Kichwa (Kvist, 1987), and may well be the fish poison species described below by members of the Santa Teresita community.

All Jambi Kichwa fish poison. A poison called "All Jambi" was the most commonly used poison by the Santa Teresita Kichwa, at least once a month. This poison comes from the roots and trunk of a vine. Used mostly in the Napo River, fish are reported to die downriver for a day after use. This was the strongest Kichwa poison. The most frequent method of suicide used by the Santa Teresita Kichwa was swallowing this poisonous plant. All Jambi was planted in a garden, but also grows in the rainforest. All Jambi can be stored for one month, but shelf life is reduced down to two days when crushed.

Cajali Tananbo Kichwa fish poison. The Santa Teresita Kichwa used another fish poison, "Cajali Tananbo", less than once a month. Elsewhere, Cajali Tananbo may have been called "Panga Jambi" or "Barbasco de Hoja". However, whether these are distinct plant poisons is unclear. In any case, Cajali tananbo was grown in a garden, but is also found in the rain forest and the leaf is crushed into paste for use in streams. Cajali Tananbo was used in small feeder streams, where it stuns fish for 2-3 hours.

Other Kichwa fish poisons. Another poison referred to as "Estella Jambi", while once commonly used, was also abandoned because there are no fish left in the feeder streams that this weaker poison was suited for.

Another poison, called “Sacha Jambi”, even in the past was used less than once a year by Santa Teresita Kichwa. Sacha Jambi may be called by various names elsewhere, such as or “Mico Jambi” or “Huasca Jambi” or “Barbasco de Monte”.

Use of synthetic fish poisons by Protectorate Waorani The protectorate Waorani are running out of natural resources to make poisons and are being taught that Western chemicals are superior. My Waorani assistant Ima describes a case a few years ago where the Westernizing Waorani in the Protectorate community of Bataboro used chemical poisons brought from the store in Coca for throwing in the river to catch fish. A Waorani family sent their children to the river to poison fish with this Western poison. While the poison was effective in killing fish, when not all of the fish guts were removed properly, a Waorani guest invited to eat the fish died after ingesting this synthetic poison. The Waorani community was unable to read the label on the container of the poison to determine what the poison was.

CHAPTER 23

POISONS II: CO-EVOLUTIONARY RELATIONSHIP BETWEEN PHYTOCHEMICAL HUNTING POISON INTAKE AND HUMAN HORMONE CYCLING?

Evolutionary Adaptation: Natural versus Synthetic Poisons

The Kawymeno Waorani are poisoning themselves daily when they eat fish caught with natural plant-based barbasco poison, yet with no noticeable negative effect on their health. In fact, Waorani in the Protectorate, just like the Santa Teresita Kichwa, use raw plant-based fish poisons as the method of choice in suicides. Why do the plant-based fish poisons, when ingested in fish food in small amounts, fail to kill or even cause minor illness to the Waorani, while synthetic poison, even diluted in the water and processed in the fish body kills them? These natural fish poisons are just as deadly as synthetic poisons. Waorani gutting of fish is just as likely to be haphazard in plant-based poisoned fish, as the haphazard gutting associated with the Waorani fatality in the synthetic fish poison example above. The original raw plant-based fish poison compounds may be altered biochemically by the fish prior to eating, reducing the venomous effect. Removal of organs that fish use to process toxins probably further reduces the plant toxins in the fish food, but does not completely eliminate them. The fact is this investigator during his time with the Waorani, frequently ate small quantities of very poisonous fish phytochemicals with no ill effects. As mentioned above, the Western physician Paracelsus suggested in the 15th century that dosage determines if the biochemical effects of a poison are toxic, or have potential

medicinal effects (Bisset, 1988). However, Paracelsus did not mention that no matter how low the dosage is, to begin with, humans must have adapted to the poison sufficiently through human evolution to develop the physiological means to process the substance.

Is human physiology adapted to hunting and fishing poison intake and, if so, why?

Tolerance by one species of life to the same toxin that kills another species is quite common in nature, as plants have developed individual evolutionary relationships with different animal species. For instance, numerous berries are poisonous to humans, but not to the birds that regularly consume these berries and spread the seeds for the plant. On the other hand, avocados and chocolate are poisonous to parrots who have never eaten or had to adapt to these particular plant-based phytochemical toxins to survive, while humans ingest these foods routinely, unaware they are processing phytochemicals that for some species are poisonous.

There is every reason to expect humans may have developed a physiology to deal with ingestion of these hunting and fishing poisons more efficiently than their prey as human survival may have once depended on the use of poison. It was suggested earlier in this chapter that most if not all hunter-gatherer groups around the world used poison to survive during the Paleolithic period, to assure enough meat and fish was obtained to survive. However, there is no evolutionary reason the animals that the Kawymeno Waorani kill and eat would have any physiological mechanisms to process these hunting and fishing poisons since

these poisons were rarely encountered during their evolutionary history other than brief brushes with scattered hunter-gatherer groups.

This dissertation suggests that all humans may have inherited from their hunter-gatherer ancestors the physiological mechanism to process these types of poisonous hunting and fishing phytochemicals. Certainly, this investigator ate poisoned fish and meat for a year with no ill effects while staying with the Kawymeno Waorani. The Deni Indians are another case in point, as drinking a hunting poison that kills monkeys and birds should have a similar effect on humans, which was not the case.

Why poisons poison: co-evolution of humans and plant physiology

. While clearly there is an extensive physiological interaction between humans and plant based poisons, did regular dietary intake of these phytochemical toxic pharmaceuticals have potentially beneficial effects for humans? Dissertation results suggest that indeed there are two possible beneficial aspects to regular ingestion of hunting and fishing poisons, the first being regulation of fertility hormones, and the second being prevention of microbial diseases, particularly staphylococcus and streptococcus bacteria. Evidence of the potential connection between Kawymeno Waorani human fertility hormones and Oonta curare (*Curarea tecunarum*) dietary intake is explored in the next section. Later, in the next chapter the potential anti-microbial effect of plant defense chemicals consumed in the form of hunting and fishing poisons is discussed.

Curare and Fertility

Clearly plants have the chemical power to alter human fertility, as many indigenous groups use plants specifically for that purpose with some success (Elizabetsky, 1994). There survival benefits for plants to control human and animal hormonal cycles, such as soliciting the collaboration of mammals and herbivores as the food system chapter 11 elaborates on. This dissertation argues that there may be benefits for plants to controlling fertility cycles in animals. In other words, there is a plant–human co-evolutionary relationship between hormone controlling phytochemicals in plants and the hormone cycles in animals, including humans.

In contrast with the fish poison, consumption of the complete body of animals hunted with *Curarea tecunarum* assures that all the *Curarea tecunarum* poison in the animal is absorbed into the human body. All the internal organs of the monkeys and birds hunted with *Curarea tecunarum*, including organs that process toxins, are eaten. In fact, the Waorani ate almost all parts of the bodies hunted with Oonta curare, including the feathers of the birds and the skins of the monkeys. However, recently the teacher in Kawymeno has discouraged the eating of bird feathers.

Warfare: A Method of Kawymeno Waorani Fertility Control

There are at least three ways population control occurred in Amazonian indigenous groups in South America; infanticide, war and fertility regulating plant intake. The discussion below suggests that fertility-controlling plants now and in the past are not used intentionally or required by the Kawymeno Waorani.

The practice of infanticide, such as occurred with the Yanomamo people (Chagnon, 1968), was one way to control population. Infanticide appears to have rarely occurred among the previous generation of Waorani now living in Kawymeno. It's probable that spearing raids that often killed whole families, including infants, made this unnecessary (Davis & Yost, 1983; Yost, 1981; Rival, 2002). From several interviews it appears that infanticide by family members occurred a few times in Kawymeno over the last 15 years, and there was pressure for another infanticide that was blocked by the chief's son while we were present in the community. The chief's son in Kawymeno prohibits infanticide in the present-day. Informal conversations with Kawymeno Waorani indicated deformity was a major reason the Waorani might practice infanticide, as a deformed child would be unlikely to survive in a hunter-gatherer society. This dissertation study indicates that infanticide has been infrequent in Kawymeno over the last few decades.

Before contact with Western cultures, the Waorani homicide rate was so high that no other form of population control was necessary. Spearing raid mortality among Waorani accounted for 39% of female deaths and 54% of male deaths. Outsiders, mainly Kichwa, shot another 17% of the Waorani population (Davis & Yost, 1983A; Yost, 1981). Thus, traditionally warlike groups such as the Waorani or Jibaro tribes did not need any family planning to keep population numbers down.

However, family planning, through the use of fertility regulating plants, was a common way that other indigenous South American groups controlled

population. It is well known that certain indigenous groups use plant phytochemicals to control fertility, including many South American Amazonian indigenous cultures (Elizabetsky, 1994). In Ecuador, three groups do not use any plants for fertility purposes, including the Waorani, Cofan and Quaiquer indigenous peoples (Kvist, 1987). However, most other indigenous Ecuadorian groups, namely the Shuar-Achuar, Colorada, Cayapa and Siona-Secoya and Lowland Kichwa, (which includes the dissertation study group Kichwa from Santa Teresita), used fertility-affecting plants to control their population (Kvist, 1987). Many of these plants were forgotten with the advent of agriculture in the lives of these indigenous peoples.

The Waorani do not use wild Amazonian plants with pharmaceutical properties to control their fertility rates (Davis & Yost, 1983 A and B; Kvist, 1987). Historically, the Waorani did not need fertility controlling plant remedies or infanticide for birth control. Previous plant usage surveys confirm the Waorani use no plants to regulate fertility (Davis & Yost, 1983A and B).

The extensive plant usage survey of the Kawymeno Waorani in this dissertation research confirms Davis and Yost's survey results that the Waorani use no plants intentionally for the purpose of fertility control.

However, that does not mean plants the Kawymeno Waorani consume in their diet do not have fertility controlling pharmaceutical properties, merely that no plants are used intentionally as birth control. Again this chapter is not about health benefits of phytochemicals but rather physiological interactions between animals and plants that in the past served a useful role in plant-mammal co-

evolution but may or may not be beneficial to the Kawymeno Waorani or plants at this moment. Health benefits have been discussed. In this chapter the particular the interaction of physiologies across plant and animal kingdoms that are related to hormones are the topic of discussion. Evolution often leaves interactions and physiology that is suited to eras like that of hunter-gatherers intimate relationship with the rain forest and its phytochemicals but is not of practical use as humans detach themselves from their natural environment and its cycles and rhythms.

Explanation of Differences in Fertility Rates across Food Systems: Hunter-Gatherers, Subsistence Farmers and Modern Agricultural Populations

Bentley has noted fertility rates vary significantly by population food system. The three distinct food systems, hunter-gathering (Waorani), subsistence farming (Kichwa) and modern agricultural food systems (USA) have distinct fertility rates (Bentley, 1993).

Ellison has suggested that nutritional intake, and in particular energy intake, might affect fertility cycles (Ellison, 1989). However, Rosetta later noted that neither nutritional intake nor exercise are likely to have any role in fertility until one gets to extremes such as outright starvation (Rosetta, 1995). Thus, the reason for fertility variation across food systems is an unresolved question.

Of the three major food systems mentioned, hunter-gatherer food systems have the greatest rate of fluctuation of food resources and their accompanying phytochemicals. Seasonal fluctuation of fertility rates is also much greater in hunter-gather populations than in agricultural populations (Leslie & Fry, 1989)

but relatively minor compared to the large singular fluctuation experienced by the Kawymeno Waorani. However, this dissertation suggests phytochemicals in normal table food in modern populations may also interact with human hormones and affect fertility rates subtly. For instance Lazlo reported over 100 plants are used by various cultures around the world to control fertility (Laszlo, 1954). Lazlo's list of potential fertility controlling foods includes vegetables and fruit eaten daily in the United States, such as asparagus (Berendes, 1902) pineapple (Gimlette, 1915) and coconuts (Riog, 1938).

It is interesting that fertility modifying phytochemicals in Curarea Tecunarum intake may affect Kawymeno Waorani appear to affect male fertility in another indigenous group. Very little has been done to investigate fertility variation across populations in men (Rossetta, 1996). However, Bentley has recorded seasonal testosterone decreases in male Lese horticulturalists in Zaire (Bentley & Goldberg, 1993), which could be dietary related. It is unknown what factors affect male fertility on a population-wide basis. This dissertation may add to this literature.



Figure 57. Kawymeno Women in the Same Stage of Pregnancy

(Note: About ¼ of all births by Kawymeno Waorani women occur annually in the space of 5 weeks. One of these women gave birth a few minutes after this photo and was back finishing the game 45 minutes later. Kawymeno births typically take little effort by the women, who often engage in hard physical labor right up to the birth and after the birth almost immediately pick up where they left off and continue unaffected to finish the same physical activity.)

Dynamic Interplay of Waorani Fertility Cycle and Dietary Intake of Curare Hunting Poison (*Curarea Tecunarum*) over a Fifteen-Year Period Remarkable Seasonal Birth Spike of Kawymeno Waorani Hunter-Gatherers over the Last Fifteen Years

Unlike other studies on fertility among hunter-gatherers that have been published over this century, this dissertation has the exact birth dates of all Kawymeno Waorani born in the last 15 years and when plotted out monthly provide a fascinating puzzle. All birth dates of Kawymeno Waorani for over 15 years (and most weights and heights) were recorded by the Ministry of Education teacher for the Kawymeno region. This teacher, who has been of great assistance in this dissertation project, is the only non-indigenous outsider the Kawymeno Waorani have permitted to live with them prior to our acceptance in the community. He recorded the date of birth (and often weight and height, which will be the subject of a future paper) of each baby born in Kawymeno. This Kawymeno Waorani hunter-gatherer birth data permits an exact look, without any guesswork or approximations, at a hunter gather group seasonal fertility cycle, which is unique opportunity for the scientific community.

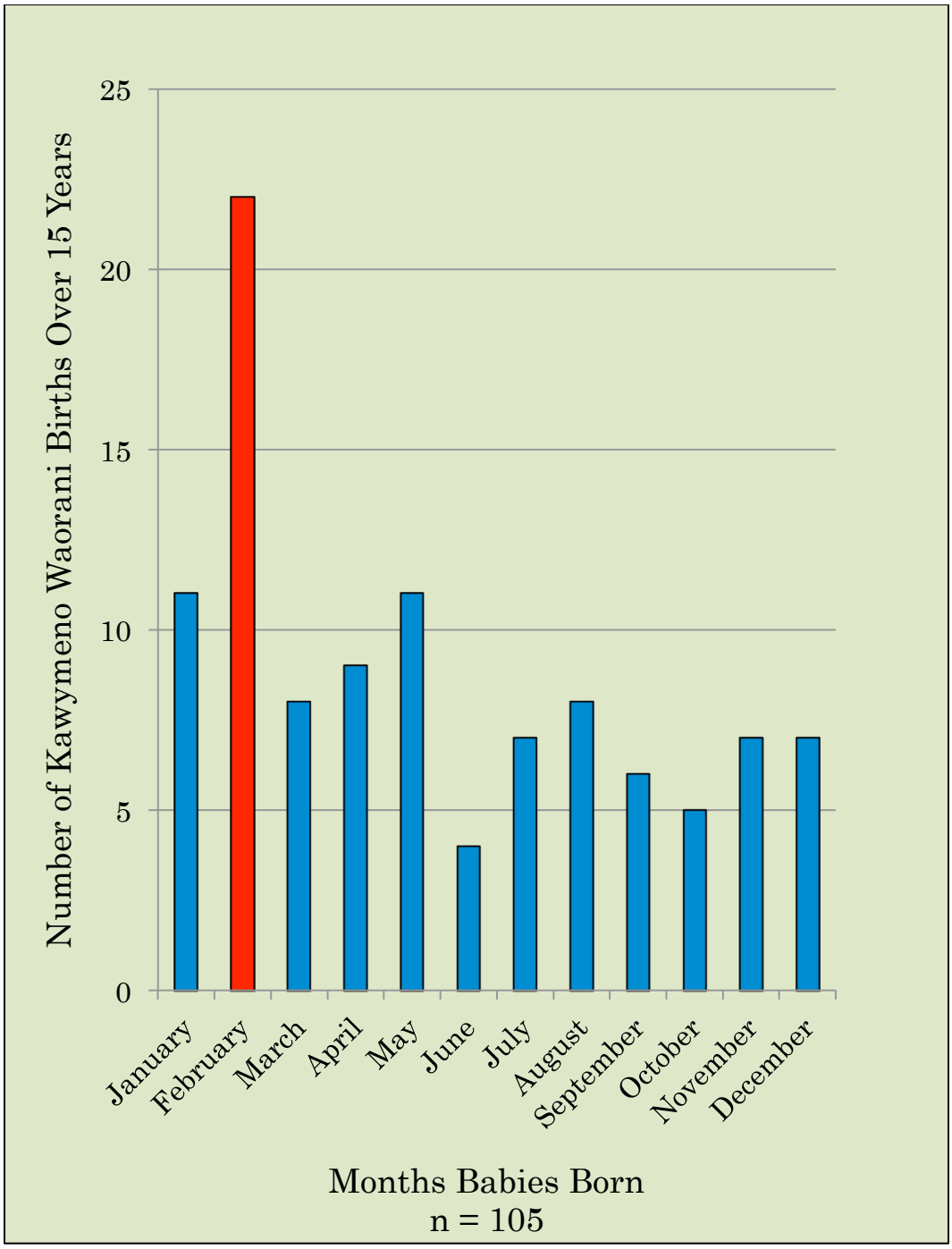


Figure 58. Month of Birth for All Kawymeno Waorani born from 1995 to 2010 (from Survey Data). 2010.

As one can observe from the chart, there is a fertility spike in Kawymeno births that has been remarkably consistent every year for the last 15 years. An

average of 21.0% of the Kawymeno Waorani births occur in the same month, February, in the absence of any social explanation. Of the 105 children born in Kawymeno over the last 15 years, 22 children or 21.0% of children were born in February.

Births from February 1st to March 8th, February plus the first week in March over 15 years are even more striking, 26 births of 105 total births, or 24.8 % of all Kawymeno births, occur in the same five-week period of the year for 15 years. This extra week does not show on the accompanying chart of the Kawymeno birth spike because whole calendar months are averaged.

Explanations for the Kawymeno ongoing, long-term, yearly birth spike

. First, we checked carefully into deliveries, there were no premature births to explain the birth spike, so then we went back nine months from February to conception times around May for clues. There are no unusual seasonal behaviors observed including increased Kawymeno Waorani social or cultural activities that would lead to increased sexual intercourse close to conception time to explain this birth spike either. We lived with the Kawymeno Waorani throughout the year and checked carefully into yearly and seasonal social activities through participant observation. There were no more social activities close to conception time than the norm throughout the year. Conversations, interviews and medical exams regarding social activities around conception time and throughout the year again revealed no unusual activities near the conception months that led to the birth spike.

The Kawymeno teacher himself has been aware of the birth spike over the last 15 years and is at a loss to explain it, but also did not believe it was related to increased sexual relations around conception time. The teacher's only suggestion was perhaps the birth spike was related to a change in diet. His thought was that seasonal switching to a different type of Chicha beverage might help explain the birth spike. Chicha is a common beverage made from slightly fermented fruits or manioc roots that is drunk 6-7 times a day by the Kawymeno Waorani. The Waorani do not appear to be aware or pre-occupied with the birth spike, which has been a regular occurrence, if the curare theory is correct, for hundreds of years or longer depending on blowgun poison hunting habits. The Waorani may be simply view fertility rises as normal and not requiring an explanation. However, seasonal changeover of the four distinct types of Chichas used by the Kawymeno Waorani hunter-gathers from Manioc root (*Manihot escuelente*) Peach Palm (*Bactris gasipaes)*, Morete fruit (*Mauritia flexuosa)* and Hungurahua (*Jessenia bataua)* fruit does not coincide with the months of conception of the birth spike. Chicha consumption is discussed further in the food system chapter. While this Chicha hypothesis possibility cannot be ruled out completely, there is also no literature documenting any fertility increases connected to Chicha consumption and all these types of Chichas are common in the diet of many indigenous groups.

Seasonal food species that might impact the Kawymeno fertility spike

So there is a real puzzle to resolve, what causes this fertility spike every year among the hunter-gatherers of Kawymeno. We thought the fertility spikes might be related to other fruit intake in the diet (besides chichi fruits), which vary

seasonally as each wild fruit food species is on a separate natural fruiting cycle. The fruiting season for every fruit food species for both Kawymeno Waorani hunter-gatherers and Kichwa Subsistence farmers was collected when the dissertation study conducted an ambitious project capturing both entire food systems and extensive data on all foods consumed. The fertility spike data chart was matched against the seasonal intake of all 137 of the most commonly consumed foods in the Kawymeno Waorani diet, starting with fruit plant intake. As the chapter on the food system indicates, the vast majority of Kawymeno Waorani dietary plant intake is in the form of a very wide variety of fruit, while meat and fish foods are fewer in species number but of great quantity per species.

The Kawymeno Waorani are keen observers of the natural cycles around them and can tell, within a few weeks, the fruiting cycle of all food fruits. Separate interviews about fruiting seasons with different Waorani yielded the same observations regarding seasonality of fruit within a few weeks. The study was able to confirm separately a sample number of fruiting cycles via participant observation (gathering fruit every week with the Waorani), which always matched the Waorani prediction. Therefore, the dissertation has confidence that the data on the fruiting seasons of food plant species is accurate. Fruiting seasons of similar species may vary considerably even within Yasuni National Park so local data specific to the Kawymeno region is essential to be accurate.

However, none of the fruiting seasons matched the months of conception for the annual Kawymeno Waorani birth spike[3], and although some fruiting seasons overlapped, these seasons extended beyond or before the conception dates. In addition, all of these fruit that were closer to the conception times were species that were sporadically consumed by the Kawymeno Waorani.

Seasonal monkey hunting with curare (Curarea Tecunarum) dart poison: correlation with fertility spike

. After fruiting seasons were checked, just to be thorough, animal consumption rates were checked even though plant phytochemical intake was the focus of the study. When the monkey consumption rates were checked, a pattern appeared. The consumption of monkeys jumped to about double for the end of April, all of May and the beginning of June in 2010. The study unexpectedly found a spike in monkey consumption that matched the time of conception for the birth spike better than any fruit species. People from Kawymeno indicated this seasonal increase in monkey consumption was standard every year. In fact all Kawymeno Waorani families prepare extra blowgun poison and darts in May every year for monkey hunting. Participant observation both in hunting and actual eating of monkeys killed each month, along with interviews regarding seasonality of monkey consumption yielded a clear picture; increase in monkey consumption matched the time of the Kawymeno birth spike conception month. While Curarea tecunarum is used for birth control in one large dose every few years small doses

[3] Waorani food fruit species that came the closest to the conception time for the birth spike were a *Cieba* species (called Bikaremo in Waorani), Koonii the fish poison mentioned previously, and two species of Waba, *Inga sp. Family Fabaceae*, (Ewemao, Wenemengo in Waorani).

by the Deni Indians, in the case of the Kawymeno Waorani sustained usage over decades or centuries may produce a different effect on fertility hormones than a one shot shock effect as practiced by the Deni Indians of Brazil. Unlike most fruit species, monkey consumption was a staple daily source of dietary intake for the Kawymeno Waorani.

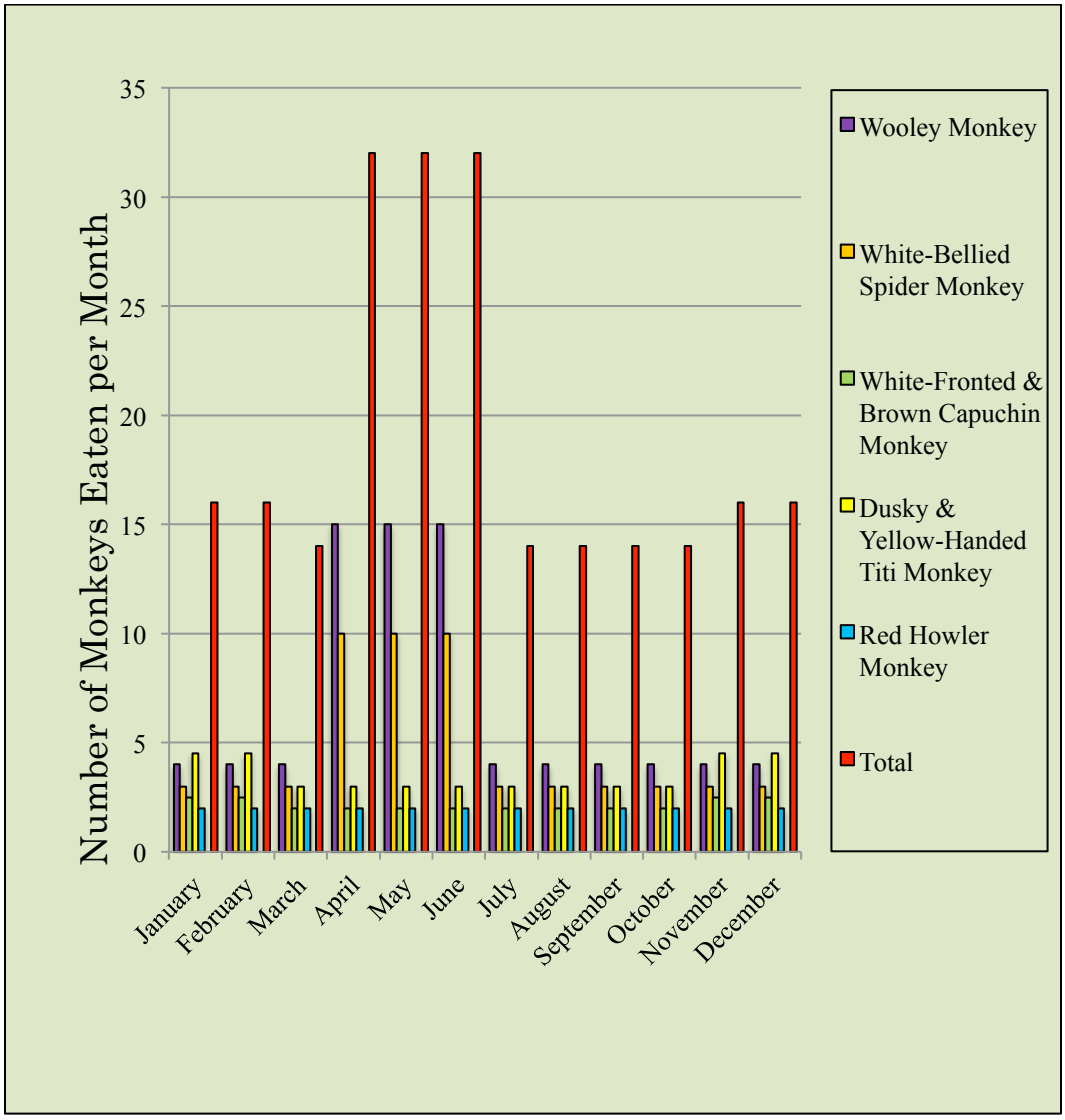


Figure 59. Seasonal Kawymeno Waorani Dietary Intake of Monkeys Poisoned with Curare Darts. 2010.

The Kawymeno Waorani indicated that they ate more monkey during May because monkeys were much fatter at that time of the year. In fact, monkeys were so fat during May that they often split open with fat when they hit the ground from the tree after being stuck with a blowgun dart. Monkeys are at their fattest during these months due to the increase in the amount of the types of fruit monkeys can digest at that time of year, as a greater variety of fruits are available during this time period. However, there was no single fruit species fruiting season that matched the monkey-fattening season, but rather a combination of a number of fruits.

Unlike the spike in fruit intake in the diet of the monkeys, the Kawymeno Waorani human dietary intake of fruit does not increase in quantity during conception months of the birth spike, in fact fruit consumption remains the same all year except for a slight dip in December. Because humans have the capacity to eat a wider variety of fruit than monkeys, there is no seasonal shortage of fruits as there is always some species of fruit in season. Monkeys on the other hand have a more limited range of fruits that they can eat and the seasonality of particular fruits affects monkeys more than humans. Humans have the adaptability and are able to successfully process more types of fruit phytochemical toxins than other rain forest primates. Eighty fruits are commonly consumed by the Kawymeno Waorani throughout the year, and still many more fruits are eaten only a few times a month during their fruiting season.

Oonta, *Curarea tecunarum* hunting poison is used to hunt birds as well as monkeys. Dissertation food system data indicated the number of food birds successfully hunted with blowgun poison by the Kawymeno Waorani remained reasonably stable throughout the year for all five principal bird types hunted; *Pipile pipile, Penelope jacquacu*, Toucans (*Ramphastos tucanus*), Macaws (*Ara ararauna/Ara macao*) and various Amazon parrot species (*Psittacidae*). Thus, the main variation in blowgun poison intake was with the large seasonal increase of Spider and Wooley monkeys.

Was there something about eating more of these monkeys that could spur fertility? Monkey dietary intake and fertility increase has not been reported elsewhere. The overall monkey consumption was striking, more than double the monkey intake occurred around the times of conception for the birth spike than in the other months of the year. When the study looked at particular species of monkey dietary intake, there was a pronounced spike of two monkey species in particular while variation of dietary intake for other monkey species was similar every month of the year. Dietary consumption of both the White-Bellied spider monkey (*Ateles belzebeth)*, and Wooley Monkey (*Lagothrix lagotricha*) fit the pattern of the conception time for the annual February birth spike in Kawymeno Waorani.

A match? Blowgun poison, monkey seasonality and the Kawymeno fertility spike

. Then we considered the fact that monkeys are hunted with blowguns. It is true that a certain number of monkeys are killed with a shotgun when shotgun

shells were sporadically available, mostly through regular gifts from the teacher in Kawymeno. Nevertheless, the majority of monkeys are still killed with Oonta (*Curarea tecunarum*) blowgun dart poison. Single ingredient *Curarea tecunarum* hunting poison is the most frequently ingested plant "food" after manioc. This dietary intake of *Curarea tecunarum* doubles each year around nine months previous to fertility spike through dart poisoned monkey flesh consumption. Thus, the sheer quantity of dietary of *Curarea tecunarum* ingested overall change in quantity seasonally is much greater than any dietary fruit phytochemical source since this curare poison phytochemical is found in a concentrated form in the flesh of major staple foods of the Kawymeno Waorani hunter-gatherer diet.

Curarea tecunarum is also used by Deni people in Brazil to control male fertility

. A literature search was conducted on Curarea tecunarum use six months after returning to Arizona State University from the Amazon. While literature on *Curarea tecunarum* hunting poison is minimal, as it has been little studied, some fascinating data did come to light. In 1972, *Curarea tecunarum* was reported as used by Deni Indians of the Rio Cunhua in Brazil to control fertility, namely the spacing of their children (Prance, 1972). Consumption of the *Curarea tecunarum* plant is planned as a group by the Deni rather than by individuals of the tribe. Evidently, both male and female Deni Indians drink *Curarea tecunarum* mixture when they use it for fertility control (Prance, 1972).

Prance noted, based on observations by missionaries, that the usage of *Curarea tecunarum* as a birth control measure by the Deni Indians affects male

fertility, not female fertility, as both sexes consume it (Prance, 1972). The Deni, like the Waorani, can have more than one spouse, although the Waorani system is more egalitarian as Waorani women are also allowed to have more than one husband. The fact that the only women that got pregnant at any given time always had the same husband suggested that the *Curarea tecunarum* affected male rather than female fertility (Prance, 1972).

Thus, a separate study of another indigenous people indicates that indeed *Curarea tecunarum* affects fertility cycles in humans and is used to control fertility in the Deni people. This adds evidence to the dissertation hypothesis that *Curarea tecunarum* has phytochemicals that regulate human hormones.

Summary of argument for cause and effect relationship between *Curarea tecunarum* phytochemical intake and the seasonal Waorani birth spike

This dissertation makes the case that variation in phytochemical intake may be a better explanation to account for fertility differences across food systems and seasonally within food systems than factors such as nutrients and exercise. Phytochemicals are known to affect hormones and fertility cycles and are used by indigenous groups for that purpose. There is no evidence that either exercise of nutrients greatly effect fertility rates. The possibility that variation in phytochemical substances known to effect fertility hormones in fact varies fertility hormones is not a controversial assumption. The largest single intake of plant phytochemicals known to effect fertility hormones by the Waorani is the intake of concentrated powerful doses of curare hunting poison. Again this

dissertation makes the case that it is quite likely that intake of a curare poison (Curarea tecunarum) known to alter fertility rates in indigenous Amazonian groups affects the fertility hormones of the Kawymeno Waorani as well. The Kawymeno Waorani birth spike is statistically significant to the point that chance of this birth spike being a random occurrence is very remote. A match between rise in intake of hunting phytochemical poisons rise and corresponding rise or drop in fertility is a correlation worth initial examination. If no other factor is found to explain this direct temporal correlation that reoccurs every year at the same time for decades then curare phytochemical intake as biochemical provoker of the birth spike can be taken as a serious candidate for cause and effect. Such an unusually large, one month, fertility spike requires an explanation beyond normal factors that impact fertility to a much lesser degree. Very concentrated, very regular doses of known fertility affecting substances like Curarea tecunarum are really a first line explanation to explain fertility variation. Lifestyle factors were thoroughly explored at the time of the study and there is no evidence of any group behavior to account for the birth spike. Intake of other substances by the Kawymeno Waorani were also thoroughly explored produced no match in timing to the birth spike. Since the monkeys that were eaten varied it is unlikely another factor beyond Curarea poisoning in a particular species of monkey flesh consumed is responsible.

Curarea tecunarum is the most likely cause of the fertility spike observed consistently in Kawymeno Waorani. At the moment there are no other alternative explanations for the fertility spike that we are aware of that may explain this

phenomena: the Waorani are not malnourished, take no other plants noted for fertility affecting properties, have no extra sexual intercourse at the necessary time, and there are no premature births in February that might cause a doubling up effect. Further, the dissertation study indicates other Waorani dietary items do not match the time cycle of the birth spike, although more careful investigation is needed.

Explaining why *Curarea tecunarum* had such different effects on the Waorani hormone system compared to the Deni

Just because large one-shot doses of the *Curarea tecunarum* hormone phytochemical produces a delay in fertility in the Deni Indians does not mean that regular doses with seasonal peaks and troughs as in the case of the Waorani do not cause cycling of fertility rather than temporary blocking of fertility. The Waorani have used regular doses of *Curarea tecunarum* blowgun poison over decades or centuries, time to adapt to its hormone affecting properties that now may regulate fertility of the Kawymeno Waorani. Further, with the Deni, *Curarea tecunarum* intake appeared to affect male fertility not female, which involves different physiological mechanisms than if *Curarea tecunarum* was a female hormone altering phytochemical. Female hormones involve cycling fertility but male hormone driven fertility tends to stay consistent with a similar dose of hormones produced daily by the human body but fertility may vary with a large increase in a substance that affects hormone functioning. Beyond a large increase in a male hormone increasing function, as is the case with the human body's reaction to most synthetic and natural pharmaceuticals when these physiological

activating chemicals exceed their therapeutic window, such a one time massive overdose as the Deni Indians consumed over a gallon at one time (Prance 1972), this may cause a shut down of hormone functioning. Dose matters greatly in the physiological effect of any phytochemical as has been argued throughout this dissertation. There is a double-edge sword effect in all phytochemical consumption which is dose related from therapeutic into the range of poisonous has been discussed in many chapters especially in relation to the Western dietary consumption of monotonous, excessive intake of a narrow range of phytochemical types. This is not necessarily a contradiction and as with all hormone affecting substances, dosage and regularity matter. Hormone cycles can be completely interrupted in large doses and merely regulated with smaller dosages. Dosage and frequency of intake may make a large difference in the way the phytochemicals in *Curarea tecunarum* affects the male human hormone cycle. Moderate consumption may increase fertility while massive doses may overwhelm and shut down male hormone functioning.

Closing remarks regarding plant-human co-evolution of the hormone system

It is well established that plant phytochemicals do affect human fertility, and are frequently used for fertility purposes by many indigenous groups (Elizabetski, 1994; Kvist, 1987). It is well within reason to suspect that *Curarea tecunarum* is a plant that may have a major affect on human and perhaps other animal fertility hormones. This warrants further investigation to see if there are practical beneficial health applications for all humans regarding the dietary intake

of Curarea tecunarum. Further, Curarea tecunarum appears be an effective antimicrobial (Davis & Yost, 1983), which heightens the mystery and increases possible health uses for this unusual plant and its defense phytochemicals.

There is no doubt that plants phytochemicals do effect fertility cycling, as the effects are well known worldwide, and phytochemicals are used for fertility regulation by many cultures (Elizabetski, 1994; Kvist, 1987). Why plants produce these hormone effecting phytochemicals is not clear but natural selection is not random and animal physiology appears to be directly targeted. While these fertility controlling phytochemicals may be produced for another plant survival purpose, in fact many phytochemicals target animal physiology with a clear purpose, such as pushing one animal into attacking another animal threatening the plant or even to encourage mammals to fertilize plants (not just insects) (Johnson, 2012; Pare and Tumlinson, 1999, Alborn 1997). The Waorani do not consume *Curarea tecunarum* intentionally for any fertility purpose, so are not the controlling party and it cannot be considered a medicinal plant since the effect is unintentional. Yet *Curarea tecunarum* plants may have had long-term control over the Kawymeno Waorani fertility cycle that may be originally been more broadly targeted toward other animal fertility cycles not humans. In the intimate interweaving of phytochemicals in the rain forest ecosystem phytochemicals of *Curarea tecunarum* are unlikely to be created by chance and may have been targeted to affect some animal hormonal system, perhaps for centuries or even millennia and the effect on humans may merely be an unintended side effect from the point of view of the plant producing the phytochemical.

This dissertation suggests plants are capable of manipulating animals biochemically for their own benefit, and through plant-animal biochemical co-evolution and have developed the phytochemical means to modify fertility in humans and other animals. Study of hunter-gatherer food systems provides a window on how plant-human co-evolution functioned for 99% of human history and is a way to better understand the ways plants control animals' physiology for their own survival needs. The physiological interaction between human reproductive hormone cycles and dietary plant phytochemical intake also warrants further investigation. For those researchers not familiar with plant phytochemicals and that field of research, acknowledging plants may have some "agency" may be an unfamiliar thought but a look at the entire field of plant biochemistry and its scholarly research provides convincing evidence that this is the case (Alborn et al, 1997; Johnson, 2012; Pare and Tumlinson, 1999; Wink 1988; Wink 2003; Wink 2009).

What happens when plant phytochemicals, such as hunting poisons that influenced fertility and perhaps other physiological processes in hunter-gatherers, potentially dating back to the Paleolithic era, are removed from the diet with the advent of agricultural systems? Hunting and fishing poisons are particularly potent phytochemicals taken in large doses compared to dietary phytochemicals from fruit. There is clearly a difference in fertility across food systems and one of the largest differences across food systems is phytochemical intake (Bentley, 1993). Fertility cycles may have been in harmony with the fluctuations of hormone-controlling substances in environment and ecosystem in hunter-gatherer

food systems, although not necessarily always a beneficial harmony for the human party. Removal of wild plants and natural plant fertility control from a human diet that has always had these phytochemicals throughout evolutionary history may leave the human fertility cycle to harmonize with whatever agriculturally produced plant hormones or even synthetic hormones modern life has put into the food and surrounding modern environment that may fill receptors in the human body designed for fertility controlling hormones from plants.

Looking at the case from a plant rather than human perspective, an important question to ask is what benefit might plants have in controlling animal fertility? Do humans have physiological receptors that were developed through human evolution for natural plant fertility controlling hormones and, if so, why? Powerful hunting poisons may not be the only hormone-altering chemicals in the human diet; subtler plant-human hormone dynamics may also take place with many other phytochemicals found in foods. Further, the larger question is how many other human hormonal cycles, beyond just fertility cycles, are or were influenced by plant phytochemicals. Finally, when the millennia-long presence of hormone-regulating natural plant substances is removed from the human diet, is there a chronic disease impact?

CHAPTER 24

CONCLUSIONS AND RECOMMENDATIONS FOR NUTRITIONISTS, AGRICULTURAL SCIENTISTS, POLICY MAKERS AND INDIVIDUALS INTERESTED IN IMPROVING THEIR HEALTH

If Hunter-Gatherers Have Better Health than Westerners Why Do They Not Live as Long as Westernized Populations?

There has been a general longstanding assumption that hunter-gatherers are not as "healthy" as humans in modern societies such as the United States (Coon 1948, Silberbaur 1965). The main basis for this assumption is that Westerners may live longer than hunter-gatherers. While Waorani hunter-gatherers prior to contact with outsiders may or may not have lived shorter lives, they rarely died of infectious or chronic disease, as studies (discussed earlier in the dissertation) going back several generations demonstrate (Yost 1981). This study argues that life longevity by itself is not a good stand-alone indicator of group health. Western longevity is not evidence of good health. Persons that are on life-support machines, are heavily medicated and receiving other medical treatments may live a long time, but are not healthy. Advances in the Western medical system have unnaturally prolonged modern lives, not created healthier human beings. Modern medicine is a form of artificial life support for an entire modern society, but that doesn't mean a long Western lifespan is an indicator of good health and freedom from disease. Before the existence of artificial life supports that biomedicine and public health use to hold together a generally sick

modern population - there was a natural form of life support – the medicinal and pharmaceutical aspects of diet.

Chronic and infectious diseases are not the primary causes of death of the Waorani hunter-gatherers of this study, and the case can be made that chronic and infectious diseases are not the primary causes of death of humanity's ancestral hunter-gatherer cultures throughout human evolutionary history. Rather chronic and infectious diseases are only the primary cause of death in agricultural communities, who have a very different lifestyle than hunter-gatherers. Hunter-gatherers die, but not from disease. Hunter-gatherers die mostly from non-disease factors such as trauma, accidents and violence. What is relevant to the health of modern populations is whether the enviable low rate of disease of our hunter-gatherer ancestors can be emulated in modern societies.

A Phytochemical Explanation for Diseases of Western Civilization

It is not principally exercise or genetics or even just nutritional intake that keeps the Kawymeno Waorani and hunter-gatherers of the past free from disease. The study control group of Kichwa subsistence farmers, as well as the change in health of the Westernizing Waorani, demonstrates that there is another factor involved. Rather the roots of human disease come from our interaction with other living organisms, as does the means to prevent disease. Further it is the interaction with plants and the food chain from the surrounding ecosystem over the millennia that results in a dietary phytochemical intake that provides low-grade, long-term preventive care against disease from surrounding living organisms that cause disease and threaten human health.

Our hunter-gatherer ancestors had few diseases because they were biochemically in sync and linked with the plant kingdom and environment where they lived via a dietary phytochemical pipeline to the natural ecosystem. Humanity owes its existence to the plant kingdom: plants produce chemicals to sustain humans, from nutrients to the oxygen in the air humans breathe to the phytochemicals humans eat that prevent death by disease.

Seasonal rotating sources of anti-microbial phytochemicals from a broad variety of wild phytochemical-rich plants have attractive aromatic smell that encourages human contact and consumption (Wink 2010). Antimicrobial phytochemicals themselves or phytochemicals associated with antimicrobials have distinct flavors and smells that animals may have developed the ability to sense and thus ingest these antimicrobial compounds for their own use. This loss of the ability to sense the microbial content of food may effect the balance anti-microbial dietary intake may be an underlying cause of disease in agricultural societies.

Accepting the paradoxical nature of food is the first step to understanding the intimate biochemical link between plants and humans. The plant–human relationship is so intertwined through millions of years of plant and animal kingdom co-evolution that every part of our human physiology is linked into plant biochemistry. The vast quantity of dietary phytochemicals that affect physiology need to be looked at holistically, not piecemeal as is the nutrition field's tendency. A holistic food system approach is essential for practical reasons of overwhelming variety of phytochemicals versus the relatively limited amount of

nutrients humans need. Thus, either the study of phytochemicals and human health needs to split into a new discipline separate from nutrition studies or nutritionists need to see the forest not just the trees, the whole ecosystem and not just the food plants and specific chemicals in these plants. An overarching theoretical base regarding phytochemicals needs to be built from the bottom up to dispense advice to those humans in need and not base advice on fragmented studies of single biochemical compounds. Nutritionist or to coin a new phrase "phytochemists" need to base their advice on biology starting with the theory of evolution. Nutritionists need to work together with agricultural scientists and not be confined to their individual disciplinary walls, as this does not suit the general public's health interests.

If we rely on agriculture to sustain us, it is the belief of this author that chronic disease levels will rise beyond human pharmaceutical or medical efforts to sustain human health on this planet in the long-run. We must listen to our ancestors as they have much to teach us, before it is too late and the last hunter-gatherer dietary guide vanishes from the earth. Remember in human evolutionary terms modern food systems and agriculture have been in existence for less than 1% of human history.

This dissertation proposes a phytochemical explanation for a wide range of health issues because the case is being made that phytochemicals have driven major parts of human physiology throughout all of human existence, and just like nutritional intake, phytochemical intake affects almost every part of human functioning. Interventional and clinical studies indicate that fruit phytochemical

consumption reduces cancer (Bub et al 2003), improves immune functioning (Bub et al 2003), improves age-related disease affecting neurological functioning (Youdim 2000, Joseph 1998, Bickford 2000), improves urinary tract health (Kiel et al 2003, Kontiokari et al 2001, Strothers et al 2002), lowers blood pressure, (Erlund 2008, Grassi et al 2005, Peng et al 2005, Ruel 2008, Taubert et al 2003), prevents and even reverses age-related eye diseases such as glaucoma, cataracts and age-related macular degeneration (Beaty 2000, Beit-Yannai 2007, Fernandez and Ashari 2008, Head 2001, Ko et al 2005, Ohira et al 2008).

Human agricultural forays in planning dietary intake are perilous without some guidance from tried and true food systems. Hunter-gathering is the only food system with a documented track record of millennia and there are lessons that agricultural scientists can learn from hunter-gatherers. Passing some of those lessons on, or at least opening debate on food system issues, is the purpose of this dissertation.

If the theories in this dissertation have validity the ideas put forward in this dissertation have major implications for the treatment of disease that merits priority at a policymaking level. If phytochemicals do play a significant role in disease protection this is also a hopeful sign for those that suffer from the diseases of modern civilization, as these diseases might be preventable through modification of the food system and what we eat.

Establishing Guidelines to Phytochemical Intake

Phytochemicals may well need to be balanced in the human body, as do all biochemical substances including nutrients. In other words, it is not the total

amount of a phytochemicals that matters, but rather how those phytochemicals are balanced and offset by other phytochemicals. Establishing phytochemical guidelines may help achieve a better balance of phytochemical intake and improve the preventative aspects that dietary phytochemical intake may have on disease.

While modern humans cannot return to hunter-gathering, understanding human dietary norms throughout evolution might begin the process of establishing guidelines to modern phytochemical intake. Differences in phytochemical intake between the Kawymeno Waorani and Santa Teresita Kichwa provide an explanation for the better health outcomes of the Kawymeno Waorani, which standard nutritional factors do not explain**.** The Kawymeno Waorani hunter-gathering food system is far from the USDA nutritional standards. Compared to the USDA standards, the Kawymeno Waorani diet has three complete food groups missing (no vegetables, grain or dairy), excessive red meat intake and fruit intake so high that human pH levels become acidic. Indeed the dissertation study urine tests indicate that the Kawymeno Waorani have an acidic average pH level of 5.3 (n=15) while the Santa Teresita Kichwa average pH level is 6.5 (n=63) which is more alkaline and "healthy". Yet Kawymeno Waorani health outcomes are favorable in comparison with the Santa Teresita Kichwa and modern farming food systems. The Santa Teresita Kichwa food system is close to USDA standards and also in line with other widely accepted health standards (organic agriculture, high vegetable, high fruit, adequate meat and dairy, with low oil, sugar, salt). Yet the Santa Teresita Kichwa subsistence

farming population has poor health outcomes compared to the Waorani hunter-gatherers.

The plant phytochemical content of the Kawymeno Waorani hunter-gatherer diet is much greater, more varied and seasonally staggered to avoid overdosing on a particular phytochemical. In contrast, the Santa Teresita Kichwa (and modern Western populations) have low variety, and monotonous, year-round dietary intake of the same phytochemicals partly due to a dependence on grains (i.e., as wheat) and/or vegetables (i.e., manioc) as a staple foods. This dissertation makes the case that the large difference in phytochemical content of diets between hunter-gatherer and subsistence agricultural food systems accounts for a major difference in the health outcomes across the board observed in the Kawymeno Waorani and Santa Teresita Kichwa. The Santa Teresita Kichwa were less healthy across almost every single category. There is every reason to suspect that a population-wide phytochemical imbalance that is a characteristic of subsistence agriculture such as the Santa Teresita Kichwa and magnified by large-scale agriculture and food production is one cause of the diseases of Western civilization.



Figure 60. Kawymeno Waorani Meals are Typically Whole Foods Not Mixed in Any Recipe or Proceeded by Any Form of Processing

Humans have a plant-driven physiology, but we have separated ourselves from these plants and the local environment that produces them. Even in the case of arctic hunter-gatherer populations with few local plants, phytochemicals come through the food chain via animal foods as this dissertation has demonstrated. Modern agriculture has added artificial substances to foods and created synthetic pharmaceuticals that may parallel natural plant compound chemical structures and utilize biochemical receptors evolutionarily designed for biochemical communication with plants and plant dietary intake. Stimulation and signaling by these food and drug additives in biochemical receptors, which were originally designed for natural phytochemicals present in the human diet throughout evolutionary history, can alter human physiological functioning. These programing miscues caused by inappropriate stimulation of phytochemical

receptors in the human body may precipitate chronic diseases caused by a malfunctioning physiology, such as the obesity example below.

The link between phytochemicals and obesity. This dissertation makes the case that losing the triggers and ability to satiate appropriately may be an underlying cause of obesity. A loss of phytochemicals originally in dietary wild plant foods has possibly not only dulled our sensing ability but also maladaptively redirected the physiological receptors and drivers that processed phytochemicals into stimulating behaviors that promote obesity. Artificial flavors and other classes of chemicals in modern foods may occupy the human body receptors that are intended to process signals from the plant that created the taste of the food and the food itself, to motivate humans and other animals to eat the food the plant provides. Insatiability for a particular flavor may be caused when modern chemicals occupy the biochemical receptors in the human body designed for satiation of phytochemicals.

The food industry has the ability to manipulate human sensors and senses that originally served a survival purpose to be maladaptive and now drive the person to eat more than they should of a food product. The flavor-changing chemicals put into food by the agro-food industry may indirectly cause obesity by altering a sense of satiation "Diet foods" while being low in calories may still stimulate the person to overeat by blocking receptors for satiation designed for phytochemicals and actual drive increased eating as discussed below. Artificial flavorings and many other food chemicals and even human-made pharmaceuticals that are similar to the original natural plant pharmaceuticals may be an underlying

cause for excessive ingestion of inappropriate foods by a large percentage of the Western population. As explained in previous chapters taste and flavor originally came from phytochemical content of the food and may have been designed as an evolutionary satiation signal, after a certain level had been reached satiation is triggered before an excess of particular food component was consumed. If you were highly sensitized to a phytochemical's taste and smell as the Waorani hunter-gatherers are, the food becomes unpalatable after a while so they stop eating it.

Advice to public health officials: measures to reduce phytochemically-related obesity. I suspect that partially due to scientists' own lack of ability to communicate through their senses with the plant world, they have made surprisingly little progress in understanding the mechanisms of plant-human communication that was probably a human norm and an essential part of plant-human co-evolution and human dietary intake and regulation.

Many medications may be even more likely obesity provoking suspects as human designed pharmaceuticals intentionally target receptors designed for phytochemicals as otherwise these medications would have little effect on the human body.

Several public and private measures can be undertaken to reduce obesity, assuming phytochemicals play a role in the recent rise in obesity in Western societies. Rather than blaming modern Americans and suggesting using willpower to control their dietary intake and fight against their own physiology, both the food and pharmaceutical industries can make an effort to eliminate substances

that encourage overeating, particularly those that mimic natural phytochemicals. Obesity is a complicated problem with many factors, but eliminating artificial substances that mimic phytochemicals and affect satiation might be a relatively easy step for the individual consumer that would not require willpower to maintain a diet or excessive time by busy consumers. The food industry might be encouraged by consumer spending or government regulation to offer healthier options. Additional research would be required to investigate this possibility. Medications and artificial contents of food may stimulate insatiability. The government could institute monitoring of the artificial smells and flavors the agro-food industry puts into foods and conduct research into whether and which of these agro-food flavor enhancers cause obesity. The FDA could more carefully monitor the obesity producing effects of medications. While not specifically designed to do so, many additives beyond those labeled flavor "enhancers" change flavor. In addition, even natural flavor-altering compounds such as traditional spice use that started with agricultural practices may be just as harmful as the artificial variety. So monitoring and research needs to extend beyond chemicals specifically labeled as effecting flavor and smell to any artificial substance that interferes with a physiological signaling system originally designed to facilitate communicate between plants and humans, not facilitate agro-food industry signals to humans.

With a lack of dietary intake of wild plant phytochemicals to guide physiological processes, the body may focus on artificial flavors and other synthetic ingredients put in food. Food taste may trigger excess consumption

because the body is tricked into thinking it is consuming what it needs and being misguided due to a lack of direction formally provided by plants developed through plant-human evolution. While phytochemical satiation is directly linked to plant food species that originally produced the scents (not animal foods or modern foods with fats and carbohydrates) the example of the garlicky peccary shows that these flavors can be readily transferred to other non-plant foods including fatty foods favored by the agro-food industry.

A losing battle for many people of sheer willpower against eating may be less an issue of character and simply more an issue of how strongly altered or affected are the plant phytochemical receptors for satiation and hunger in their bodies. For those worried about obesity to avoid a battle of willpower by simply trying to reduce calories, those interested in losing weight might simply bypass the agro-food industry flavor altering chemicals instead of worrying obsessively about fat and carbohydrate intake. Perhaps by avoiding artificial chemicals that offset the body's natural receptor driven response to phytochemical scents for hunger and satiation is a more practical solution that fighting your own physiology and to get to one root of the obesity problem. Alternatively, the agro-food industry can collaborate and introduce naturally phytochemically rich foods and suggestions at the end of the chapter give some guidelines as to how to do this.

Beyond avoidance of certain agro-food industry foods, through appropriate use of natural phytochemical intake therapy, modern humans may be able to re-sensitize their satiation system and begin moving towards the level of

taste and smell discrimination hunter-gatherers like the Kawymeno Waorani still have.

A warning, the word "natural" does not equal healthy. That is if "natural" means agricultural innovations such as spices that blanket the original taste of foods. Suggestions for increasing the variation of phytochemicals in the diet are provided later in the chapter.

Natural phytochemical therapy to reduce obesity suggested by this dissertation results would include reduction or elimination of salt, natural spices, avoiding complicated recipes and mixing of food and other measures traditionally considered not relevant to obesity by nutritionists.

Satiation problems due to lack of wild varied phytochemical intake: loss of the ability to detect toxicity of modern food. The loss of the ability to sense toxins from plant and artificial food in the modern diet may also be hazard. As discussed in the Plant-Human Co-Evolution Chapter, there are many reasons to suspect an agricultural diet may have more concentrated, monotonous and – ultimately in the long-term – more toxic phytochemical content than a hunter-gather diet. A loss of ability to sense the phytochemical toxin content of food in a modern diet, and perhaps even comparable artificial toxins may lead to excessive intake of these substances. Thus, to compound the actual increase in phytochemical toxicity in the modern diet, there may also be a decrease in the ability to physiologically sense this toxic increase and satiate when the dietary phytochemical toxin levels become too high.

Unlike the Kawymeno Waorani, people in agricultural systems may not be able to sense when our diet is toxic. Thus, modern agriculture has created a food system that blinds humans to the tastes and smells meant to prevent over-consumption of phytochemical toxins in food, at the same time increasing the toxicity of the modern diet. It is a double blow to human health.

In sum in the modern diet taste and smell may no longer serve a useful function in the human body, as they have throughout human evolution, due to phytochemical deficiencies and their replacement by artificial chemicals that fit into phytochemical receptors. The human body could innately sense how to balance its own diet for millennia before the advent of the nutritional profession. Exhorting individuals to use willpower against their own physiological directives is failing and nutritionists are letting the general public down by counting calories and nutrients instead of looking for the underlying reasons we have an obesity epidemic in Western society. It is time for nutritionists to think outside of the box and start to consider the other ingredients in foods, namely phytochemicals, beyond the standard nutrients.

The USDA and Phytochemicals

An important guideline to be learned from hunter-gatherer diets is to avoid over simplistic nutritional thinking. It is important not to assume there is a dichotomy – that a food is either healthy or bad for you. This dissertation makes the case that all foods are double-edged swords, while being nutritious at the same time be capable of causing disease. This is due to the pharmaceutical aspects of food, which are almost always ignored since agricultural produced foods are not

poisonous in the first bite. When an authority figure dispensing health or nutrition education says “this is a healthy food”, it is important to think critically and conduct research to understand the pros and cons of each food and food group and take factors beyond what the “experts” say are the relevant nutritional requirements that can be met with X increase of said vitamin. Experts’ know-how only reaches as far as their discipline goes. The real world is not encased in convenient disciplinary lines such as those by which the nutrition field defines itself. Agriculture and the agro food industry organizes of and bringing into existence of entire food groups that were not present for 99% of human dietary history. The human body is unlikely to adapt evolutionarily because even if modern dietary intake causes serious disease modern medicine allows humans to live long enough to reproduce. The suggestion in the Food Pyramid that eating enough of each supposedly natural grouping of foods not previously eaten by humans in any quantity will lead to good health does not make common sense. In fact, these USDA food groups look suspiciously like agro-food industries rather than meaningful demarcations of appropriate nutritional diversity. Critical thinking is in order to evaluate the recommendations of an authority figure or institution defining novel grouping of foods as healthy food groups.

A look at the modern food system though examining grain and vegetable intake is illustrative. The USDA recommendations for consumption of grains and non-fruiting vegetables (and their constituent phytochemicals) are excessive by hunter-gather standards, since hunter-gatherers ate virtually none.

While nutrient-rich, nevertheless non-fruiting vegetables are not an evolutionary normal part of the human diet despite what vegetarians groups might suggest but rather a product of agriculture and in many cases have been altered by modern biotechnology. Kawymeno Waorani eat none of the following: leafy greens such as lettuce, kale, cabbage and spinach; non-starchy roots such as carrots, onion and garlic; stems such as celery, broccoli, rhubarb and cauliflower. All these non-fruiting vegetables that are considered almost essential for human health by nutritionists were completely missing from the human diet until very recently. Phytochemical intake from grain-fed meat, poultry and fish is also far from the human norm. As argued in this chapter, animal food will also pass processed phytochemical compounds of grains through the food chain to humans, making animal based agricultural foods (phytochemically-speaking) part of the grain category of foods. Dairy foods were also completely absent from a hunter-gatherer diet and grain-fed dairy animals are yet another conduit of phytochemicals from grains. Non-fruiting vegetables and their potential anti-herbivore and even anti-human phytochemical content are yet another example of a food group that was virtually absent in hunter-gatherer diets with the exception of a few tubers.

In regards to every single category of the USDA recommended dietary intake, the Kawymeno Waorani either eat either virtually none of the category (grains, vegetables, oils) or the reverse, an excessive amount of the food category (meats and fruits). If the Kawymeno Waorani hunter-gatherer diet phytochemical intake is even close to the prehistoric norm for humanity throughout the

millennia, then something needs to be rethought about the USDA dietary recommendations principally because the USDA recommendations completely ignore phytochemical intake when suggesting how the American population should eat.

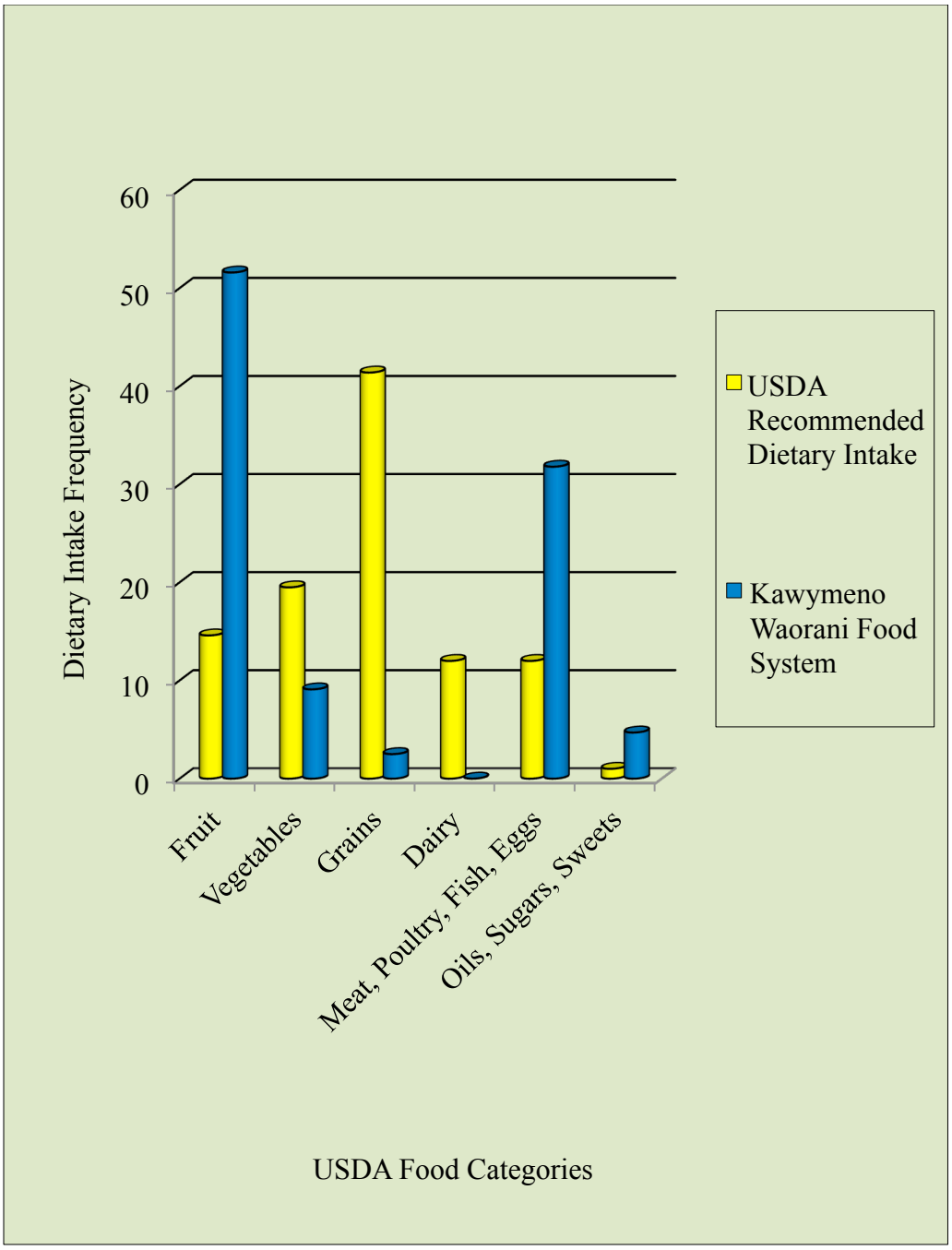


Figure 61. Comparison of USDA Recommended Dietary Intake and Kawymeno Waorani Food System (percent of total per capita dietary intake per USDA food category).

Dietary Phytochemically-Related Diseases That May Be Preventable

What may be an ideal dietary intake nutritionally may be considered toxic when using phytochemical standards. USDA dietary recommendations could be

unintentionally worsening the health of the American population by potentially recommending a phytochemically toxic diet and at the same time ignoring the beneficial and disease-preventing qualities of phytochemicals.

Agricultural scientists need to be willing to think outside their agricultural mindset for a more critical look at agriculture itself. Even the name "Department of Agriculture" indicates a prejudice against looking at other food systems, beyond agriculture, for innovation. The USDA needs comparative studies of food systems that do not have grains, vegetables, and dairy and do have excessive red meat combined with other foods to see if their food pyramid standards are actually part of a diet for which humanity has physiologically evolved. While we cannot return to hunter-gathering we can increase the variety and quantity of phytochemicals in the modern diet and a start might mean considering phytochemicals when forming food groups and other tools for dietary recommendations that serve as advice to the general public, tools that may over-simplify what is a complicated reality. This dissertation study serves as one type of study model for comparative food system research, but further studies would require much more manpower, funding and expertise.

Mixing: Foods, Nutritionists and Phytochemicals

Another oversimplification typical of the nutritional field is that foods are viewed as separate entities whose total nutritional and phytochemical content can simply be added up to equal a total nutritional intake of any given substance. In a real food, nutrients and phytochemicals are not separate shielded biochemical entities - they interact with each other. In fact it is well known that

phytochemicals interact biochemically with nutrients. Thus, nutritional content is partially a reflection of phytochemical content. Phytochemical content alters nutritional content. Nutritionists should not ignore the interaction between phytochemicals and nutrients. Thus, trying to pick apart the ingredients of foods and present these bits of chemicals (such as any given vitamin) on a cereal box, as what the human body really ends up with when the food is digested is misleading. Foods need to be viewed as a whole, which is more than the sum of their parts, and an important part of a whole food entity is their phytochemical content.

Food contents, even nutrients, are pharmaceuticals that interact with each other and with human physiology, changing chemical form considerably. All foods have pharmaceutical properties and are altered by the chemical properties of the foods they are mixed with in a recipe. Modern humans eat recipes not foods. Mixing foods together changes nutritional and phytochemical content.

Hunter-gatherers like the Kawymeno Waorani do not mix their foods and throughout most of hominoid history, meals were plain, one-food ingredient affairs that the human body was chemically adapted to handling. Individuals planning their diet should think through how they mix foods in recipes, and what foods are eaten together in a meal. The mixture of foods in a recipe matters, perhaps as much as the individual foods themselves, in terms of physiological impact on the human body.

The cooking of food is a source of phytochemical alteration and toxicity producing an estimated 2,000 mg of untested burnt material daily per person in

the United States (Ames and Profet, 1992). For instance, roasted coffee alone is known to contain 826 volatile chemicals (Maarse, 1989).

Dietary Suggestions to Prevent Phytochemically-Based Disease in Western Populations

Planning a diet based on change rather than consistency over the year to maximize biochemical variety may be key to preventing both chronic and infectious diseases, both by avoiding over-toxicity and maximizing beneficial phytochemicals such as antioxidants, antimicrobial and anti-parasitic plant defense chemicals. American staple foods, such as wheat, may be the most important foods to rotate to avoid phytochemicals overwhelming the human metabolic system. In excess, natural phytochemical poisons are just as carcinogenic, mutagenic, teratogenic and clastrogenic, as their human-made synthetic counterparts (Ames, et al. 1990). Ames estimates that Americans eat 1,500 mg of natural phytochemical natural defense pesticides daily – 10,000 times more than the American daily dietary intake of synthetic pesticide residues (Ames and Profet, 1992).

Trying a different world cuisine every month with real food changes, not just changing sauces and flavoring, is an enjoyable method to maintain a diet based on change rather than consistency. In other words, not just re-arranging the ingredients in a recipe or introducing flavor-altering substances such as natural spices, but actually using some different underlying foods. In the case of animal foods where there may be fewer alternatives, using animal foods that themselves have been given a different diet would be a way to maintain a diet based on change not consistency.

Phytochemicals: a New Job for Nutritionists

Phytochemicals span a large biochemical variety of substances that may prove very challenging to put on the outside of a box of cereal. Nevertheless, guidelines for dietary intake of biochemical classes of phytochemicals and foods especially rich in them should be made to make sure all helpful phytochemical classes are included in modern dietary intake. For instance, guidelines need to begin to be considered for classes of phytochemicals such as antioxidants and plant foods that have a high content of antioxidants ingredients. Examples of biochemical families of plant defense chemicals are available in the chapter on plant–human co-evolution. Striving for balance and variety may be preferable to meeting any abstract minimum daily requirements, especially in the case of phytochemicals, which at their base are a large variety of biochemicals compared to recognized standard nutrients.

Just as important as maximizing the beneficial aspects of phytochemical intake is preventing over toxicity from monotonous dietary duplication of phytochemicals. Phytochemical toxin build-up may cause chronic disease, thus rotating foods may be key to preventing chronic disease. While eating the same food month after month, year after year may provide enough nutrients it may also over-toxify the body's phytochemical processing capacity. Rather than the daily requirements typical of nutritional advice, in the case of phytochemicals providing weekly or monthly limits may be in order to encourage rotation of foods with a high content of certain phytochemicals. The body may need recovery time from extended exposure to natural phytochemical pharmaceuticals/pesticides

that a day or two break would not provide. Thus, large chunks of time in which a food is withdrawn from the diet may be more helpful than rotating a food in and out rapidly every week or two. Organizations and even stores could set up a diet rotation plan, even a color coded one, a color on the package or store section for each "seasonal" rotation that would make it easier for consumers to follow a rotation of foods.

The above is the nutritional science challenge; below is the challenge of the agricultural science community: to develop more phytochemically rich foods that can then become nutritional recommendations.

The Pharmaceutical Industry: Competing for Plant Phytochemical Receptors in the Human Body

Although actual statistics may be hard to obtain, a look around at family and friends and the sales figures of pharmaceutical corporations confirms the fact that Americans use drugs as frequently as the Santa Teresita Kichwa study population use medicinal plants to control diseases that diet does not prevent. The pharmaceutical industry needs to be aware of the issues in creating pharmaceuticals with a similar chemical structure to natural dietary phytochemicals recently eliminated from the diet of humanity. Plugging synthetic pharmaceuticals into chemical receptors that were the domain of plants may cause inadvertent physiological reactions such as altering satiation and causing obesity, as suggested in the previous section. The fact that such a large percentage of the American population is on prescribed pharmaceuticals makes control of pharmaceutical products as important as control of the agro-food industry additives to foods.

Populations that are particularly vulnerable include unborn children receiving maternal synthetic pharmaceuticals that may mimic the natural pharmaceuticals. Some predetermined physiological programming, such as developing various metabolic and enzymatic capabilities to metabolize nutrients may be stimulated by dietary intake in utero as the fetus prepares its body to survive in the environment and food system into which it will be born (Gluckman, 2004, 2005). A mismatch between fetal expectation of its post-natal environment and food system and actual post-natal environment and food system may end up creating inappropriate physiological development (Gluckman, 2004, 2005). Evolutionarily in hunter-gatherer societies, fetus exposure to environmental phytochemicals via maternal diet may have helped the fetus physiologically program the creation or enhancement of receptors for dietary plant phytochemical intake later in life. Exposure to synthetic pharmaceuticals that mimic phytochemicals may enhance or create receptors for synthetic drugs rather than plant foods in utero in an infant. Instead of preparing the infant for dietary intake of plant foods the agro-food industry and pharmaceutical industry chemicals may stimulate inappropriate development of human receptors and physiology for non-foods and artificial chemicals driving the person physiologically to seeking and absorbing an inappropriate diet as they develop. Part of this dietary programming may be irreversible after birth.

The pharmaceutical and bio-medical industry also overwhelm the elderly with synthetic versions of phytochemical-like drugs in an attempt to compensate for chronic diseases that may have a dietary phytochemical and perhaps even

medication component from fetus onward to start with. Some of these chronic diseases of later life in the elderly may even have been caused by synthetic pharmaceutical intake in utero leading to inappropriate phytochemical receptor programming prior to birth.

Agricultural Solutions to Modify the Phytochemical Content of Foods

If appropriate food options do not exist in an agricultural population, individual dietary change options are limited for the population. The agricultural and food industry can start practices to understand how it can cost-effectively modify the phytochemical content of foods to include phytochemicals similar to those produced in wild plants. Study of hunter-gather food systems may provide invaluable clues to modifying present agricultural techniques to have a better balance of phytochemicals.

One agricultural solution would be for medical anthropologists and others investing time in hunter-gathering food systems to work with agricultural and botany specialists to develop model gardens that more closely approximate the way plants grow in non-agricultural settings by naturally stimulating antioxidant and anti-microbial variety of phytochemical output. Unlike wild plants, human agricultural crops do not undergo a process of natural selection. Most agricultural plants survive until harvesting through human protection rather than by their own phytochemical resources. Human “artificial selection” (or better said lack of selection) may reduce their phytochemical producing capacity.

Rather than coddling agricultural plants with protective pesticides and herbicides, an agricultural method that more closely mirrors real natural selection

for phytochemicals can produce plants with a more varied phytochemical content with similarities to wild plants. One idea would be to introduce organisms into these experimental gardens that represent a threat to food plants in order to stimulate phytochemical output of plant defense phytochemicals such as those found in wild plants. Microbes and parasites in particular might be good introductions for such model gardens to stimulate natural pharmaceutical production of anti-microbials and anti-parasite compounds.

Too much human contact with crops might be problematic by stimulating anti-herbivore compounds and even phytochemicals directed directly against humans as discussed previously in this dissertation.

Since even plant-to-plant communication (Alborn, et al., 1997) stimulates phytochemical defense, placement of wild plants that are particularly active signalers to crop species might be another good introduction in the model garden. Beyond active signalers, planting wild plants next to crops that stimulate competitive phytochemicals (as plants fight each other for territory and resources) but do not destroy crops may also be a good introduction to a model garden.

Location of model gardens in or near natural settings, particularly rain forests and other environments that are especially bio-diverse, instead of artificial open fields may be another way to stimulate production of phytochemicals. Model gardening in rain forests may provide income for indigenous inhabitants in an area where they, rather than the agricultural experts, have greater expertise. Model gardening in rain forests might also provide a financial motivation to preserve rain forests. The use of wild plants such as those the Kawymeno Waorani use may be

helpful introductions to a model garden to learn from and study their phytochemical interaction with agricultural crops.

The money that the agriculture industry could put into preservation of hunter-gather food systems, while understanding hunter-gatherer food systems and the way they stimulate phytochemical dietary and experimenting in the rain forest to develop phytochemically rich crops might help sustain aspects of the world's remaining hunter-gatherer cultures and food systems and even spark an interest in returning to some aspects of a hunter-gather lifestyle.

While I am leery of biotechnology, biotechnology could be useful in bringing a wider selection of wild plants under cultivation while selectively avoiding the elimination of phytochemical-producing components of plants. Humanity's crops species need to be more diverse to increase phytochemical variety. Bringing a wider variety of wild plant food species under major cultivation via biotechnology, particularly fruits or fruiting "vegetables" (rather than grains and non-fruiting vegetables) as major food resources may also be helpful in avoiding - over-toxification by chronic use of staple grain and vegetable species. Particularly in poorer nations and populations without the purchasing power to buy a diversity of foods, the norm is reliance on a few staple foods, which can lead not only to a nutritional deficiency, but a phytochemical imbalance and potential toxicity as well.

Wild phytochemical honey production: a model project. I would suggest that the agricultural industry utilize honey as a vehicle to create a food product with a concentrated healthy variety of wild plant pharmaceuticals. Large

populations of millions of humans cannot forage for wild foods in the rainforest. However, beehives can be placed near appropriate wild ecosystems and plants. Bee products, such as honey, acquire the pharmacological profile of the plants on which bees feed. The resins bees gather from plants for use in the construction of bee honeycombs and production of honey contains a broad spectrum of antimicrobial pharmaceutical protection, originating chemically from phytochemicals the bees bring to the hive, against bacteria, viruses and fungi. Thus, honey itself varies in pharmacological properties depending on the particular plant flowers used by the bees and these can be manipulated by the apiculture industry. The wild honey eaten by the Kawymeno Waorani has wild plant defense phytochemicals from the rainforest food chain that are quite different from the phytochemicals found in domesticated honey consumed by Westerners. Although not for the purpose of creating a concentrated dietary source of wild phytochemicals, apiculturists have long practiced exclusive honey production from select plants and these techniques can be refined for enriched wild rainforest plant defense pharmaceutical honey production. For instance, especially potent antimicrobial chemical properties are found in New Zealand and Australian honey from bees that feed on *Leptospermum Myrtaceae* (Lusby, 2002). By providing bees with access to an appropriate wild ecosystem, honey production is one way modern agriculture can create a custom-made phytochemically rich food that mimics a wild plant hunter-gather diet and comes from a natural ecosystem.

The most important lesson from plant-bee co-evolution is not just potential agricultural use of bee products, but as a reflection of human co-evolution with plants. If bees can convert plant defense pharmaceuticals into chemical defense of their own it is not so far-fetched to suggest humans have matched this insect feat and have long converted plant defense phytochemicals into compounds in the human body that protect against diseases.

Preservation of the World's Remaining Hunter-Gatherers and Their Food Systems

Chronic disease levels continue to soar to a level that an over-confident biomedical industry cannot contain. Modern nations are accumulating debt in part due to their population's chronic disease levels that surpasses the ability of biomedical systems to control. The U.S. government and international community would benefit by putting funding into hunter-gather research, as the return on the investment is so potentially large in terms of finding ready-made dietary solutions that have always existed, but are being marginalized and forgotten. Even skeptics of this type of applied hunter-gather public health food system research should remember there are few research projects with such enormous potential for improving global food systems and thus humanities survival at such a minimal cost. There is nothing to lose and only a small amount of groups such as the Kawymeno Waorani left that still practice hunter-gathering, almost all in the South American Amazon.

Preserving the remaining hunter-gathering food systems left in the world should be a major priority for those interested in preserving humanity's food system heritage, as well as eliminating guesswork for model gardens and other

projects to find the way to increase the phytochemical content of crops by having an actual living hunter-gathering food system to learn about human dietary norms. Hunter-gatherers, as they are forced into modern life, should be provided as generous a funding as possible to encourage and ensure survival of their food system and the culture that maintains the food system. This would help all of us to learn about humanity's dietary norms and provide a source of pride for indigenous culture in their own traditions. The power of admiration from outsiders for a food system that in many ways is superior to the modern food system, rather than contempt for indigenous culture, would be a valuable tool to help the indigenous take pride in their culture and food system instead of seeking to become modernized. Attention and respect shown towards indigenous traditions may also help maintain the cultural integrity of transitioning hunter-gather cultures by showing these indigenous peoples that the modern world values what they have to offer as a culture and a food system. Demonstrating that the modern world wants to learn from indigenous traditions encourages indigenous groups to preserve their culture. As was stated in the beginning of this chapter, religious missionaries and sometimes well-meaning development specialists have done the opposite, denigrating indigenous lifestyle as primitive and encouraging conversion to a modern food system and cultural dietary practices that worsen rather than improve health.

Studies such as this dissertation are making initial steps that require follow up to take appropriate action to preserve as much as is possible of the vital living human heritage of our hunter-gather food system and its phytochemical content.

In Kawymeno, one investigator or a small group of interested persons' efforts cannot match the billions of dollars international oil companies are using right now to subvert the culture and dietary heritage of the Kawymeno Waorani. Trillions of dollars of oil exist 25 minutes away from Kawymeno in one of the largest untapped oil deposits left in Latin America - a potential oil field called ITT (Ishpingo, Timbaku and Tiputini). Before the Kawymeno Waorani disappear, an effort needs to be made to raise funding to preserve the Kawymeno Waorani way of life and food system. I have made efforts to try to preserve the Kawymeno Waorani food system and culture by encouraging projects such as ecotourism that involve rather than marginalize the Waorani. Major funding is needed within a year or two to stop the Kawymeno Waorani hunter-gatherers – the last vestige of the Waorani hunter-gathering system – from going into extinction as a functioning culture.

If scientists and experts regard the indigenous as too primitive to contribute to their own preservation, this will contribute to the status quo of most international development projects today – forcing projects on indigenous groups planned by people in a far away Washington, D.C. office. On the other hand, academics, especially those working with indigenous groups, can go beyond merely academic study of ancestral diets or indigenous culture in general and become more active in encouraging the formation of global groups of indigenous leaders to meet regularly with scientists, development workers, environmentalists and other interested parties. These should not just be symbolic meetings – the indigenous peoples themselves need to work alongside scientists to help support

indigenous food systems projects that instill pride in indigenous groups and maintain their way of life. The creation of self-supporting businesses focused on indigenous culture would help avoid the type of economic dependence on the outside world that the Kawymeno Waorani are beginning to face without an alternative to fall back on.

Armchair theorizing that typifies the ancestral diet academic field needs to be replaced by action to preserve and learn from existing hunter-gatherers rather than lament their passing. Future work for academics includes capturing and documenting complete indigenous food systems, particularly those that still engage in hunter gathering, and encouraging preservation of indigenous traditions that hold these food systems together. A food system does not survive once certain cultural values disappear.

REFERENCES

Abate, N., & Chandalia, M. (2001). Ethnicity and type 2 diabetes: Focus on asian indians. *Journal of Diabetes and its Complications, 15*, 320-327.

Abbie, A. A. (1960). Physical changes in australian aborigines consequent upon european contact. *Oceania, 31*(2), 140.

Abelson, P. (1990). Medicine from plants. *Science, 247* (4942), 513-513.

Ackerknecht, E. E. H. (1947). Primitive surgery. *American Anthropologist, 49* (1), 25-45.

Akarele, O. (1990). Medicinal plants in traditional medicine. In H. Wagner, & N. R. Farnsworth (Eds.), *Economic and medicinal plant research* (4th ed., pp. 5-16). New York: Academic Press.

Alborn, H. H. T. (1997). An elicitor of plant volatiles from beet armyworm oral secretion. *Science (New York, N.Y.), 276*(5314), 945-949.

Alcorn, J. (1984). *Huastec mayan ethnobotany.*

Alcorn, J. (2000). Factors influencing botanical resource perception among the huastec: Suggestions for future ethnobotanical inquiry. In P. Minnis (Ed.), *Ethnobotany: A reader* (pp. 17-28). Norman, Oklahoma: University of Oklahoma Press.

Alderman MH, Cohen H, Madhavan S. (1998). Dietary sodium intake and mortality: The national health and nutrition examination survey (NHANES I). *The Lancet, 351*(9105), 781-785.

Ames, B. N. (2006). Low micronutrient intake may accelerate the degenerative diseases of aging through allocation of scarce micronutrients by triage. *Proceedings of the National Academy of Sciences, 103*(47), 17589-17594.

Ames, B.N., Profet, M., Gold, L.S. (1990). Dietary pesticides (99.99% all natural). *Proceedings of the National Academy of Sciences of the United States of America, 87*(19), 7777-7781.

Ames, B. N., & Gold, L. S. (1989). Pesticides, risk and applesauce. *Science, 244*(4906), 755-757.

Ames, B. N., Profet, M., & Gold, L. S. (1990). Nature's chemicals and synthetic chemicals: Comparative toxicology. *Proceedings of the National Academy of Sciences of the United States of America, 87*(19), 7782-7786.

Ames, B. N., Shigenaga, M. K., & Hagen, T. M. (1993). Oxidants, antioxidants, and the degenerative diseases of aging. *Proceedings of the National Academy of Sciences of the United States of America, 90*, 7915-7922.

Ames, B., & Profet, M. (2006). Nature's pesticides. *Natural Toxins, 1*(1), 2-3.

Amiguet, V. V. T. (2005). A consensus ethnobotany of the Q'eqchi' maya of southern belize. *Economic Botany, 59*(1), 29-42.

Andersson, J. O., Sjögren, A. M., Davis, L. A. M., Embley, T. M., & Roger, A. J. (2003). Phylogenetic analyses of diplomonad genes reveal frequent lateral gene transfers affecting eukaryotes. *Current Biology, 13*(2), 94-104.

Andres-Lacueva, C.; Shukitt-Hale, B.; Galli, R. L.; Jauregui, O.; Lamuela-Raventos, R. M.; Joseph, J. A. Anthocyanins in aged blueberry-fed rats are found centrally and may enhance memory. Nutr. Neurosci. 2005, 8, 111–120.

Angel, L. J. (1984). Health as a crucial factor in the changes from hunting to developed farming in the eastern mediterranean. In M. N. Cohn, & G. J. Armelagos (Eds.), *Paleopathology at the origins of agriculture* (pp. 51-73). New York: Academic Press.

Angle, J. (1980). The epidemiology of myopia. *Am.J.Epidem. 111*, 220-236.

Ankli, A., Sticher, O., & Heinrich, M. (1999). Medical ethnobotany of the yucatec maya: Healers' consensus as a quantitative criterion. *Economic Botany, 53*(2), 144-160.

Ankli, A., Sticher, O., & Heinrich, M. (1999). Yucatec maya medicinal plants versus non-medical plants: Indigenous characterization and selection. *Human Ecology, 27*, 557-580.

Armelagos, G. G. J. (2005). Genomics at the origins of agriculture, part one. *Evolutionary Anthropology, 14*(2), 68-77.

Armelagos, G. G. J., & Harper, K. N. (2005). Genomics at the origins of agriculture, part two. *Evolutionary Anthropology, 14*, 109-121.

Arnason, J. T., Guillet, G., & Durst, T. (2004). Phytochemical diversity of insect defenses in tropical and temperate plant families. In R. T. Carde, & J. G. Millar (Eds.), *Advances in insect chemical ecology* [Advances in Insect Chemical Ecology] (pp. 1-20). New York: Cambridge University Press. doi: 0521792754

Arvindakshan, M., Ghate, M., Ranjekar, P. K., Evans, D., & Mahadik, S. P. (2003). Supplementation with a combination of ω-3 fatty acids and antioxidants (vitamins E and C) improves the outcome of schizophrenia. *Schizophrenia Research, 62*(3), 195-204.

Asin, H. R. G., & Van Theil, P. H. (1963). On intestinal protozoa in the urban and bushland population in suriname. *Tropical and Geographical Medicine, 15*, 108-120.

Auricchio, S. (1985). Toxicity mechanisms of wheat and other cereals in celiac disease and related enteropathies. *Journal of Pediatric Gastroenterology and Nutrition, 4*(6), 923.

Baer, G. M. (1975). *The natural history of rabies*. New York: Academic Press.

Balick, M. J. (1994). Ethnobotany, drug development and biodiversity conservation- exploring the linkages. In M. J. Balick (Ed.), *Ethnobotany and the search for new drugs* (pp. 7-8). Chichester: John Wiley & Sons, Ltd.

Balick, M. J. (2007). Ethnobotany and the identification of therapeutic agents from the rainforest. In D. J. Chadwick, & J. Marsh (Eds.), *Ciba foundation symposium 154 - bioactive compounds from plants* () John Wiley & Sons, Ltd. doi: 10.1002/9780470514009.ch3

Balick, M. J., & Cox, P. A. (1997). *People, plants and culture: The science of ethnobotany*. New York: Scientific American Library.

Balick, M. J., Elisabetsky, E., & Laird, S. A. (Eds.). (1996). *Medicinal resources of the tropical forest: Biodiversity and its importance to human health*. New York: Columbia University Press.

Balick, M. J., & Mendelsohn, R. (1992). Assessing the economic value of traditional medicines from tropical rain forests. *Conservation Biology, 6*, 128-130.

Balick, M. J., Rivier, L., & Plowman, T. (1982). The effects of field preservation on alkaloid content of fresh coca leaves (erythroxylum spp.). *Journal of Ethnopharmacology, 6*, 287-291.

Barclay, L. (Life Extension 2008). Fighting depression and improving cognition with omega-3 fatty acids. *Life Extension, 13*(10), 64-71.

Barltrop, J., & Jeffreys, A. D. (1954). Curare and related topics. part 1. A preliminary examination of chondrodendron limaciifolium. *Journal of the Chemical Society,* 159-164.

Barnes, K. C., Armelagos, G. J., & Morreale, S. C. (1999). Darwinian medicine and the emergence of allergy. In W. R. Trevathan, E. O. Smith & J. McKenna (Eds.), *Evolutionary medicine and health: New perspectives* (pp. 209-244). Oxford: Oxford University Press.

Barnicot, N. A., Bennett, F. J., Woodburn, J. C., Pilkington, T. R., & Antonis, A. (1972). Blood pressure and serum cholesterol in the hadza of tanzania. *Human Biology, 44*(1), 87-116.

Baruzzi, R. G., Marcopito, L. F., Serra, L. C., Souza, F. A. A., & Stabile, C. (1977). The kren-akorore; a recently contacted indigenous tribe. *Health and Disease in Tribal Societies,* 179-211.

Basu, A. A. (2009). Pomegranate juice: A heart-healthy fruit juice. *Nutrition Reviews, 67*(1), 49-56.

Basu, A. A. (2010). Berries: Emerging impact on cardiovascular health. *Nutrition Reviews, 68*(3), 168-177.

Battino, M. M. (2009). Bioactive compounds in berries relevant to human health. *Nutrition Reviews, 67*, S145-S150.

Bauer, W. (1981). Curare-pfeilgiftberetung-huete. *Arch Volkerkunde, 35*, 15-30.

Baumann, M., Bell, J., Koechlin, F., & Pimbert, M. (Eds.). (1996). *The life industry: Biodiversity, people and profits*. London: Intermediate Technology Publications.

Bays, R. P. (1953). Facts and fallacies regarding the blood pressure of different regional and racial groups. *Circulation (New York, N.Y.), 8*(5), 655.

Beatty, S. (2000). The role of oxidative stress in the pathogenesis of age-related macular degeneration. *Survey of Ophthalmology, 45*(2), 115.

Beatty, S. (2000). The role of oxidative stress in the pathogenesis of age-related macular degeneration. *Survey of Ophthalmology, 45*(2), 115.

Beckerman, S., Erickson, P. I., Yost, J., Regalado, J., Jaramillo, L., Sparks, C., Long, K. (2009). Life histories, blood revenge, and reproductive success among the waorani of ecuador. *Proceedings of the National Academy of Sciences, 106*(20), 8134-8139.

Beier, R. C. (1990). Natural pesticides and bioactive components in foods. *Reviews of Environmental Contamination and Toxicology,* (113), 47-137.

Beit-Yannai, E. E. (2006). Decrease in reducing power of aqueous humor originating from glaucomatous rabbits. *Eye (London), 21*(5), 658.

Beit-Yannai, E. E. (2007). Does the aqueous humor have a role in mitogen-activated protein kinase (MAPK) intracellular signaling in glaucoma? *Medical Hypotheses, 68*(2), 299-302.

Belanger, J., & Johns, T. (2008). Biological diversity, dietary diversity, and eye health in developing country populations: Establishing the evidence-base. *EcoHealth, 5*, 244-256.

Belderok, B., Mesdag, H., & Donner, D. A. (2000). *Bread-making quality of wheat: A century of breeding in europe (parts 1 & 2)*. New York: Springer-Verlag.

Bennett, A. E. (1968). The history of the introduction of curare into medicine. *Anesthesia and Analgesia, 47*(5), 484.

Bennett, F. (1970). Helminth and protozoal parasites of the hadza of tanzania. *Transactions of the Royal Society of Tropical Medicine and Hygiene, 64*(6), 857-880.

Bentley, G. (1993). Seasonal effects on salivary testosterone levels among iese males of the ituri forest, zaire. *American Journal of Human Biology, 5*(6), 711-717.

Bentley, G., Jasienska, G., & Goldberg, T. (1993). Is the fertility of agriculturalists higher than that of nonagriculturalists? *Current Anthropology, 34*(5), 778-785.

Bentley, G. R., Goldberg, T., & Jasienska, G. (1993). The fertility of agricultural and non-agricultural traditional societies. *Population Studies, 47*(2), 269-281.

Benyshek, D. C. (2005). Type 2 diabetes and fetal origins: The promise of prevention programs focusing on prenatal health in high prevalence native american communities. *Human Organization, 64*(2), 192-200.

Benz, B. B. F. (2001). Archaeological evidence of teosinte domestication from guila naquitz, oaxaca. *PNAS : Proceedings of the National Academy of Sciences, 98*(4), 2104-2106.

Benzie, I. F. F. (2003). Evolution of dietary antioxidants. *Comparative Biochemistry and Physiology, A*(136), 113-136.

Berendes, J. (1902). *Die arzneimittellehre des dioskurides*. Stuttgart, Germany: Enke 2.

Bergstrom, C. T., & Feldgarden, M. (2007). The ecology and evolution of antibiotic-resistant bacteria. In S. C. Stearns, & J. C. Koella (Eds.), *Evolution in health and disease* (pp. 125-137). Oxford: Oxford University Press.

Bergstrom, C. C. T. (2006). How do adaptive immune systems control pathogens while avoiding autoimmunity? *Trends in Ecology & Evolution (Amsterdam), 21*(1), 22-28.

Bergthorsson, U., Adams, K. L., Thomason, B., & Palmer, J. D. (2003). Widespread horizontal transfer of mitochondrial genes in flowering plants. *Nature, 424*, 197.

Bergthorsson, U., Richardson, A., Young, G., Goertzen, L., & Palmer, J. D. (2004). Massive horizontal transfer of mitochondrial genes from diverse land plant donors to the basal angiosperm amborella. *PNAS : Proceedings of the National Academy of Sciences, 101*(51), 17747-17752.

Berlin, B. (1992). Ethnobiological classification: Principles of categorization of plants and animals in traditional societies. In B. Berlin (Ed.), *Ethnobiological classification* (pp. 293-295) Princeton University Press.

Berlin, B., Breedlove, D. E., & Raven, P. H. (1974). *Principles of tzeltal plant classification: An introduction to the botanical ethnography of a mayan-speaking people of highland chiapas.* . New York: Academic Press.

Berlin, E. A., & Berlin, B. (2005). Some field methods in medical ethnobiology. *Field Methods, 17*(3), 235-268.

Bernard, H. R. (1994). *Research methods in anthropology: Qualitative and quantitative approaches* (2nd ed.). Walnut Creek: Alta Mira.

Betz, V. M. (1999). Early plant domestication in mesoamerica. *Athena Review, 2*(2), 24-31.

Bickford, P. C. (2000). Antioxidant-rich diets improve cerebellar physiology and motor learning. *Brain Research, 866*(1-2), 211.

Billing, J. (1998). Antimicrobial functions of spices: Why some like it hot. *The Quarterly Review of Biology,* 3.

Bisset, N. G. (1989). Arrow and dart poisons. *Journal of Ethnopharmacology, 25*, 1-41.

Bisset, N. G. (1991). One man's poison, another man's medicine? *Journal of Ethnopharmacology, 32*, 71-81.

Bjeldanes, L. F. (1983). Hazards in the food supply: Lead, aflatoxins and mutagens produced by cooking. In J. Weininger (Ed.), *Nutrition update* (pp. 105-113). New York: John Wiley.

Björkman, C., & Larsson, S. (1991). Pine sawfly defence and variation in host plant resin acids: A trade-off with growth. *Ecological Entomology, 16*, 283-289.

Black, F. F. L. (1975). Infectious diseases in primitive societies. *Science (New York, N.Y.), 187*(4176), 515-518.

Black, F. L. (1966). Measles endemicity in insular populations: Critical community size and its evolutionary implication. *Journal of Theoretical Biology, 11*(2), 207.

Black, F. L. (1992). Why did they die? *Science (New York, N.Y.), 258*, 1739.

Black, F. L., Pinheiro, F. D., Oliva, O., Hierholzer, W. J., Lee, R. V., Briller, J. E., & Richards, V. A. (1978). Birth and survival patterns in numerically unstable proto agricultural societies in the brazilian amazon. *Medical Anthropology, 2*, 95-127.

Blackwell, A. D., Snodgrass, J. J., Madimenos, F. C., & Sugiyama, L. S. (2010). Life history, immune function, and intestinal helminths: Trade-offs among immunoglobulin E, C-reactive protein, and growth in an amazonian population. *American Journal of Human Biology, 22*(6), 836-848.

Block, G., Patterson, B., & Subar, A.Fruit, vegetables, and cancer prevention: A review of the epidemiological evidence. *Nutrition and Cancer, 18*, 1-29.

Blumler, M. A., Byrne, R., Belfer-Cohen, A., Bird, R. M., Bohrer, V. L., Byrd, B. F., Riley, T. J. (1991). The ecological genetics of domestication and the origins of agriculture [and comments and reply]. *Current Anthropology, 32*(1), 23-54.

Boppre, M. (1986). Insects pharmacopgagously utilizing defensive plant chemicals (pyrrolizide alkaloids). *Naturwissenschaften, 73*, 17-26.

Borek, C. (2001). Antioxidant health effects of aged garlic extract *J. Nutr., 131*(3), 1010S-1015S.

Boster, J. S., Yost, J., & Peeke, C. (2004). Rage,revenge, and religion: Honest signaling of aggression and nonaggression in waorani coalition violence. *Ethos, 31*(4), 471-494.

Botanical museum leaflets (1983) Cambridge, MA.: Botanical Museum.

Bourbonnais-Spear, N., Awad, R., Maquin, P., Cal, V., Vindas, P. S., Poveda, L., & Arnason, J. T. (2005). Plant use by the Q'eqchi' maya of belize in ethnopsychiatry and neurological pathology. *Economic Botany, 59*(4), 326-336.

Bourre, J. M. (2006). Effect of the nutrients on structure and function of the nervous system: Update on dietary requirements for the brain. *Journal Nutritional Health Aging, 10*(5), 386-399.

Bradley, C. E. (1956). Yerba de la fleche: Arrow and fish poison of the american southwest. *Economic Botany, 10*(4), 362-366.

Brand-Miller, J. C., & Holt, S. H. A. (1998). Australian aboriginal plant foods: A consideration of their nutritional composition and health implications. *Nutrition Research Reviews, 11*(1), 5.

Bras, G. D., Berry, M., & Gyorgy, P. (1957). Plants as aetiological factor in veno-occlusive disease of the liver. *Lancet, 1*(6976), 960-962.

Brattsten, L. L. B. (1979). Ecological significance of mixed-function oxidations. *Drug Metabolism Reviews, 10*(1), 35-58.

Bressani, R., & Scrimshaw, N. S. (1958). Lime-heat effects on corn nutrients, effect of lime treatment on in vitro availability of essential amino acids and solubility of protein fractions in corn. Journal of agricultural food chemicals *Journal of Agricultural Food Chemicals, 6*(10), 774-778.

Brett, J. (1994). *Medicinal plant selection criteria among the tzeltal maya of highland chiapas, mexico.* (PhD, UCSF).

Broothaerts, W., Mitchell, H. J., Weir, B., Kaines, S., Smith, L. M., Yang, W., . . . Jefferson, R. A. (2005). Gene transfer to plants by diverse species of bacteria. *Nature, 433*, 629-633.

Brothwell, D. R. (1981). *Digging up bones*. Ithaca: Cornell University Press.

Brown, P., & Maeda, T. (2004). Post-pleistocene diachronic change in east asian facial skeletons: The size, shape and volume of the orbits. *Anthropological Science, 112*, 29-40.

Browner, C. H. (1985). Criteria for selecting herbal remedies. *Ethnology, 24*(13), 32.

Browner, C. H., Ortiz de Montellano, B. R., & Rubel, A. J. (1988). A methodology for cross-cultural ethnomedical research. *Current Anthropology, 29*(5), 681-702.

Bub, A. A. (2003). Fruit juice consumption modulates antioxidative status, immune status and DNA damage. *The Journal of Nutritional Biochemistry, 14*(2), 90-98.

Buckley, C. E., Larrick, J. W., & Kaplan, J. E. (1985). Population differences in cutaneous methacholine reactivity and circulating IgE concentrations. *Journal of Allergy and Clinical Immunology, 76*(6), 847-854.

Burkhart, C. N., & Burkhart, C. G. (2005). Assessment of frequency, transmission, and genitourinary complications of enterobiasis (pinworms). *International Journal of Dermatology, 44*, 837-840.

Bye, R. (1993). The role of humans in the diversification of plants in mexico. In T. P. Ramamoorthy, R. A. Bye, A. Lot & J. E. Fa (Eds.), *Biological diversity of mexico: Origins and distribution.* (pp. 707-731). Mexico: UNAM.

Bye, R. A. (1986). Medicinal plants of the sierra madre: Comparative study of tarahumara and mexican market plants. *Economic Botany, 40*(1), 103-124.

Caeser, D. M. (1993). *The relationship of structure and function in mayan home gardens.* (B.A., UC Santa Cruz).

Candela, M., Consolandi, C., Severgnini, M., Biagi, E., Castiglioni, B., Vitali, B., . . . Brigidi, P. (2010). High taxonomic level fingerprint of the human intestinal microbiota by ligase detection reaction - universal array approach. *BMC Microbiology, 10*(1), 116.

Carlsen, M. H., Halvorsen, B. L., Holte, K., Bøhn, S. K., Dragland, S., Sampson, L., Blomhoff, R. (2010). Additional file 1: The antioxidant food table. *Nutritional Journal, 9*(3), 1-138.

Carlsen, M. H., Halvorsen, B. L., Holte, K., Bøhn, S. K., Dragland, S., Sampson, L., Blomhoff, R. (2010). The total antioxidant content of more than 3100 foods, beverages, spices, herbs and supplements used worldwide. *Nutrition Journal, 9*(3), 1-11.

Carod, F. J., & Vasquez, C. (1996). Una vision transcultural de la patologia neurologica y mental en una comunidad maya tzeltal de los altos de chiapas. *Revista De Neurologia, 24*(131), 848-854.

Carper, J. (1997). *The food pharmacy*. Sydney: Simon and Schuster.

Carrera-Bastos, P., Fontes-Villalba, M., O'Keefe, J. H., Lindeberg, S., & Cordain, L. (2011). The western diet and lifestyle and diseases of civilization. *Research Reports in Clinical Cardiology, 2*, 15-35.

Carroll, R. L. (1997). Rates of evolution. In R. L. Carroll (Ed.), *Patterns and processes of vertebrate evolution* (pp. 72-80). Cambridge: Cambridge University Press.

Cartwright, C. P. (1999). Utility of multiple-stool-specimen ova and parasite examinations in a high-prevalence setting. *Journal of Clinical Microbiology, 37*(8), 2408.

Carvalho Goncalves, M. L., Araujo, A., & Ferreira, L. F. (2003). Human intestinal parasites in the past: New findings and a review. *Memórias do Instituto Oswaldo Cruz, 98*(1), 103-118.

Casas, A., Vázquez, M. C., Viveros, J. L., & Caballero, J. (1996). Plant management among the nahua and the mixtec in the balsas river basin, mexico: An ethnobotanical approach to the study of plant domestication. *Human Ecology, 24*(4), 455-478.

Cashman, K. D. (2008). Altered bone metabolism in inflammatory disease: Role for nutrition. *Proceedings of the Nutrition Society, 67*(2), 196.

Casley-Smith, J. R. (1959). Blood pressures in australian aborigines. *The Medical Journal of Australia, 46*(19), 627-633.

Castro, C. E. (1987). Nutrient effects on DNA and chromatin structure. *Annual Review of Nutrition,* , 407-421.

Chagnon, N. (1968). *Yanomamo: The fierce people*. New York: Holt, Reinhardt, Winston.

Chan, M. S. (1997). The global burden of intestinal nematode infections - fifty years on. *Parasitology Today, 13*(11), 438443.

Chase, D. Z., & Chase, A. F. (2006). Framing the mayan collapse. In G. M. Schwartz, & J. J. Nichols (Eds.), *After collapse: The regeneration of complex societies* (pp. 168-187). Tucson: University of Arizona Press.

Cheeke, P. R. (Ed.). (1989). *Toxicants of plant origin, volumes 1 -4* . Boca Raton: CRC Press.

Chen, J. R., Hsu, S. F., Hsu, C. D., Hwang, L. H., & Yang, S. C. (2004). Dietary patterns and blood fatty acid composition in children with attention-deficit

hyperactivity disorder in taiwan. *Journal of Nutritional Biochemistry, 15*, 467-472.

Chernela, J. M., & Thatcher, V. E. (1993). The effects of settlement on the prevalence of ascaris infection in two amerindian populations of the brazilian amazon. *Acta Amazonica, 23*(1), 25-35.

Chilton, M. D. (1988). Plant genetic engineering: Progress and promise. *Journal of Agricultural and Food Chemistry, 36*, 3-5.

Chilton, M. D. (2001). Agrobacterium: A memoir. *Plant Physiology, 125*, 9-14.

Christen, W. W. G. (2008). Dietary carotenoids, vitamins C and E, and risk of cataract in Women A prospective Study. *Archives of Ophthalmology (1960), 126*(1), 102.

Christen, W. W. G. (2008). Dietary carotenoids, vitamins C and E, and risk of cataract in Women A prospective Study. *Archives of Ophthalmology (1960), 126*(1), 102.

Chucair, A. A. J. (2007). Lutein and zeaxanthin protect photoreceptors from apoptosis induced by oxidative stress: Relation with docosahexaenoic acid. *Investigative Ophthalmology & Visual Science, 48*(11), 5168-5177.

Chun, O.K. et al (2008) Serum C-Reactive protein concentrations are inversely associated with dietary flavonoid intake in US adults. *Journal of Nutrition* 138, 753-760.

Clark, G. (1971). *Stone-age hunters* (3rd ed.). London: Thames & Hudson.

Clark, G. (1977). *World pre-history-new perspective* (3rd ed.). Cambridge: Cambridge University Press.

Cochran, G. M., Ewald, P. W., & Cochran, K. D. (2000). Infectious causation of disease: An evolutionary perspective. *Perspectives in Biology and Medicine, 43*(3), 407-448.

Cockburn AI. (1967). *Infectious diseases. their evolution and eradication.*

Code of ethics and standards of practice of the international society of ethnobiology. (1996). *Fifth International Congress of Ethnobotany,* Nairobi, Kenya.

Conklin, H. C. (1954). An ethnoecological approach to shifting agriculture. *Transactions of the New York Academy of Sciences Series II, 17*, 133-142.

Connor, W. E. (1997). Should a low-fat, high-carbohydrate diet be recommended for everyone? *The New England Journal of Medicine, 337*(8), 562-567.

Conti, K. M. (2006). Diabetes prevention in indian country: Developing nutrition models to tell the story of food-system change. *Journal of Transcultural Nursing, 17*, 234-245.

Cook, G. C. (1994). Enterobius vermicularis infection. *Gut, 35*, 1159-1162.

Cooper, P. J., Ayre, G., Martin, C., Rizzo, J. A., Ponte, E. V., & Cruz, A. A. (2008). Geohelminth infections: A review of the role of IgE and assessment of potential risks of anti-IgE treatment. *Allergy, 63*, 409-417.

Cordain, I., Watkins, B. A., Florant, G. L., Kelher, M., Rogers, L., & Li, Y. (2002). Fatty acid analysis of wild ruminant tissues: Evolutionary implications for reducing diet-related chronic disease. *European Journal of Clinical Nutrition, 56*, 181-191.

Cordain, L. (1999). Cereal grains: Humanities double-edged sword. In A. P. Simopoulos (Ed.), *Evolutionary aspects of nutrition and health, diet, exercise, genetics and chronic disease* (84th ed., pp. 19-73). Basel: Karger.

Cordain, L. (2002). *The paleo diet*. New York: John Wiley and Sons, Inc.

Cordain, L., Eaton, S. B., Brand-Miller, J. C., Mann, N. J., & Hill, K. (2002). The paradoxical nature of hunter-getherer diets: Meat-based, yet non-atherogenic. *European Journal of Clinical Nutrition, 56*(1), S42-S52.

Cordain, L., Eaton, S. B., Sebastian,A.,Mann,N., Lindeberg, S., Watkins, B. A., O'Keefe, J. H., & Miller, J. B. (2005). Origins and evolution of the western diet: Health implications for the 21st century. *American Journal of Clinical Nutrition, 81*(2), 341-354.

Cordain, L., & Friel, J. (2005). *The paleo diet for athletes*. New York: Holtzbrinck Publishers.

Cordain, L., Miller, J. B., Eaton, S. B., Mann, N. J., Holt, S. H. A., & Speth, J. D. (2000). Plant-animal subsistence ratios and macronutrient energy estimations in worldwide hunter-gatherer diets. *The American Journal of Clinical Nutrition, 71*(3), 682.

Cordain, L. L., Eaton, S. B., Miller, J. B., Lindeberg, S., & Jensen, C. (2002). An evolutionary analysis of the aetiology and pathogenesis of juvenile-onset myopia. *Acta Ophthalmologica Scandinavica, 80*(2), 125-135.

Costo, R. H., & Costo, J. (1995). *Natives of the golden state: The california indians*. San Francisco: Indian Historian Press.

Cox, P. A., & Elmqvist, T. (1991). Indigenous control of tropical rainforest reserves: An alternative strategy for conservation. *Ambio, 20*, 317-321.

Cox, P. A., & Elmqvist, T. (1993). Ecocolonialism and indigenous knowledge systems: Village controlled rainforest preserves in samoa. *Pacific Conservation, 1*, 11-25.

Cox, P. A., & Balick, M. J. (1994). The ethnobotanical approach to drug discovery. *Scientific American, 270*(6), 82-87.

Crawford, M. A.Fatty-acid ratios in free-living and domestic animals. *Lancet, 291*, 1329-1333.

Crompton, D. W. T. (1999). How much human helminths is there in the world? *The Journal of Parasitology, 85*(1), 397-403.

Crump, J. A. (1901). Trephining in the south seas. *The Journal of the Anthropological Institute of Great Britain and Ireland, 31*, 167.

Das, A. A. (2012). Plant volatiles as method of communication. *Plant Biotechnology Reports,*

Davis, C. C., & Wurdack, K. J. (2004). Host to parasite gene transfer in flowering plants: Phylogenetic evidence from malpighiales. *Science, 305*, 676-678.

Davis, E. W. (1983). The ethnobiology of the haitian zombi. *Journal of Ethnopharmacology, 9*, 85-104.

Davis, E. W., & Yost, A. Y. (1983). The ethnomedicine of the waorani of amazonian ecuador. *Journal of Ethnopharmacology, 9*, 273-297.

de la Torre L, Navarrete H Muriel MP, Macía MJ, Balslev H (Ed.). (2008). *Enciclopedia de las plantas útiles del ecuador,* Quito and Aarhus: Herbario QCA de la Escuela de Ciencias Biológicas de la Pontificia Universidad Católica del Ecuador and Herbario AAU Department of Biological Sciences, University of Aathus.

de la Torre, S. (2010). Los primates ecuatorianos, estudios y perspectivas. *Avances En Ciencias e Ingenierias, 2*, 27-35.

de Laszlo, H., & Henshaw, P. S. (1954). Plant materials used by primitive peoples to affect fertility. *Science, 119*(3097), 626-631.

de Lorgeril, M., Salen, P., Martin, J. L., Monjaud, I., Delaye, J., & Mamelle, N. (1999). *Mediterranean diet, traditional risk factors, the rate of cardiovascular complications after myocardial infarction: Final report of the lyon diet heart study.* (No. 99). Dallas: American Heart Association.

de Sahagún, B., & de Bustamante, C. M. (1829). *Historia general de las cosas de nueva españa* (2nd ed.). Santa Fe, NM: School of American Research.

de Sherbinin, A. A. (2008). Is poverty more acute near parks? an assessment of infant mortality rates around protected areas in developing countries. *Oryx, 42*(01), 26.

De Wet, J. M. J., Harlan, J. R., & Grant, C. A. (1975). Weeds and domesticates: Evolution in the man-made habitat. *Economic Botany, 29*(2), 99-107.

Degen, T. T. (2004). High genetic variability of herbivore-induced volatile emission within a broad range of maize inbred lines. *Plant Physiology (Bethesda), 135*(4), 1928-1938.

Ding, Y. J., & He, X. X. (1986). Traditional chinese herbs in treatment of neurological and neurosurgical disorders. *Canadian Journal of Neurological Sciences, 13*(3), 210-213.

Dittmar, K. (2009). Old parasites for a new world: The future of paleoparasitological research. A review. *Journal of Parasitology, 95*(2), 365-371.

Dobkin de Rios, M. (1974). The influence of psychotropic flora and fauna on maya religion. *Current Anthropology, 15*, 147-164.

Dobson, A. P. (1988). The population biology of parasite-induced changes in host behavior. *The Quarterly Review of Biology,* 139.

Domínguez, X. A. (1985). Screening of medicinal plants used by huastec mayans of northeastern mexico. *Journal of Ethnopharmacology, 13*(2), 139.

Donnison, C. P. (1929).Blood pressure in the African native: its bearing upon the aetiology of hyperpiesa and artherio-sclorosis *The Lancet (British Edition), 213*(5497), 6.

Dorweiler, J., Stec, A., Kermicle, J., & Doebley, J. (1993). Teosinte-glume-architecture-1 - a genetic-locus controlling a key step in maize evolution. *Science, 262*(5131), 233-235.

D'Ovidio, R. R. (2004). Characterization of the complex locus of bean encoding polygalacturonase-inhibiting proteins reveals subfunctionalization for

defense against fungi and insects. *Plant Physiology (Bethesda), 135*(4), 2424-2435.

Dudareva, N. N. (2004). Biochemistry of plant volatiles. *Plant Physiology (Bethesda), 135*(4), 1893-1902.

Dufour, D. L. (1989). Effectiveness of cassava detoxification techniques used by indigenous peoples in northwest amazonia. *Interciencia, 14*(2), 86.

Dunn, F. L. (1972). Intestinal parasitism in malayan aborigines (orang asli). *Bulletin of the World Health Organization, 46*, 99-113.

Durmaz, B., Yakinei, C., Koroglu, M., Rafiq, M., Durmaz, R., & Yologlu, S. (1996). Concentrations of total serum IgE in parasitized children and the effects of the antiparasitic therapy on IgE levels. *Journal of Turgut Özal Medical Center, 3*(4), 332-335.

Dyer, L. L. A. (2001). Trade-offs in antiherbivore defenses in piper cenocladum: Ant mutualists versus plant secondary metabolites. *Journal of Chemical Ecology, 27*(3), 581-592.

Eastwell, H. D. (1979). Pica epidemic; a price for sedentarism among australian ex-hunter-gatherers. *Psychiatry, 42*(3), 264.

Eaton, S. S. B. (1985). Paleolithic nutrition A consideration of its nature and current implications. *The New England Journal of Medicine, 312*(5), 283-289.

Eaton, S. S. B. (1992). Humans, lipids and evolution. *Lipids, 27*(10), 814-820.

Eaton, S. B. (2002). Evolutionary health promotion: A consideration of common counterarguments. *Preventive Medicine, 34*(2), 119.

Eaton, S. B. (2006). The ancestral human diet: What was it and should it be a paradigm for contemporary nutrition? *Proceedings of the Nutritional Society, 65*, 1-6.

Eaton, S. B., & Cordain, L. (1997). Evolutionary aspects of diet: Old genes, new fuels - nutritional changes since agriculture. *World Review of Nutrition and Dietetics, 81*, 26-37.

Eaton, S. B., Eaton, S. S. B., Sinclair, A. J., Cordain, L., & Mann, N. J. (1998). Dietary intake of long-chain polyunsaturated fatty acids during the paleolithic. *World Review of Nutrition and Dietetics, 83*, 12-23.

Eaton, S. B., Eaton, S. B. I., & Konner, M. J. (1997). Paleolithic nutrition revisited: A twelve-year retrospective on its nature and implications. *European Journal of Clinical Nutrition, 51*(4), 207.

Eaton, S. B. S. B. (1988). Stone agers in the fast lane: Chronic degenerative diseases in evolutionary perspective. *The American Journal of Medicine, 84*(4), 739-749.

Eaton, S. S. B. (2000). Paleolithic vs. modern diets - slected pathophysiological implications. *European Journal of Nutrition, 39*(2), 67-70.

Economic Research Service (ERS). (2001). *Diet, consumption and health*.United States Department of Agriculture.

Eddy, S. S. R. (2001). Non-coding RNA genes and the modern RNA world. *Nature Reviews.Genetics, 2*(12), 919-929.

Eder, J. F. (1978). The caloric returns to food collecting: Disruption and change among the batak of the philippine tropical forest. *Human Ecology, 6*(1), 55-69.

Eder, J. F. (1984). The impact of subsistence change on mobility and settlement pattern in a tropical forest foraging economy: Some implications for archeology. *American Anthropologist, 86*(4), 837-853.

Edmonson, M. S. (Ed.). *Meaning in mayan languages*. The Hague: Mouton and Co.

Egert, M., de Graaf, A. A., Smidt, H., de Vos, W. M., & Venema, K. (2006). Beyond diversity: Functional microbiomics of the human colon. *Trends in Microbiology, 14*(2), 86-91.

Elisabetsky, E. (1986). New directions in ethnopharmacology. *Journal of Ethnobiology, 6*, 121-128.

Elisabetsky, E. (1991). Sociopolitical, economical and ethical issues in medicinal plant research. *Journal of Ethnopharmacology, 32*(1-3), 235.

Elisabetsky, E., & Shanley, P. (1994). Ethnopharmacology in the brazilian amazon. *Pharmacology and Therapeutics, 64*, 201-214.

Elisabetsky, E. E. (2002). Ethnomedicine and drug discovery chapter 11 traditional medicines and the new paradigm of psychotropic drug action. *Advances in Phytomedicine Series, 1*, 133-144.

Elliott, D. R., Summers, R., & Weinstock, J. (2007). Helminths as governors of immune-mediated inflammation. *International Journal of Parasitology, 37*, 457-464.

Ellison, P. (1989). Reproductive ecology and human fertility. In Lasker, GW and Mas-Taylor, CGN (Ed.), *Application of biological anthropology to human affairs*. Cambridge: Cambridge University Press.

Emboden, W. (1972). *Narcotic plants, hallucinogens, stimulants, inebriants and hypnotics - their origins and uses.*

Emlen, S. T. (2000). Hamilton symposium. *Behavioral Ecology, 12*(3), 261-268.

Emsley, R., Oosthuizen, P., & van Rensburg, S. J. (2003). Clinical potential of omega-3 fatty acids in the treatment of schizophrenia. *CNS Drugs, 17*(15), 1081-1091.

Eong, K. G. A. (1993). Education and myopia in 110,236 young singaporean males. *Singapore Medical Journal, 34*, 489.

Eong, K. G. A. (1993). Race, culture and myopia in 110,236 young singaporean males. *Singapore Medical Journal, 34*, 29.

Erlund, I. (2008). Favorable effects of berry consumption on platelet function, blood pressure, and HDL cholesterol. *The American Journal of Clinical Nutrition, 87*(2), 323.

Etkin, N. N. L. (1996). Medicinal cuisines: Diet and ethopharmacology. *Pharmaceutical Biology, 34*(5), 313-326.

Etkin, N. L. (1982). Food as medicine and medicine as food:: An adaptive framework for the interpretation of plant utilization among the hausa of northern nigeria. *Social Science & Medicine (1982), 16*(17), 1559.

Etkin, N. L. (1988). Ethnopharmacology: Biobehavioral approaches in the anthropological study of indigenous medicines. *Annual Review of Anthropology, 17*, 23-42.

Etkin, N. L. (1993). Anthropological methods in ethnopharmacology. *Journal of Ethnopharmacology, 38*, 93-104.

Etkin, N. L. (1997). Plants as antimalarial drugs: Relation to G6PD deficiency and evolutionary implications. In L. S. Greene, & M. E. Danubio (Eds.), *Adaptation to malaria: The interaction of biology and culture* (pp. 139-176). New York: Gordon and Breach Publishers.

Etkin, N. L. (2001). Perspectives in ethnopharmacology: Forging a closer link between bioscience and traditional empirical knowledge. *Journal of Ethnopharmacology, 76*(2), 177-182.

Etkin, N. L. (2003). The co-evolution of people, plants, and parasites: Biological and cultural adaptations to malaria. *Proceedings of the Nutritional Society, 62*, 311-317.

Etkin, N. L. (2006). *Edible medicines: An ethnopharmacology of food*. Tucson: University of Arizona Press.

Etkin, N. L., & Ross, P. J. (1991). Should we set a place for diet in ethnopharmacology? *Journal of Ethnopharmacology, 32*, 25-36.

Etkin, N. L., & Ross, P. R. (1994). Pharmacological implications of "wild" plants in hausa diet. *Eating on the wild side: The pharmacologic, ecologic, and social implications of using noncultigens* (pp. 85-101). Tucson: University of Arizona Press.

Etkin, N. L., & Ross, P. R. (2000). The ethnopharmacology of fermented medicinal foods. In R. Chaves (Ed.), *Proceedings of the international symposium on ethnobotany*. San Jose: Universidad para la Paz.

Evans, L. T. (1998). *Feeding ten billion plants: Plants and population growth*. Cambridge: Cambridge University Press.

Ewald, P. (1994). *Evolution of infectious disease*. New York: Oxford University Press.

Ewald, P. W. T. (1993). The evolution of virulence. *Scientific American,* , 86-93.

Ewald, P. P. W. (1980). Evolutionary biology and the treatment of signs and symptoms of infectious disease. *Journal of Theoretical Biology, 86*(1), 169-176.

Fairfield, K. K. M. (2002). Vitamins for chronic disease prevention in adults: Scientific review. *JAMA : The Journal of the American Medical Association, 287*(23), 3116-3126.

Farnsworth, N. R. (1985). Medicinal plants in therapy. *Bulletin of the World Health Organization, 63*(6), 965.

Farnsworth, N. R. (1993). Ethnopharmacology and future drug development: The north american experience. *Journal of Ethnopharmacology, 38*, 145-152.

Faust, E. C. (1955). History of human parasitic infections. *Public Health Reports, 70*(10), 958-965.

Fedoroff, N. V., & Brown, N. M. (2004). *Mendel in the kitchen: A scientists view of genetically modified food*. Washington, DC: National Academy of Sciences.

Felger, R. S., & Moser, M. B. (1985). *People of the desert and sea: Ethnobotany of the seri indians*. Tucson: University of Arizona Press.

Fenwick, G. G. R. (1983). Bitterness in brussels sprouts (brassica oleracea L. var.gemmifera): The role of glucosinolates and their breakdown products. *Journal of the Science of Food and Agriculture, 34*(1), 73-80.

Fernandez, M. M. M. (2008). Nutrition and the prevention of cataracts. *Current Opinion in Ophthalmology, 19*(1), 66-70.

Fernandez, M. M. M. (2008). Nutrition and the prevention of cataracts. *Current Opinion in Ophthalmology, 19*(1), 66-70.

Ferroir, J. P., Fenelon, G., & Billy, C. (1997). Epilepsy, cerebral calcifications and celiac disease. *Revue Neurologique, 153*(5), 354-356.

Flannery, K. V. (1973). The origins of agriculture. *Annual Review of Anthropology, 2*, 271-310.

Flaxman, S. M. (2000). Morning sickness: A mechanism for protecting mother and embryo. *The Quarterly Review of Biology,*113.

Folkers, K. K. (1939). Erythrina alkaloids. v. comparative curare-like potencies of species of the genus erythrina. *Journal of the American Pharmaceutical Association, 28*(12), 1019-1028.

Food and Agriculture Organization (FAO) United Nations. (1994). *Fats and oils in human nutrition: Report of the joint expert consultation.* (No. 57). Rome: Food and Agriculture Organization (FAO).

Food and Agriculture Organization (FAO) United Nations. (1996). *World food summit.*. Rome: Food and Agriculture Organization (FAO).

Food and Agriculture Organization (FAO) United Nations. (2000a). *The state of food and agriculture.* (). Rome: Food and Agriculture Organization (FAO).

Food and Agriculture Organization (FAO) United Nations. (2000b). *The state of food insecurity in the world 2000.* (). Rome: Food and Agriculture Organization (FAO).

Food and Agriculture Organization (FAO) United Nations. (2004). *World agriculture towards 2015/2030.* (). Rome: Food and Agriculture Organization (FAO).

Ford, R. I. (1978). Ethnobotany: Historical diversity and synthesis. In R. I. Ford (Ed.), *The nature and status of ethnobotany* (pp. 33-49). Ann Arbor: University of Michigan Museum of Anthropology.

Ford, R. I. (1978). *The nature and status of ethnobotany*. Ann Arbor: University of Michigan Museum of Anthropology.

Foster, G. G. M. (1976). Disease etiologies in non-western medical systems. *American Anthropologist, 78*(4), 773-782.

Frank, D. N., St Amand, A. L., Feldman, R. A., Boedeker, E. C., Harpaz, N., & Pace, N. R. (2007). Molecular-phylogenetic characterization of microbial community imbalances in human inflammatory bowel diseases. *Proceedings of the National Academy of Sciences of the United States of America, 104*(34), 13780-13785.

Franke, K. K. W. (1936). The ability of rats to discriminate between diets of varying toxicity. *Science (New York, N.Y.), 83*(2153), 330-332.

Freeland, W. J. (1974). Strategies in herbivory by mammals: The role of plant secondary compounds. *The American Naturalist,* 269.

Freeland, W. J. W. J. (1989). Choice of mixed diets by herbivores: The idiosyncratic effects of plant secondary compounds. *Biochemical Systematics and Ecology, 17*(6), 493-497.

Frei, B., Sticher, O., Veisca, C. T., & Heinrich, M. (1998). Medicinal and food plants: Isthmus sierra zapotec criteria for selection. *Angewandte Botanik, 72*, 82-86.

Fry, H., & Hall HJ. (1975). Human coprolites from antelope house: Preliminary analysis. *Kiva, 41*(1), 87-96.

Fullagar, R. (1997). Pleistocene seed-grinding implements from the australian arid zone. *Antiquity, 71*(272), 300-307.

Fumagalli, M., Pozzoli, U. C.,R., Comi, G. P., Riva, S., Clerici, M., Bresolin, N., & Sironi, M. (2009). Parasites represent a major selective force for interleukin genes and shape the genetic predisposition to autoimmune conditions. *The Journal of Experimental Medicine, 206*(6), 1395-1408.

Futuyma, D. (1997). Chapter 2: A synopsis of evolutionary theory. *Evolutionary biology, 3rd edition* (3rd ed., pp. 79-32). Sunderland, Massachusetts: Sinauer Associates.

Galinat, W.C. (1967). The diffusion of Eight–rowed maize from the southwest to the central plains. *Monograph series 1* (pp. 1-16). Amherst: Massachusetts Agricultural Experimental Station.

Galland, L. (2010) Diet and inflammation. *Nutrition in Clinical Practice*. 25(6) 634.

Gallavotti, A. A. (2004). The role of barren stalk1 in the architecture of maize. *Nature (London), 432*(7017), 630-635.

Gandon, S., Mackinnon, M. J., Nee, S., & Read, A. F. (2001). Imperfect vaccines and the evolution of pathogen virulence. *Nature, 414*, 751-756.

Garcia, J., & Hankins, W. G. (1975). The evolution of bitter and the acquisition of toxiphobia. In D. A. Denton, & J. P. Coghlan (Eds.), *Olifaction and taste V* (pp. 39-45). New York: Academic Press.

Gardener, G., & Haliweil, B. (2000). *Overfed and underfed: The global epidemic of malnutrition*. Washington, D.C.: Worldwatch Institute.

Gerszten, P. C. (1998). Diseases of the skull in pre-columbian south american mummies. *Neurosurgery, 42*(5), 1145.

Gibbs, W. W. W. (2003). The unseen genome: Gems among the junk. *Scientific American, 289*(5), 46-53.

Gilani, A. A. H. (2005). Trends in ethnopharmacology. *Journal of Ethnopharmacology, 100*(1-2), 43-49.

Gill, S. R., Pop, M., Deboy, R. T., Eckburg, P. B., Turnbaugh, P. J., Samuel, B. S, Nelson, K. E. (2006). Metagenomic analysis of the human distal gut microbiome. *Science, 312*(5778), 1355-1359.

Gilmore, M. M. R. (1932). Importance of ethnobotanical investigation. *American Anthropologist, 34*(2), 320-327.

Gimlette, G. (1915). *Malay poisons and charm cures*. London: Churchill.

Giraud, E. E. (1993). Production of a lactobacillus plantarum starter with linamarase and amylase activities for cassava fermentation. *Journal of the Science of Food and Agriculture, 62*(1), 77-82.

Gluckman, P. P. D. (2005). Environmental influences during development and their later consequences for health and disease: Implications for the interpretation of empirical studies. *Proceedings of the Royal Society.B, Biological Sciences, 272*(1564), 671-677.

Gluckman, P. D. (2004). Living with the past: Evolution, development, and patterns of disease. *Science, 305*(5691), 1733-1736.

Gluckman, P. D., & Hanson, M. A. (2006). Evolution, development and timing of puberty. *Trends in Endocrinology and Metabolism, 17*(1), 7-12.

Gluckman, P. D., & Hanson, M. A. T. (2004). The development origins of hte metabolic syndrome. *Trends in Endocrinology and Metabolism, 15*(4), 183-187.

Gluckman, P. P. D. (2005). The developmental origins of adult disease. *Maternal and Child Nutrition, 1*(3), 130-141.

Gobbi, G. (2005). Coeliac disease, epilepsy and cerebral calcifications. *Brain & Development (Tokyo.1979), 27*(3), 189.

Gómez-Pompa, A.J; sosa, V. 1987 "The "pet kot": A man-made tropical forest of the maya.". *Interciencia, 12*(1), 10.

Goncalves, M. L. C., Araujo, A., & Ferreira, L. F. (2003). Human intestinal parasites in the past: New findings and a review. *Memórias do Instituto Oswaldo Cruz, 96*(1), 103-118.

Goodman, A. (1985). Disease and death at dr. dickenson'ts mounds. *Natural History, 94*(9), 12.

Goodrich R.R. M. (1989).Glucosinate changes in blanched brocolli. *Journal of Food Processing and Preservation, 13*(4), 275-280.

Gramly, R. M. (1976). Upper pleistocene archaeological occurrences at site GvJm/22, lukenya hill, kenya. *Man (London),* 319.

Greaves, M. (2000). *Cancer: The evolutionary legacy*. New York: Oxford University Press.

Greaves, T. (1994). *Intellectual property rights for indigenous people: A sourcebook*. Oklahoma City, OK: Society for Applied Anthropology.

Guderian, R. H., Mackenzie, C. D., & Williams, J. F. (1986). Letter to editor: High voltage shock treatment for snake bite. *The Lancet,*

Habermehl, G. (1983). *Poisonous animals and their toxins* (3rd ed.). Berlin: Springer-Verlag.

Habetha, M. M. (2005). Symbiotic hydra express a plant-like peroxidase gene during oogenesis. *Journal of Experimental Biology, 208*(11), 2157-2165.

Hadjivassiliou, M. M. (1996). Does cryptic gluten sensitivity play a part in neurological illness? *The Lancet (North American Edition), 347*(8998), 369-371.

Hagen, E. H. (1999). The functions of postpartum depression *Evolution and Human Behavior, 20*, 325-359.

Hambidge, K. M. (2004). Zinc absorption from low-phytate hybrids of maize and their wild-type isohybrids. *The American Journal of Clinical Nutrition, 79*(6), 1053.

Hammerschmidt, R. J., & Schultz, C. (1996). Multiple signals and defense in plant defense against pathogens and herbivores. In J. T. Romeo (Ed.), *Phytochemical diversity and redundancy in ecological interactions* (pp. 121-154). New York: Plenum Press.

Hancock, J. F. (2004). *Plant evolution and the origin of crop species, 2nd ed.* Wallingford, UK: CAB International.

Hansson, G. G. K. (2005). Inflammation, atherosclerosis, and coronary artery disease. *The New England Journal of Medicine, 352*(16), 1685-1695.

Harborne, J. J. B. (1986). Recent advances in chemical ecology. *Natural Product Reports, 3*(0), 323.

Harborne, J. B. (1978). *Biochemical aspects of plant and animal co-evolution. annual proceedings of the phytochemical society of europe.* . London: Academic Press.

Harborne, J. B. (1982). *Introduction to ecological biochemistry*. London: Academic Press.

Harborne, J. B. (1993). *Introduction to ecological biochemistry, 4th ed.* . London: Academic Press.

Harborne, J. B. (2000). Advances in flavonoid research since 1992. *Phytochemistry (Oxford), 55*(6), 481.

Harlan, J. J. R. (1976). Diseases as a factor in plant evolution. *Annual Review of Phytopathology, 14*(1), 31-51.

Harlan, J.R.(1967). A wild wheat harvest in turkey. *Archaeology, 20*, 197.

Harlan, J. J. R. (1971). Agricultural origins: Centers and noncenters. *Science (New York, N.Y.), 174*(4008), 468-474.

Harlan, J. J. R. (1975). Our vanishing genetic resources. *Science (New York, N.Y.), 188*(4188), 617-621.

Harlan, J. R. (1973). Comparative evolution of cereals. *Evolution, 27*(2), 311.

Harlan, J. R. (1976). The plants and animals that nourish man. *Scientific American, 235*(2), 89.

Harlan, J. J. (1976). Genetic resources in wild relatives of Crops1. *Crop Science, 16*(3), 329.

Hattori, M., & Taylor, T. D. (2990). The human intestinal microbiome: A new frontier of human biology. *DNA Research, 13*(1), 1-12.

Hausfater, G. (1984). A little thing that ticks off baboons. *Natural History, 93*(2), 52.

Head, K. (2001). Natural therapies for ocular disorders part two: Cataracts and glaucoma. *Alternative Medicine Review, 6*(2), 141.

Head, K. (2001). Natural therapies for ocular disorders part two: Cataracts and glaucoma. *Alternative Medicine Review, 6*(2), 141.

Heaney, R. K., & Genwick, G. R. (1987). *Identifying toxins and their effects*. In D. H. Watson (Ed.), *Natural toxicants inFoods. progress and prospects* (pp. 76-109). Chichester: Ellis Horwood.

Hedrick, P. P. W. (1997). HLA and mate selection: No evidence in south amerindians. *American Journal of Human Genetics, 61*(3), 505-511.

Hegner, R., Root, F. M., Augustine, D. L., & Huff, C. G. (1938). *Parasitology with special reference to man and domesticated animals*. New York: D. Appleton-Century.

Heinrich, M. (1998). Medicinal plants in mexico: Healers' consensus and cultural importance. *Social Science & Medicine (1982), 47*(11), 1859.

Heinrich, M. (2001). Journal of ethnopharmacology: An interdisciplinary journal devoted to indigenous drugs. *Journal of Ethnopharmacology, 76*(2), 137.

Heinz, H. J. (1961). Factors governing the survival of bushmen worm parasites in the kalahari. *South African Journal of Science, 8*, 207.

Hernandez, E. X. (1971). *Apuntes sobre la exploracion etnobotanica y su metodología*. Chapingo, Mexico: Escuela Nacional de Agricultura.

Hernandez, F. (2000). Materia medicinal de la nueva españa. In A. H. de León-Portilla (Ed.), *Antiguedades de la nueva españa* (). Madrid: Informacion y Revistas, S.A.

Hernandez-Gomez, J. A. (1994). Chia (salva hispanica): Antecedentes y perspectivas en mexico. In E. Cuevas-Sacnez (Ed.), *Primer simposio internacional sobre etnobotanica en mesoamerica* (pp. 173-178). Chapingo, Mexico: Universidad Autonoma.

Hill, J. O., Thacker, S., Newby, D., Sykes, M. N., & Digirolamo, M. (1988). Influence of food restriction coupled with weight cycling on carcass energy restoration during ad-libitum refeeding. *International Journal of Obesity, 12*(6), 547-555.

Hill, K. K. (1993). Life history theory and evolutionary anthropology. *Evolutionary Anthropology, 2*(3), 78-88.

Hirayama, S. S. (2004). Effect of docosahexaenoic acid-containing food administration on symptoms of attention-deficit/hyperactivity disorder — a placebo-controlled double-blind study. *European Journal of Clinical Nutrition, 58*(3), 467-473.

Hoberg, E. P., Alkire,N,L, de Queiroz, A., & Jones, A. (2001). Out of africa: Origins of the taenia tapeworms in humans. *Proceedings of the Royal Society of London, 268*, 781-787.

Hole, F. (373). Origins of agriculture. In S. Jones, R. Martin & D. Pilbeam (Eds.), *The cambridge encyclopedia of human evolution* (pp. 379). Cambridge: Cambridge Press.

Holm, S. (1937). The ocular refraction state of the Palae Negroids in gabon, french equatorial africa. *Acta Ophthalmol Suppl, 13*, 1-299.

Hough, W. W. (1897). The hopi in relation to their plant environment. *American Anthropologist, 10*(2), 33-44.

Houghton, J. T. (2004). *Global warming, a complete briefing, 3rd ed,* Cambridge: Cambridge University Press.

Houghton, P. J., & Osibogun, I. M. F. (1993). Flowering plants used against snakebite. *Journal of Ethnopharmacology, 39*, 1-29.

Howe, H. F., & Westley, L. C. (1988). *Ecological relationships of plants and animals*. New York: Oxford Press.

Hurtado, A. M., Frey, M. A., Hurtado, I., Hill, K., & Baker, J. (2008). The role of helminthes in human evolution: Implications for global health in the 21st century. In S. Elton, & P. O'Higgins (Eds.), *Medicine and evolution: Current applications, future prospects* (pp. 151-178). New York: CRC Press.

Hurtado, A. M., Hill, K., Hurtado, I., & Rodriguez, S. (1996). The evolutionary context of chronic allergic conditions: The hiwi of venezuela. *Human Nature, 8*(1), 51-75.

Hurtado, A. M., & Hill, K. R. (1990). Seasonality in a foraging society: Variation in diet, work effort, fertility, and sexual division of labor among the hiwi of venezuela. *Journal of Anthropological Research, 46*(3), 293-346.

Hurtado, A. M., Lambourne, C. A., James, P., Hill, K., Cheman, K., & Baca, K. (2005). Human rights, biomedical science, and infectious diseases among south american indigenous groups. *Annual Review of Anthropology, 34*, 639-665.

Huxtable, R. J. (1980). Herbal teas and toxins: Novel aspects of pyrrolizidine poisoning in the U.S. *Perspectives in Biology and Medicine, 24*, 1-14.

Inhorn, M. M. C. (1990). The anthropology of infectious disease. *Annual Review of Anthropology, 19*(1), 89-117.

Irons, W. W. (1998). Adaptively relevant environments versus the environment of evolutionary adaptedness. *Evolutionary Anthropology, 6*(6), 194-204.

Iyayi, E. A., & Tewe, O. O. (1986). *Preparation of cassava foods: Removal of its toxic factor* [*Proceedings of the National Seminar on Nigerian Food, Culture*]. Nigeria: Institute of African Studies/Ibadan Press.

Jackson, F. (1996). The coevolutionary relationship of humans and domesticated plants. *American Journal of Physical Anthropology, 101*(s23), 161.

Jackson, F. L. C. (1994). Nutrition and gene expression. *American Journal of Human Biology, 6*(3), 401-404.

Jackson, F. L. C. F. L. C. (1991). Secondary compounds in plants (allelochemicals) as promoters of human biological variability. *Annual Review of Anthropology, 20*(1), 505-544.

Jackson, L. C. (1985). Influence of dietary cyanide on immunoglobulin and thiocyanate levels in the serum of liberian adults. *Journal of the National Medical Association, 77*(10), 777.

Jackson, L. C. (1988). Possible adaptation to serum thiocyanate overload associated with chronic sublethal dietary cyanide ingestion. *Human Biology, 60*(4), 615.

Jain, S. K. (1989). Methods and approaches in ethnobotany. *Society of Ethnobiology,*

James, M. M. G. (1995). Characterization of the maize gene sugary1, a determinant of starch composition in kernels. *The Plant Cell, 7*(4), 417-429.

Janzen, D. H. (1968). Host plants as islands in evolutionary and contemporary time. *The American Naturalist, 102*(928), 592-595.

Janzen, D. H. (1977). Promising directions of study in tropical animal-plant interactions. *Annals of the Missouri Botanical Garden, 64*(4), 706.

Janzen, D. H. (1978). Complications in interpreting the chemical defenses of trees against tropical arboreal plant-eating vertebrates. In C. F. Montgomery (Ed.), *The ecology of arboreal folivores* (pp. 73-84). Washington, D.C.: Smithsonian Institution.

Jarret E. E. (1973). Threadworms and IgE in allergic asthma. *Clinical and Experimental Allergy, 3*(2), 203-207.

Jarret E. E. (1982). Production and activities of IgE in helminth infection. *Progress in Allergy, 31*, 178-195.

Jelliffe, D. B., Woodburn, J., Bennett, F. J., & Jelliffe, E. F. P. (1962). The children of the hadza hunters. *Tropical Pediatrics,* , 907-913.

Johanson, D. (1998). Reading the minds of fossils. *Scientific American, 278*, 102.

Johns, T. T. (1999). Saponins and phenolic content in plant dietary additives of a traditional subsistence community, the batemi of ngorongoro district, tanzania. *Journal of Ethnopharmacology, 66*(1), 1-10.

Johns, T. (1990). *With bitter herbs they shall eat it: Chemical ecology and the origins of human diet and medicine*. Tucson, Arizona: University of Arizona Press.

Johns, T., & Chapman, L. (1995). Phytochemicals ingested in traditional diets and medicines as modulators of energy mechanism. In J. T. Arnason, R. Mata &

R. T. Romeo (Eds.), *Phytochemistry of medicinal plants* (pp. 161-168). New York: Plenum Press.

Johns, T., & Etkin, N. L. (1998). "Pharmafoods" and "nutraceuticals": Paradigm shifts in biotherapuetics. In H. D. V. Pendergast, D. R. Etkin, D. R. Harris & P. J. Houghton (Eds.), *Plants for food and medicine* (pp. 3-16). Kew: Royal Botanic Gardens.

Johns, T., & Eyzaguirre, P. B. (2007). BiofortiWcation, biodiversity and diet: A search for complementary applications against poverty and malnutrition. *Food Policy, 32*, 1-24.

Johns, T., & Kubo, I. (1988). A survey of traditional methods employed for the detoxification of plant food. *Journal of Ethnobiology, 8*, 81-129.

Johns, T., & Maundu, P. (2006). Forest biodiversity, nutrition and population health in market-oriented food systems. *Unasylva, 57*(224), 34-40.

Johns, T., Smith, I. F., & Eyzaguirre, P. B. (2006). *Understanding the links between agriculture and health: Agrobiodiversity, nutrition and health.* (No. 12). Washington, D.C.: International Food Policy Research Institute.

Johnson, S. S. D. (2011). Mammal pollinators lured by the scent of a parasitic plant. *Proceedings of the Royal Society.B, Biological Sciences, 278*(1716), 2303-2310.

Joint FAO/WHO ad hoc Expert Committee. (1971). *Energy and protein requirements: Food and nutrition series.* (). Rome: Food and Agriculture Organization (FAO).

Jones, H. I. (1980). Intestinal parasite infections in western australian aborigines. *The Medical Journal of Australia, 2*, 375-380.

Jones, V. (1941). The nature and scope of ethnobotany. *Chronica Botanica, 6*(10), 219-221.

Joseph, J. A. (1998). Long-term dietary strawberry, spinach, or vitamin E supplementation retards the onset of age-related neuronal signal-transduction and cognitive behavioral deficits. *The Journal of Neuroscience, 18*(19), 8047.

Kalt, W. W. (2008). Identification of anthocyanins in the liver, eye, and brain of blueberry-fed pigs. *Journal of Agricultural and Food Chemistry, 56*(3), 705-712.

Kaminer B. B. (1960). Blood pressure in bushmen of the kalahari desert. *Circulation (New York, N.Y.), 22*(2), 289-295.

Kaplan, J. E. (1980). Infectious disease patterns in the waorani, an isolated amerindian population. *The American Journal of Tropical Medicine and Hygiene, 29*(2), 298.

Kaplan, J. E. (1984). Workup on the waorani. *Natural History, 93*(9), 68.

Karsten, R. (1935). The head-hunters of western amazonas: The life and culture of the jibaro indians of eastern ecuador and peru. *Soc. Sci. Fennicum, 7*(1), 1.

Kashambuzi, E. (1999). *The paradox of hunger and abundance*. Orlando, Florida: Rivercross Publishing.

Kataria, A. (1988). Effect of domestic processing and cooking on the antinutrients of black gram. *Food Chemistry, 30*(2), 149.

Katz, S. S. H. (1974). Traditional maize processing techniques in the new world. *Science (New York, N.Y.), 184*(4138), 765-773.

Katz, S. H. (1987). Fava bean consumption: A case for the co-evolution of genes and culture. In M. Harris, & E. Ross (Eds.), *Food and evolution* (pp. 133-169). Philadelphia: Temple University Press.

Katz, S. H. (1987). Food and biocultural evolution: A model for the investigation of modern nutritional problems. In F. E. Johnson (Ed.), *Nutritional anthropology* (). New York: Alan Liss, Inc.

Kerr, R. R. A. (2006). CLIMATE CHANGE: Yes, it's been getting warmer in here since the CO2 began to rise. *Science (New York, N.Y.), 312*(5782), 1854-1854.

Kiel, R. J. (2003). Does cranberry juice prevent or treat urinary tract infection? *The Journal of Family Practice, 52*(2), 154.

Kikkert, J. R., Vidal, J. R., & Reisch, B. I. (2005). Stable transformation of plant cells by particle bombardment/biolistics. *Methods in Molecular Biology (Clifton, N.J.), 286*, 61-78.

King, S. R. (1994). Establishing reciprocity: Biodiversity, conservation and new models for cooperation between forest dwelling people and the pharmacuetical industry. In T. Greaves (Ed.), *Intellectual property rights for indigenous people* (pp. 71-82). Oklahoma City, OK: Society for Applied Anthropology.

Kingsbury, J. M. (1983). The evolutionary and ecological significance of plant toxins. In R. F. Keeler, & A. T. Tu (Eds.), *Handbook of natural toxin: Plant & fungal toxins* (pp. 675-706). New York: Marcel Dekker.

Klein, J. (1978). Susto: The anthropological study of diseases of adaptation. *Social Science & Medicine.Part B, Medical Anthropology, 12*, 23.

Ko, M. M. L. (2005). Dynamic changes in reactive oxygen species and antioxidant levels in retinas in experimental glaucoma. *Free Radical Biology & Medicine, 39*(3), 365-373.

Konner, M. (2010). Invited review: Paleolithic nutrition. *Nutrition in Clinical Practice, 25*(6), 594-602.

Kontiokari, T. T. (2001). Randomised trial of cranberry-lingonberry juice and lactobacillus GG drink for the prevention of urinary tract infections in. *BMJ.British Medical Journal (Clinical Research Ed.), 322*(7302), 1571-1571.

Kothari, A. (1994). Agricultural biodiversity: Luxury or necessity, seminar 418. In D. Rangnekar (Ed.), *Plant breeding, biodiversity loss and intellectual property rights*. London: Kingston University.

Krauss, R. R. M. (2000). AHA dietary guidelines : Revision 2000: A statement for healthcare professionals from the nutrition committee of the american heart association. *Stroke (1970), 31*(11), 2751-2766.

Kraybill, N. (1977). Pre-agricultural tools for the preparation of foods in the old world. In C. Reed (Ed.), *Origins of agriculture* (pp. 487-517). Hague, Netherlands: Mouton.

Kron, M. M. A. (2000). Hyperimmunoglobulinemia E in the absence of atopy and filarial infection: The huaorani of ecuador. *Allergy and Asthma Proceedings, 21*(6), 335-341.

Krukoff, B. A. (1937). Notes on the botanical components of curare. *Bulletin of the Torrey Botanical Club, 64*(6), 401.

Krukoff, B. A., & Smith, A. C. (1939). Notes on the botanical components of curare-II. *Bulletin of the Torrey Botanical Club, 66*(5), 305.

Kurokawa, K. K. (2007). Comparative metagenomics revealed commonly enriched gene sets in human gut microbiomes. *DNA Research, 14*(4), 169-181.

Kvist, L. P. (1987). Ethnobotanical aspects of lowland ecuador. *Opera Botanica,* (92), 83-108.

la Torre, L. L. (2009). Contrasting palm species and use diversity in the yucatan peninsula and the ecuadorian amazon. *Biodiversity and Conservation, 18*(11), 2837-2853.

Laird, S. A. (2002). *Biodiversity and traditional knowledge: Equitable partnerships in practice*. London: Earthscan.

Lancaster, P. P. A. (1982). Traditional cassava-based foods: Survey of processing techniques. *Economic Botany, 36*(1), 12-45.

Larrick J.J. W.(1983). Does hyperimmunoglobulinemia-E protect tropical populations from allergic disease? *Journal of Allergy and Clinical Immunology, 71*(2), 184-188.

Larrick, J. W., Yost, J. A., & Kaplan, J. (1978). Snake bite among the waorani indians of eastern ecuador. *Transactions of the Royal Society of Tropical Medicine and Hygiene, 72*(5), 542-543.

Larrick, J. J. W. (1979). Part one: Patterns of health and disease among the waorani indians of eastern ecuador. *Medical Anthropology, 3*(2), 147-189.

Larsen, C. S. (1997). *Bioarcheology: Interpreting behavior from the human skeleton*. Cambridge: Cambridge University Press.

Larsen, C. C. S. (1995). Biological changes in human populations with agriculture. *Annual Review of Anthropology, 24*(1), 185-213.

Laughlin, W. (1968). The demography of hunters: An eskimo example. In R. B. Lee (Ed.), *Man the hunter* (pp. 241-249). Chicago: Aldine.

Leaf, A., & Weber, P. C. (1987). A new era for science in nutrition. *The American Journal of Clinical Nutrition, 45*, 1048-1053.

Lee, M. (1989). *Indians of the oaks*. San Diego: San Diego Museum of Man.

Lee, R. B. (1968). What hunters do for a living or how to make out on scarce resources. In W. Laughlin (Ed.), *Man the hunter* (pp. 30-48). Chicago: Aldine.

Lee, R. B. (1980). Lactation, ovulation, infanticide, and women's work: A study of hunter-gatherer population regulation. In M. N. Cohen, R. S. Malpass & H. G. Klein (Eds.), *Biosocial mechanisms of population regulation* (pp. 321-347). New Haven, CT.: Yale University Press.

Lei, V. V. (1999). Degradation of cyanogenic glycosides by lactobacillus plantarum strains from spontaneous cassava fermentation and other microorganisms. *International Journal of Food Microbiology, 53*(2-3), 169-184.

Lempert, D. (1997). Commentary: Accountability in anthropological ethics-protecting our integrity and the peoples we serve. *Practicing Anthropology, 19*(2), 36-39.

Leonti, M. (2003). Antiquity of medicinal plant usage in two macro-mayan ethnic groups (mexico). *Journal of Ethnopharmacology, 88*(2-3), 119.

Leonti, M. M. (2002). Medicinal plants of the popoluca, méxico: Organoleptic properties as indigenous selection criteria. *Journal of Ethnopharmacology, 81*(3), 307-315.

Leonti, M. M. (2003). Medicinal flora of the popoluca, mexico: A botanical systematical perspective. *Economic Botany, 57*(2), 218-230.

Leopold, A. A. C. (1972). Toxic substances in plants and the food habits of early man. *Science (New York, N.Y.), 176*(4034), 512-514.

Leslie, P. P. W. (1989). Extreme seasonality of births among nomadic turkana pastoralists. *American Journal of Physical Anthropology, 79*(1), 103-115.

Letvin, N. L. (2005). Progress toward an HIV vaccine. *Annual Review of Medicine, 56*, 213-223.

Leung, A. Y. (1980). *Encyclopedia of common natural ingredients used in foods, drugs and cosmetics*. New York: John Wiley and Sons.

Levin, B. R. (1996). The evolution and maintenance of virulence in microparasites. *Emerging Infectious Diseases, 2*(2), 93-102.

Levine, M. (1995). Determination of optimal vitamin C requirements in humans. *The American Journal of Clinical Nutrition, 62*(6), 1347S.

Levy, S. S. B. (1998). The challenge of antibiotic resistance. *Scientific American, 278*(3), 46-53.

Lewallen, S. S. (1995). A population-based survey of the prevalence of refractive error in malawi. *Ophthalmic Epidemiology, 2*(3), 145-149.

Lewin L. (1923). *Die pfeilgitte*. Barth, Leipzig: Verlag.

Lewis, W. H. (1995). Medicinal plants as sources of new therapeutics. *Annals of the Missouri Botanical Garden,*16.

Ley, R. E., Hamady, M., Lozupone, C., Turnbaugh, P. J., Ramey, R. R., Bircher, J. S., Gordon, J. I. (2008). Evolution of mammals and their gut microbes. *Science, 320*(5883), 1947-1951.

Lin, R. I. (1994). Phytochemical and antioxidants. In I. Goldberg (Ed.), *Functional foods: Designer foods, pharmafoods, nutraceuticals* (pp. 393-453). New York: Aspen.

Linares, E. (1987). A study of four medicinal plant complexes of mexico and adjacent united states. *Journal of Ethnopharmacology, 19*(2), 153.

Lipp, F. F. J. (1989). Methods for ethnopharmacological field work. *Journal of Ethnopharmacology, 25*(2), 139-150.

Lipsitch, M. (2001). The rise and fall of antimicrobial resistance. *Trends in Microbiology, 9*(9), 438-444.

Lisiecki, L. E. (2005). A plio-pleistocene stack of 57 globally distributed benthic δ18O records. *Paleoceanography, 20*(1), 17-33.

London, D. S. (2006). Psychiatric agriculture: Systemic nutritional modification and mental health in the developing world. *Medical Hypotheses, 66*(6), 1234.

London, D. S. (2008). *Field notes on the waorani foragers of Ecuador* .unpublished.

London, D. S., & London, A. L. (2007). *We were taught to plant corn not to kill: Secret of the silence of the mayan people*. New Haven: Back Up Books International Human Rights Press.

Loreille, O. O. (2003). Evolution of ascariasis in humans and pigs: A multi-disciplinary approach. *Memórias do Instituto Oswaldo Cruz, 98*, 39-46.

Lorenz, K. (1990). Cereals and schizophrenia. *Advances in Cereal Technology, 10*, 435-469.

Lorri, W., & Svanberg, U. (1994). Lower prevalence of diarrhoea in young children fed lactic acid-fermented cereal gruels. *Food and Nutrition Bulletin, 15*, 57-63.

Lucena, M. (1992). *Asi vivían los aztecas*. Madrid: Anaya.

Lynch, N. R., Lopez, R., Isturiz, G., & Tenias-Salazar, E. (1983). Allergic reactivity and helminthic infection in amerindians of the amazon basin. *International Archives of Allergy and Applied Immunology, 72*, 369-372.

Maarse, H., & Visscher, C. (1989). *Volatile compounds in foods*. The Netherlands CIVO-TNO: Zeist.

MacDonald, A. A. S. (2002). Immunology of parasitic helminth infections. *Infection and Immunity, 70*(2), 427-433.

Maddocks, I., & Vines, A. P. (1966). The influence of chronic infection on blood-pressure in new guinea males. *Lancet, 2*(7457), 262-264.

Mann, C. C. (2006). *1491, the americas before columbus*. London: Granta.

Mann, G. V. (1962). Cardiovascular disease in african pygmies. A survey of the health status, serum lipids and diet of pygmies in congo. *Journal of Clinical Epidemiology, 15*(4), 341.

Mann, G. V. G. V. (1964). Cardiovascular disease in the masai. *Journal of Atherosclerosis Research, 4*(4), 289-312.

Marks, I. M., & Nesse, R. M. (1994). Fear and fitness: An evolutionary analysis of anxiety disorders. *Ethology and Sociobiology, 15*, 247-261.

Marlowe, F. W., & Berbesque, J. C. (2009). Tubers as fallback foods and their impact on hadza hunter-gatherers. *American Journal of Physical Anthropology, 140*(751), 758.

Martin, G. J. (1995). *Ethnobotany: A methods manual*. London: Chapman and Hall.

Martin, W. (2005). Molecular evolution: Lateral gene transfer. *Heredity, 94*, 565-566.

Martin, W. W. (1999). Mosaic bacterial chromosomes: A challenge en route to a tree of genomes. *BioEssays, 21*(2), 99-104.

Matricardi, P. M., Rosmini, F., Riondino, S., Fortini, M., Ferrigno, L., Rapicetta, M., & Bonini, S. (2000). Exposure to foodborne and orofecal microbes versus airborne viruses in relation to atopy and allergic asthma: Epidemiological study. *British Medical Journal, 320*, 412-417.

Matsumoto, H.; Nakamura, Y.; Iida, H.; Ito, K.; Ohguro, H. Comparative assessment of blackcurrant anthocyanins in rabbit and rat ocular tissues. Exp. Eye Res. 2006, 83, 348–356.

Matsuoka, Y. Y. (2005). Origin matters: Lessons from the search for the wild ancestor of maize. *Breeding Science, 55*(4), 383-390.

Mayr, E. (1961). Cause and effect in biology. *Science, 134*, 1501-1506.

McCarron, D. D. A. (1998). Biomedicine:Diet and blood pressure--the paradigm shift. *Science (New York, N.Y.), 281*(5379), 933-934.

McClintock, B. (1987). In Moore J. A. (Ed.), *The discovery and transposition of disposable elements*. New York: Garland Publishing.

McCune, L. M., & Johns, T. (2007). Antioxidant activity relates to plant part, life form and growing condition in some diabetes remedies. *Journal of Ethnopharmacology, 112*, 461-469.

McCune, L. M., Owen, P., & Johns, T. (2006). Flavonoids, xanthones and other antioxidant polyphenols. *Traditional Medicine for Modern Times: Antidiabetic Plants,* 293-299.

McDade, T. W., Williams, S., & Snodgrass, J. J. (2007). What a drop can do: Dried blood spots as a minimally invasive method for integrating biomarkers into population-based research. *Demography, 44*(4), 899-925.

McDaniel, E. G., & Hundley, J. M. (1958). Alkali-treated corn and niacin deficiency [Abstract]. *Fed. Proc.,* (17) 484.

McGee, J. J. (1976). A case of veno-occlusive disease of the liver in britain associated with herbal tea consumption. *Journal of Clinical Pathology, 29*(9), 788-794.

McLister, J. J. D. (2004). Effects of consumption of juniper ( ) on cost of thermoregulation in the woodrats and at different acclimation temperatures. *Physiological and Biochemical Zoology, 77*(2), 305-312.

McMurry, M. P. (1982). Dietary cholesterol and the plasma lipids and lipoproteins in the tarahumara indians: A people habituated to a low cholesterol diet after weaning. *The American Journal of Clinical Nutrition, 35*(4), 741.

McNicholl, B., Egan-Mitchell, B., & Stevens, F. M. (1981). History, genetics and natural history of celiac disease. In D. N. Walcher, & N. Kretchmer (Eds.), *Food nutrition and evolution* (pp. 179-199). New York: Masson Publishing.

Melendez, A. A. J. (2007). Inhibition of FcεRI-mediated mast cell responses by ES-62, a product of parasitic filarial nematodes. *Nature Medicine, 13*(11), 1375-1381.

Mellen, G. A. (1974). El uso de las plantas medicinales en guatemala. *Guatemala Indígena, 9*, 99-179.

Mellor, J. J. E. (1995). Schizophrenic symptoms and dietary intake of n−3 fatty acids. *Schizophrenia Research, 18*(1), 85-86.

Mercke, P. P. (2004). Combined transcript and metabolite analysis reveals genes involved in spider mite induced volatile formation in cucumber plants. *Plant Physiology (Bethesda), 135*(4), 2012-2024.

Messer, E. (1991). Systematic and medicinal reasoning in mitla folk botany. *Journal of Ethnopharmacology, 33*(1-2), 107.

Meyer, H. J. (1962). Pharmacology of the active principles of kavaroot (pipermethysticum forst). *Archives of the Institute of Pharmacodynamic Therapy, 138*, 505-536.

Miller, J. J. S. (2005). Sampling a diverse flora for novel biochemicals: An analysis of NCI collections from madagascar. *Economic Botany, 59*(3), 221-230.

Millspaugh, C. F. (1974). *An illustrated and descriptive guide to plants indigenous and naturalized in the united states which are used as medicine.* . New York: Dover Publications.

Mitchell, E. A. E. A. (1987). Clinical characteristics and serum essential fatty acid levels in hyperactive children. *Clinical Pediatrics, 26*(8), 406-411.

Moeller, S. S. M. (2006). Associations between intermediate age-related macular degeneration and lutein and zeaxanthin in the carotenoids in age-related eye disease study (CAREDS) Ancillary study of the women's health Initiative</subtitle>. *Archives of Ophthalmology (1960), 124*(8), 1151.

Moerman, D. E. (1979). Symbols and selectivity: A statistical analysis of native american medical ethnobotany. *Journal of Ethnopharmacology, 1*(2), 111.

Moerman, D. E., Pemberton, R. W., Kiefer, D., & Berlin, B. (1999). A comparative analysis of five medicinal floras. *Journal of Ethnobiology, 19*(1), 49-67.

Moerman, D. D. E. (2005). "Symbols and selectivity" revisited. *Journal of Ethnopharmacology, 100*(1-2), 40-42.

Mohabbat,O, Youngos,M.S., Merzad, A. A., Srivastava, R. N., Sediz, G. G., & Aram, G. N. (1976). An outbreak of hepatic veno-occlusive disease in north-west afganistan. *Lancet, 2*, 269-271.

Møller, L. L. N. (2007). Human antibody recognition of anisakidae and trichinella spp. in greenland. *Clinical Microbiology and Infection, 13*(7), 702-708.

Money, N. P. (2007). *The triumph of fungi: A rotten history*. Oxford: Oxford University Press.

Monteith, J. L. (1965). Light distribution and photosynthesis in field crops. *Annals of Botany, 29*(1), 17.

Moreau, E. (2010). Immunity against helminths: Interactions with the host and the intercurrent infections. *Journal of Biomedicine & Biotechnology, 2010*

Morgan, R. (1973). Refractive problems in northern natives. *Can J Ophthalmol, 8*, 226-228.

Morris, A. (1999). The agricultural base of the pre-incan andean civilizations. *The Geographical Journal,* 286.

Morton, J. J. F. (1972). Further associations of plant tannins and human cancer. *Pharmaceutical Biology, 12*(1), 1829-1841.

Moshi, M. M. J. (2005). Plants used to treat epilepsy by tanzanian traditional healers. *Journal of Ethnopharmacology, 97*(2), 327-336.

Murphy, D. J. (2007). *Plant breeding and biotechnology: Societal context and the future of agriculture*. Cambridge: Cambridge University Press.

Murphy, D. J. (2008). *Peoples, plants and genes*. Oxford: Oxford University Press.

Murray, S. S., Schoeninger, M. J., Bunn, H. T., Pickering, T. R., & Marlett, J. A. (2001). Nutritional composition of some wild plant foods and honey used by hadza foragers of tanzania.Journal of food composition and analysis *, 14*, 3-13.

Muskiet, F. A. J. F. A. J. (2010). Lessons from shore-based hunter-gatherer diets in east africa. *Human brain evolution the influence of freshwater and marine food resources* (pp. 77-104).

Nabhan, G. P. (1989). *Enduring seeds: Native american agriculture and wild plant conservation*. San Francisco: North Point Press.

Nabhan, G. P. (2005). *Some like it hot: Food, genes and cultural diversity*. Washington, D.C.: Island Press.

Nadel, D. (1999). The oldest ever brush hut plant remains from ohalo II, jordan valley, israel (19,000 BP). *Antiquity, 73*(282), 755.

Nadel, D. D. (2004). From the cover: Stone age hut in israel yields world's oldest evidence of bedding. *PNAS : Proceedings of the National Academy of Sciences, 101*(17), 6821-6826.

Nahrstedt, A. A. (1985). Cyanogenic compounds as protecting agents for organisms. *Plant Systematics and Evolution, 150*(1-2), 35-47.

National Research Council. (1975). *Underexploited tropical plants with promising economic value*. Washington, D.C.: National Academy Press.

National Research Council. (1989). *Lost crops of the incas: Little known plants of the andes with promise for worldwide cultivation*. Washington, D.C.: National Academy Press.

Naughton, J. M., O'Dea, K., & Sinclair, A. J. (1986). Animal foods in traditional australian aboriginal diets: Polyunsaturated and low in fat. *Lipids, 21*(11), 684-690.

Neel, J. V. (1964). Studies on the xavante indians of the brazilian mato grosso. *American Journal of Human Genetics, 16*(1), 52.

Neel, J. V. (1977). Health and disease in unacculturated amerindian population. *Health and Disease in Tribal Societies,* , 155-177.

Neish, A. S. (2009). Microbes in gastrointestinal health and disease. *Gastroenterology, 136*(1), 65-80.

Nesse, R. R. M. (2006). Medicine needs evolution. *Science (New York, N.Y.), 311*(5764), 1071-1071.

.

Nesse, R. M. (2005). Natural selection and the regulation of defenses: A signal detection analysis of the smoke detector principle. *Evoluation and Human Behavior, 26*, 88-105.

Nesse, R. M. (2007). The importance of evolution for medicine. In W. R. Trevathan, & E. O. Smith (Eds.), *Evolutionary medicine, second edition* (2nd ed., pp. 416-432). New York: Oxford University Press.

Nesse, R. M., & Stearns, S. C. (2008). The great opportunity: Evolutionary applications to medicine and public health. *Evolutionary Applications, 1*, 28-48.

Nesse, R. M., & Williams, G. (1994). *Why we get sick: The new science of darwinian medicine*. New York: Times Books.

Nesse, R. R. M. (2008). What evolutionary biology offers public health. *Bulletin of the World Health Organization, 86*(2), 83-83.

Niewinski, M. M. (2008). Advances in celiac disease and gluten-free diet. *Journal of the American Dietetic Association, 108*(4), 661.

Nishiyama, I. (1971). Evolution and domestication of the sweet potato. *Botanical Magazine, 84*, 377-387.

O'Keefe, J. J. H. (2008). Dietary strategies for improving post-prandial glucose, lipids, inflammation, and cardiovascular health. *Journal of the American College of Cardiology, 51*(3), 249-255.

Oakley, K. P. (1959). Contributions on trepanning or trephination in ancient and modern times. *Man (London), 59*, 93.

O'Dea, K. K. (1984). Marked improvement in carbohydrate and lipid metabolism in diabetic australian aborigines after temporary reversion to traditional lifestyle. *Diabetes (New York, N.Y.), 33*(6), 596-603.

O'Dea, K. K. (1991). Traditional diet and food preferences of australian aboriginal hunter-gatherers [and discussion]. *Philosophical Transactions.Biological Sciences, 334*(1270), 233-241.

Oehme, F. W. (1978). Traditional diet and food preferences of australian aboriginal hunter-gatherers. In R. F. Keeler, K. R. Van Kampen & L. F. James (Eds.), *Effects of poisonous plants in livestock* (pp. 67-80). New York: Academic Press.

Ohira, A., Ueda, T., Ohishi, K., Hiramitsu, T., Akeo, K., & Obara, Y. (2008). Oxidative stress in ocular disease. *Nippon Ganka Gakkai Zasshi, 112*(1), 22-29.

Oke, O. L. (1977). The prophylactic action of cassava. *Proceedings of the Fourth Symposium of the International Society for Tropical Root Crops,* Ottawa.

Orellana, S. L. (1987). *Indian medicine in highland guatemala*. Albuquerque: University of New Mexico Press.

Ortiz de Montellano, B., & Browner, H. (1985). *Chemical bases for medicinal plant (sonora, mexico)*. Austin: Benson Latin American Collection.

Pare, P. P. W. (1999). Plant volatiles as a defense against insect herbivores. *Plant Physiology (Bethesda), 121*(2), 325-332.

Parke, D. V. (1968). *Biochemistry of foreign compounds*. Oxford: Pergamon Press.

Partridge, L., & Gems, D. (2006). Beyond the evolutionary theory of ageing, from functional genomics to evo-gero. *Trends in Ecology & Evolution, 21*(6), 334-340.

Pédron, T., & Sansonetti, P. (2008). Commensals, bacterial pathogens and intestinal inflammation: An intriguing ménage à trois. *Cell Host and Microbe, 3*(6), 344-347.

Peeke, C. M. (1973). *Preliminary grammer of the auca*. Oklahoma: Norman: Summer Institute of Linguistics.

Peeke, C. M. (2003). *A bibliography of the waorani of ecuador.* (). Dallas, TX.: SIL International.

Pennington, R. (2001). Hunter-gatherer demography. In C. Panter-Brick, R. H. Layton & P. Rowley-Conwy (Eds.), *Hunter-gatherers: An interdisciplinary perspective* (pp. 171-266). Cambridge: Cambridge University Press.

Pereira, M. M. E. (1989). Lactation and care for unrelated infants in forest-living ringtailed lemurs. *American Journal of Primatology, 18*(2), 101-108.

Perrot E, V. E. (1913). *Poisons des fleches et poisons d'epreuve*. Paris: Vigot Freres.

Peterson, D. A., Frank, D. N., Pace, N. R., & Gordon, J. I. (2008). Metagenomic approaches for defining the pathogenesis of inflammatory bowel diseases. *Cell Host and Microbe, 3*(6), 417-427.

Peterson-Burch, B. B. D. (2000). Retroviruses in plants? *Trends in Genetics, 16*(4), 151-152.

Petry, T. W. (1984). Characterization of hepatic DNA damage induced in rats by the pyrrolizidine alkaloid monocrotaline. *Cancer Research (Baltimore), 44*(4), 1505.

Phelan, P. L., & Stinner, B. R. (1992). Microbial mediation of plant-herbivore ecology. In G. A. Rosenthal, & M. R. Berenbaum (Eds.), *Herbivores: Their interactions with secondary plant metabolites* (). New York: Academic Press.

Phillips, O. L. (1996). Some quantitative methods for analyzing ethnobotanical knowledge. In M. N. Alexiades (Ed.), *Selected guidelines for ethnobotanical research: A field manual* (pp. 171-197). New York: The New York Botanical Garden.

Phillips, O. O. (1993). The useful plants of tambopata, peru: I. statistical hypotheses tests with a new quantitative technique las plantas útiles de tambopata, perú: I. pruebas estadisticas de hipótesis etnobotánicas con una nueva técnica cuantitativa. *Economic Botany, 47*(1), 15-32.

Phytochemical diversity and redundancy in ecological interactions In Romeo J. T., Sanders J. A. (Eds.), . New York: Plenum Press.

Pichersky, E. (2004). Plant scents what we perceive as a fragrant perfume is actually a sophisticated tool used by plants to entice pollinators, discourage microbes and fend off predators. *American Scientist, 92*, 514.

Piechulla, B. B. (2003). Plant scents ? mediators of inter- and intraorganismic communication. *Planta, 217*(5), 687-689.

Piperno, D. D. R. (2001). The earliest archaeological maize (zea mays L.) from highland mexico: New accelerator mass spectrometry dates and their implications. *PNAS : Proceedings of the National Academy of Sciences, 98*(4), 2101-2103.

Piperno, D. D. R. (2004). Processing of wild cereal grains in the upper palaeolithic revealed by starch grain analysis. *Nature (London), 430*(7000), 670-673.

Pirie, N. W. (1987). *Leaf protein and its by-products in human and animal nutrition*. Cambridge: Cambridge University Press.

Plotkin, M., & Famolare, L. (Eds.). (1992). *Sustainable harvest and marketing of rain forest products*. Washington, D.C.: Island Press.

Pope, K. K. O. (2001). Origin and environmental setting of ancient agriculture in the lowlands of mesoamerica. *Science (New York, N.Y.), 292*(5520), 1370-1373.

Popkin, B. B. (2007). The nutrition transition in high- and low-income countries: What are the policy lessons? *Agricultural Economics, 37*, 199-211.

Porres, J. J. M. (2003). Effect of natural and controlled fermentation on chemical composition and nutrient dialyzability from beans (L.). *Journal of Agricultural and Food Chemistry, 51*(17), 5144-5149.

Poulter, N. R. (1985). Migration-induced changes in blood pressure: A controlled longitudinal study. *Clinical and Expiremental Pharmacology and Physiology, 12*(3), 211-216.

Poulter, N. R., Khaw, K. T., Mugambi, M., Peart, W. S., Rose, G., & Sever, P. (1985). Blood pressure patterns in relation to age, weight and urinary electrolytes in three kenyan communities. *Transactions of the Royal Society of Tropical Medicine and Hygiene, 79*, 389-392.

Praba-Egge, A. D., Cone, S. W., Araim, O., Freire, I. L., Paida, G. V., Escalante, J., Merrell, R. C. (2003). Snakebites in the rainforests of ecuador. *World Journal of Surgery, 27*(2), 234.

Prance, G. T. (1972). Ethnobotanical notes from amazonian brazil. *Economic Botany, 26*(3), 221.

Prevalence of myopia in school children in vanuatu. (1985). *Acta Ophthalmologica (Oxford, England), 63*(3), 323-326.

Price P.P. (1984). Immunological consequences of intestinal helminth infections. humoral responses to ovalbumin. *Parasite Immunology, 6*(6), 499-508.

Prinz, A. (1990). Misunderstandings between ethnologists, pharmacologists and physicians in the field of ethnopharmacology. In J. Fleurentin, P. Cabalion, G. Mazars, J. Dos Santos & C. Younos (Eds.), *Ethnopharmacologie: Sources, methodes, objectifs* (pp. 95-99). Metz, France: ORSTOM Editions.

Profet, M. (1988). The evolution of pregnancy sickness as protection to the embryo against pleistocene teratogens. *Evolutionary Theory, 8*, 177-190.

Profet, M. (1991). The function of allergy: Immunological defense against toxins. *The Quarterly Review of Biology,* 23.

Profet, M. (1992). Pregnancy sickness as adaptation: A deterrent to maternal ingestion of teratogens. In J. Barkow, L. Cosmides & J. Tooby (Eds.), *The adapted mind: Evolutionary psychology and the generation of culture* (pp. 327-365). New York: Oxford University Press.

Purves, W. K., Sadava, D., Orians, G. H., & Heller, C. (2004). *Life: The science of biology, 7th ed.* . New York: W.H. Freeman.

Qin, J. (2010). A human gut microbial gene catalogue established by metagenomic sequencing. *Nature, 464*, 59-65.

Raul Alvarez-Venegas, R., Sadder, M., Hlavacka, A., Baluška, F., Xia, Y., Lu, G., Avramova, Z. (2006). The *arabidopsis* homolog of trithorax, ATX1, binds phosphatidylinositol 5-phosphate, and the two regulate a common set of target genes . *Proceedings of the National Academy of Sciences of the United States of America, 103*(15), 6049-6054.

Rausser, G. C., & Small, A. A. (2000). Valuing research leads: Bioprospecting and the conservation of genetic resources. *Journal of Political Economy,*

Reid, W. W. V. (1995). Biodiversity and health: Prescription for progress. *Environment (Washington, D.C.), 37*(6), 12-39.

Reinhard, K. J. (1988). Cultural ecology of prehistoric parasitism on the colorado plateau as evidenced by coprology. *American Journal of Physical Anthropology, 77*(3), 355-366.

Reinhard, K. J., Ambler, R., & McGuffie, M. (1985). Diet and parasitism at dust devil cave. *American Antiguity, 50*(4), 819-824.

Rhone, M. M. (2008). Phytochemicals and age-related eye diseases nutrition reviews©, vol. 66, no. 8. *Nutrition Reviews, 66*(8), 465-472.

Richards, T. T. A. (2006). Evolution of filamentous plant pathogens: Gene exchange across eukaryotic kingdoms. *Current Biology, 16*(18), 1857-1864.

Richardson, A., & Puri, B. (2002). A randomized double-blind, placebo-controlled study of the effects of supplementation with highly unsaturated fatty acids on ADHD-related symptoms in children with specific learning difficulties. *Progress in Neuro-Psychopharmacology and Biological Psychiatry, 26*(2), 233-239. doi: 10.1016/S0278-5846(01)00254-8

Richardson, A. A. O. (2006). Horizontal gene transfer in plants. *Journal of Experimental Botany, 58*(1), 1-9.

Riog, J. y. M. (1945). *Plantas medicinales, aromatics and venenosas de cuba*. Havana, Cuba: Cultural.

Rissanen, T. H. (2003). Low intake of fruits, berries and vegetables is associated with excess mortality in men: The kuopio ischaemic heart disease risk factor (KIHD) study. *The Journal of Nutrition, 133*(1), 199.

Rival, L. (1993). The growth of family trees: Understanding huaorani perceptions of the forest. *Man, 28*(4), 635-652.

Rival, L. M. (2002). *Trekking through history: The huaorani of amazonian ecuador*. New York: Columbia University Press.

Rogozov, V. (2008). Letter to the editor: The effectiveness of 112-year-old curare. *International Anestesia Research Society, 106*(2), 266.

Rook, G. A. W. (2008). Review series on helminths, immune modulation and the hygiene hypothesis: The broader implications of the hygiene hypothesis. *Immunology, 126*, 3-11.

Ross, P. P. J. (1996). A changing hausa diet. *Medical Anthropology, 17*(2), 143-163.

Rosseta, L. (1996). Non-pathological source of variablility in fertility between/within subject and between populations. *Variability in Human Fertility,* , 91-105.

Round, J. L., & Mazmanian, S. K. (2009). The gut microbiota shapes intestinal immune responses during health and disease. *National Review of Immunology, 9*(5), 313-323.

Roys, R. L. (1931). *The ethnobotany of the maya*. New Orleans: Tulane Univ. Press.

Rozin, P. P. (1986). Food likes and dislikes. *Annual Review of Nutrition, 6*(1), 433-456.

Ruel, G. (2008). Low-calorie cranberry juice supplementation reduces plasma oxidized LDL and cell adhesion molecule concentrations in men. *British Journal of Nutrition, 99*(2), 352.

Ruff, C. C. B. (1997). Body mass and encephalization in pleistocene homo. *Nature (London), 387*(6629), 173-176.

Salzano, F. M. (1988). *South american indians: A case study in evolution*. Oxford: Claredon Press.

San Giovanni, J. P., Chew, E. Y., & Clemons, T. E. (2007). The relationship of dietary carotenoid and vitamin A, E, and C intake with age-related macular degeneration in a case-control study: AREDS report no. 22. *Arch Ophthalmol., 125*, 1225-1232.

Saouma, E. (1992). Preambulo. In J. E. Hernandez, & J. Leon (Eds.), *Cultivos marginados: Otra perspective de 1492* (). Mexico: Organization para la Agricultura y Alimentacion, Produccion y Proteccion Vegetal.

Sawaya, A. L., Dallal, G., Solymos, G., de Sousa, M. H., Ventura, M. L., Roberts, S. B., & Sigulem, D. M. (1995). Obesity and malnutrition in a shantytown population in the city of sao paulo, brazil. *Obesity Research, 3 Suppl 2*, 107s-115s.

Schery, R. W. (1972). *Plants for man*. New Jersey: Prentice-Hall.

Schildknecht, H. (1977). Protective substances of anthropods and plants. *Pont. Acad. Sci. Scripta Varia, 3*, 59-107.

Schimel, D. D. (2006). Ecology: Climate change and crop yields: Beyond cassandra. *Science (New York, N.Y.), 312*(5782), 1889-1890.

Schneider, W. (1986). The strange fate of pyrrolizidine alkaloids. In Chapman,R.F.,Bernays,E.A.Stoffolano,J.G. (Ed.), *Perspectives in chemoreception behavior* (pp. 123-142). New York: Springer.

Schobert, H. H. H. H. (2002). Chemicals and materials from coal in the 21st century. *Fuel (Guildford), 81*(1), 15-32.

Schoeninger, M. J. (2001). Composition of tubers used by hadza foragers of tanzania. *Journal of Food Composition and Analysis, 14*(1), 15-25.

Schoental, R. (1968). Toxicology and carcinogenic action of pyrrolizidine alkaloids. *Cancer Research (Baltimore), 28*(11), 2237.

Schoental, R. (1982). Health hazards of pyrrolizidine alkaloids: A short review. *Toxicology Letters, 10*(4), 323-326.

Schreckinger, M. E., Lotton, J., Lila, M. A., & de Mejia, E. G. (2010). Berries from south america: A comprehensive review on chemistry, health potential, and commercialization. *Journal of Medicinal Food, 13*(2), 233-246. doi: 10.1089/jmf.2009.0233

Schultes, R. E. (1994). Burning the library of amazonia. *The Sciences, 34*(2), 24-30.

Schultes, R. E., & Hofmann, A. (1992). *Plants of the gods: Origins of hallucinogenic use* (2nd ed.). New York: McGraw-Hill Book Company.

Schultes, R. E., & von Reis, S. (Eds.). (1995). *Ethnobotany: Evolution of a discipline*. London: Chapman and Hall, Ltd.

Shaper, A. G. (1963). Serum lipids in three nomadic tribes of northern kenya. *The American Journal of Clinical Nutrition, 13*(3), 135.

Shaper, A. G., Wright, D. H., & Kyobe, J. (1969). Blood pressure and body build in three nomadic tribes of northern kenya. *East African Medical Journal, 46*(5), 273-281.

Sherman, P. (2001). Protecting ourselves from food spices and morning sickness may shield us from toxins and microorganisms in the diet. *American Scientist, 89*, 142.

Shipek, F. C.*The autobiography of delphina cuero*. Melno Park, CA.: Bellena Press.

Shipek, F. C. (1981). A native american adaptation to drought: The kumeyaay as seen in the san diego mission records 1770-1798. *Ethnohistory,* 295.

Shipek, F. C. (1982). Kumeyaay socio-political structure. *Journal of California and Great Basin Anthropology, 4*(2), 296-303.

Shuster, L. L. (1964). Metabolism of drugs and toxic substances. *Annual Review of Biochemistry, 33*(1), 571-596.

Sianto, L. L. (2005). The finding of echinostoma (trematoda: Digenea) and hookworm eggs in coprolites collected from a brazilian mummified body dated 600–1,200 years before present. *The Journal of Parasitology, 91*(4), 972-975.

Sianto, L. L. (2009). Animal helminths in human archaeological remains: A review of zoonoses in the past. *Revista do Instituto De Medicina Tropical De São Paulo, 51*(3), 119-130.

Simoons, F. J. (1981). Celiac disease as a geographic problem. In D. N. Walcher, & N. Kretchmer (Eds.), *Food nutrition and evolution* (pp. 179-199). New York: Masson Publishing.

Sing, C. F., Haviland, M. B., & Reilly, S. L. (1996). Genetic architecture of commonmultifactorial diseases. In D. Chadwick, & G. Cardew (Eds.), *Variation in the human genome (ciba foundation symposium 197)* (pp. 211-232). Chichester: Wiley Press.

Singh, M. M. M. (1976). Wheat gluten as a pathogenic factor in schizophrenia. *Science (New York, N.Y.), 191*(4225), 401-402.

Sinnett, P. F. (1973). Epidemiological studies in a total highland population, tukisenta, new guinea:: Cardiovascular disease and relevant clinical, electrocardiographic, radiological and biochemical findings. *Journal of Clinical Epidemiology, 26*(5), 265.

Skeller, E. (1954). Anthropological and ophthalmological studies on the angmagssalik eskimos. *Meddr Gronland, 107*, 167-211.

Smith, B. B. D. (2006). Eastern north america as an independent center of plant domestication. *PNAS : Proceedings of the National Academy of Sciences, 103*(33), 12223-12228.

Smith, B. D. (1998). *The emergence of agriculture*. New York: Scientific American Library.

Snowdon, R. R. J. (2004). Molecular markers in brassica oilseed breeding: Current status and future possibilities. *Plant Breeding, 123*(1), 1-8.

Sokol, H., Pigneur, B., Watterlot, L., Lakhdari, O., Bermúdez-Humarán, L. G., Gratadoux, J. J.,Langella, P. (2008). Faecalibacterium prausnitzii is an antiinflammatory commensal bacterium identified by gut microbiota analysis of crohn disease patients. *Proceedings of the National Academy of Sciences of the United States of America, 105*(43), 16731-16736.

Solbrig, O. T., & Solbrig, D. J. (1990). *No small potatoes: The importance of crops in history*. Boston, MA: Harvard University Press.

Soleri, D. D. (2005). Scenarios as a tool for eliciting and understanding farmers' biological knowledge. *Field Methods, 17*(3), 283-301.

Soubeyrand, B. B. (2002). Microbial evolution (communication arising): Antitoxin vaccines and pathogen virulence. *Nature (London), 417*(6889), 609-610.

Soustelle, J. (1955). *La vie quotidienne des azteques a la veille de la conquete espannole*. Paris: Hachette.

Spencer, P. P. S. (1987). Guam amyotrophic lateral sclerosis-parkinsonism-dementia linked to a plant excitant neurotoxin. *Science (New York, N.Y.), 237*(4814), 517-522.

Sperduto, R. (1983). Prevalence of myopia in the united states. *Arch Ophthalmol, 101*, 405-407.

Spielmann, K. K. A. (1989). A review: Dietary restrictions on hunter-gatherer women and the implications for fertility and infant mortality. *Human Ecology : An Interdisciplinary Journal, 17*(3), 321-345.

Stahl, A. B. (1984). Hominid dietary selection before fire [and comments and reply]. *Current Anthropology,* 151.

Stearns, S. C. (Ed.). (1999). *Evolution in health and disease*. Oxford: Oxford University Press.

Stearns, S. C. (1999). Introducing evolutionary thinking. In S. C. Stearns (Ed.), *Evolution in health and disease* (). Oxford: Oxford University Press.

Stearns, S. C. (2001). Evolution in health and disease: Work in progress. *The Quarterly Review of Biology, 76*, 417-432.

Stearns, S. C., & Koella, J. C. (Eds.). (2007). *Evolution in health and disease (2nd edition)*. New York: Oxford University Press.

Stecher, B., Robbiani, R., Walker, A. W., Westendorf, A. M., Barthel, M., Kremer, M., Hardt, W. D. (2007). Salmonella enterica serovar typhimurium exploits inflammation to compete with the intestinal microbiota. *PLoS Biology, 5*(10), 2177-2189.

Steinkraus, K. H. (1998). Bio-enrichment: Production of vitamins in fermented foods. In B. J. B. Wood (Ed.), *Microbiology of fermented foods, 2nd ed.* (pp. 603-621). London: Blackie Academic.

Stepp, J. R., Wyndham, F. S., & Zarger, R. K. (2002). Ethnobiology and biocultural diversity. *7th International Congress of Ethnobiology,* Athens, GA.

Stepp, J. J. R. (2001). The importance of weeds in ethnopharmacology. *Journal of Ethnopharmacology, 75*(1), 19-23.

Stewart, T. D. (1957). *Stone age skull surgery: A general review, with emphasis on the new world. annual report.* (). Washington, D.C.: Smithsonian Institution.

Stinson, S. S. (1992). Nutritional adaptation. *Annual Review of Anthropology, 21*(1), 143-170.

Stothers, L. (2002). A randomized trial to evaluate effectiveness and cost effectiveness of naturopathic cranberry products as prophylaxis against urinary tract infection in women. *Canadian Journal of Urology, 9*(3), 873-879.

Strassman, B. I., & Dunbar, R. (1999). Stone age legacies and modern medicine. *Evolution in Health and Disease,* 91-101.

Strassmann, B. I., & Dunbar, R. I. M. (1999). Human evolution and disease: Putting the stone age in perspective. In S. C. Stearns (Ed.), *Evolution in health and disease* (). Oxford: Oxford University Press.

Stross, B. (1973). Acquisition of botanical terminology by tzeltal children. *Inebriants and hypnotics, their origins and uses*. New York: Collier Books.

Summers, R. R. W. (2005). Trichuris suis therapy in crohn's disease. *Gut, 54*(1), 87-90.

Svarstad, H., & Dhillion, S. (Eds.). (2000). *Responding to bioprospecting: From biodiversity in the south to medicines in the north*. Oslo, Norway: Spartacus Forlag.

Swain, T. T. (1977). Secondary compounds as protective agents. *Annual Review of Plant Physiology, 28*(1), 479-501.

Syvanen, M., & Kado, C. I. (2002). *Horizontal gene transfer*. London: Academic Press.

Tabuti, J. R. S. (2003). Traditional herbal drugs of bulamogi, uganda: Plants, use and administration. *Journal of Ethnopharmacology, 88*(1), 19.

Tattersall, I. (1999). *Becoming human: Evolution and human uniqueness.* New York: Harcourt Brace.

Taylor, N. (1965). *Plant drugs that changed the world*. New York: Dodd, Mead.

Theakston, R. D., Laing, G. D., Fielding, C. M., Freire, A., Touzet, J. M., Vallejo, F. Warrell, D. A. (1995). Treatment of snake bites by bothrops species and lachesis muta in ecuador: Laboratory screening of candidate antivenoms. *Transactions of the Royal Society of Tropical Medicine and Hygiene, 89*, 550-554.

Theakston, R. D., Reid, H. A., Larrick, J. W., Kaplan, J., & Yost, J. A. (1981). Snake venom antibodies in ecuadorian indians. *The Journal of Tropical Medicine and Hygiene, 84*(5), 199-202.

Trevathan, W. R. (2007). Evolutionary medicine. *Annual Review of Anthropology, 36*, 139-154.

Trevathan, W. R., Smith, E. O., & McKenna, J. (Eds.). (2007). *Evolutionary medicine and health: New perspectives 2nd edition*. Oxford: Oxford University Press.

Tripplett, K. (1999). *Plant resin technology among colonial and modern maya of guatemala.* (Unpublished Ph.D.). University of Texas at Austin, Austin, TX.

Trotter, R. T. (1986). Informant consensus: A new approach for identifying potentially effective medicinal plants. In N. L. Etkin (Ed.), *Plants in*

indigenous medicine and diet: Biobehavioral approaches (pp. 91-112). Bedford Hills, New York: Redgrave.

Truswell, A. A. S. (1977). Ciba foundation symposium 49 - health and disease in tribal societies Ciba/Health diet and nutrition of hunter-gatherers. *Ciba Foundation Symposium 49 - Health and Disease in Tribal Societies,* , 213-226.

Truswell, A. S. (2001). Energy balance, food and exercise. *Nutrition and fitness: Metabolic studies in health and disease 4th international conference on nutrition and fitness, athens, may 2000. pt. 2* (pp. 13-25)

Truswell, A. S., Kennelly, B. M., Hansen, J. D. L., & Lee, R. B. (1972). Blood pressures of !kung bushmen in northern botswana. *American Heart Journal, 34*(1), 5-12.

Tučková, L. L. (1995). Molecular mimicry as a possible cause of autoimmune reactions in celiac disease? antibodies to gliadin cross-react with epitopes on enterocytes. *Clinical Immunology and Immunopathology, 74*(2), 170-176.

Turlings, T. T. C. J. (2006). Exploiting scents of distress: The prospect of manipulating herbivore-induced plant odours to enhance the control of agricultural pests. *Current Opinion in Plant Biology, 9*(4), 421-427.

Turnbaugh, P. J., Hamady, M., Yatsunenko, T., Cantarel, B. L., Duncan, A., Ley, R. E., Gordon, J. I. (2009). A core gut microbiome in obese and lean twins. *Nature, 457*(7228), 480-484.

Turnbaugh, P. J., Ley, R. E., Hamady, M., Fraser-Liggett, C. M., Knight, R., & Gordon, J. I. (2007). The human microbiome project. *Nature, 449*(7164), 804-810.

Turnbaugh, P. J., Ley, R. E., Mahowald, M. A., Magrini, V., Mardis, E. R., & Gordon, J. I. (2006). An obesity-associated gut microbiome with increased capacity for energy harvest. *Nature, 444*(7122), 1027-31.

Tyrrell, D. A. J. D. A. J. (1977). Ciba foundation symposium 49 - health and disease in tribal societies Ciba/Health aspects of infection in isolated communities. *Ciba Foundation Symposium 49 - Health and Disease in Tribal Societies,*137-153.

United Nations. (1992). Multilateral convention on biological diversity. *Earth Summit,* Rio de Janeiro.

Van Assche, F. F. A. (2001). Long-term consequences for offspring of diabetes during pregnancy. *British Medical Bulletin, 60*(1), 173-182.

Van Peer, P. (2003). The early to middle stone age transition and the emergence of modern human behaviour at site 8-B-11, sai island, sudan. *Journal of Human Evolution, 45*(2), 187.

Vavilov, N. I. (1926). Centres of origin of cultivated plants. *Bulletin of Applied Botany and Genetics, 16*, 139-248.

Vicente-Carbajosa, J. (1997). A maize zinc-finger protein binds the prolamin box in zein gene promoters and interacts with the basic leucine zipper transcriptional activator Opaque2. *PNAS : Proceedings of the National Academy of Sciences, 94*(14), 7685.

Vietmeyer, N. D. (1978). Neglected riches of nature. *The smithsonian book of invention* (). Washington, D.C.: Smithsonian Exhibition Books.

Visser, M. (1986). *Much depends on dinner: The extraordinary history, mythology, allure and obsessions of an ordinary meal.*. New York: Grove Press.

Vitte, C. C. (2006). Eukaryotic transposable elements and genome evolution special feature: Analysis of retrotransposon structural diversity uncovers properties and propensities in angiosperm genome evolution. *PNAS : Proceedings of the National Academy of Sciences, 103*(47), 17638-17643.

Voigt, R. R. G. (2001). A randomized, double-blind, placebo-controlled trial of docosahexaenoic acid supplementation in children with attention-deficit/hyperactivity disorder. *The Journal of Pediatrics, 139*(2), 189-196.

Vuorinen, T. T. (2004). Emission of plutella xylostella-induced compounds from cabbages grown at elevated CO2 and orientation behavior of the natural enemies. *Plant Physiology (Bethesda), 135*(4), 1984-1992.

Wadee, A. A. A. (1987). Development of specific IgE antibodies after repeated exposure to snake venom. *Journal of Allergy and Clinical Immunology, 80*(5), 695-698.

Wagner, G. (1998). Complexity matters. *Science (New York, N.Y.),* 1158.

Wagner, H. K. M. (1995). Immunostimulants and adaptogens from plants. In J. T. Amason (Ed.), *Phytochemistry of medicinal plants* (pp. 1-17). New York: Plenum Press.

Wahl, H. A. (1954). A preliminary study of the genus chenopodium in north america. *Bartonia, 27*, 1-46.

Walker, M. (2000). She's gotta have it. *New Scientist,* , 1-3.

Wang, Q. Q. (2006). Eukaryotic transposable elements and genome evolution special feature: Remarkable variation in maize genome structure inferred from haplotype diversity at the bz locus. *PNAS : Proceedings of the National Academy of Sciences, 103*(47), 17644-17649.

Warren, K. S., & Mahmoud, A. A. F. (1975). Algorithms in the diagnosis and management of exotic diseases. V. enterobiasis. *The Journal of Infectious Diseases, 132*(2), 229-232.

Wassen, H. (1935). Notes on southern groups of choco Indians in colombia. *Ethno Studier, 1*, 35-82.

Watkins, D. I., McAdam, S. N., Liu, X., Strang, C. R., Milford, E. L., Levine, C. G.Hughes, A. L. L.,N.L. (1992). New recombinant HLA-B alleles in a tribe of south american amerindians indicate rapid evolution of MHC class I loci. *Nature, 357*, 329-333.

Waxman, D. D. (1998). Pleiotropy and the preservation of perfection. *Science (New York, N.Y.), 279*(5354), 1210-1213.

Wein, E. E. (1995). Evaluating food use by canadian aboriginal peoples. *Canadian Journal of Physiology and Pharmacology, 73*(6), 9-64.

Weinstock, J. J. V. (2004). Helminths and harmony. *Gut, 53*(1), 7-9.

Wilk, R. R. (1981). *Agriculture, ecology and domestic organization among the kekchi maya.* (Ph.D., University of Arizona). *University of Arizona Press,*

Williams, D. D. E. (2001). The effect of indian or anglo dietary preference on the incidence of diabetes in pima indians. *Diabetes Care, 24*(5), 811-816.

Williams, G. C. (1991). The dawn of darwinian medicine. *The Quarterly Review of Biology,* 1.

Williams, G. C. (1992). *Natural selection: Domains, levels, and challenges*. New York: Oxford University Press.

Williams, R. T. (1959). *Detoxification methods*. New York: Wiley.

Wingert, T. (1995). Epidemiology of ametropia of US army recruits. *Military Medicine, 160*, 89-91.

Wink, M. M. (1986). Acquired toxicity ? the advantages of specializing on alkaloid-rich lupins to macrosiphon albifrons (aphidae). *Die Naturwissenschaften, 73*(4), 210-212.

Wink, M. M. (1988). Plant breeding: Importance of plant secondary metabolites for protection against pathogens and herbivores. *Theoretical and Applied Genetics, 75*(2), 225-233.

Wink, M. M. (2010) Introduction: Biochemistry, Physiology and Ecological Functions of Secondary Metabolites. Biochemistry of plant secondary metabolism 1-19

Wolf, S.S. (1989). Movement protein of tobacco mosaic virus modifies plasmodesmatal size exclusion limit. *Science (New York, N.Y.), 246*(4928), 377-379.

Wood, B. B. (1999). The human genus. *Science (New York, N.Y.), 284*(5411), 65-71.

Woodburn, J. (1968). An introduction to hazda ecology. In R. B. Lee, & I. DeVore (Eds.), *Man the hunter* (pp. 49-55). Chicago: Aldine.

World Cancer Research Fund, & American Institute for Cancer Research. (1997). *Food, nutrition, and the prevention of cancer: A global perspective.* Washington, D.C.: American Institute for Cancer Research.

World Health Organization (WHO). (2003). WHO/UN organizational fact sheet. *Traditional Medicine, 5*(134)

World Health Organization (WHO). (2005). *World health organization global database on obesity*

World Health Organization (WHO). (2007). *Global database*

Wrick, K. (1994). Potential role of functional food in medicine and public health. In I. Goldberg (Ed.), *Functional foods: Designer foods, pharmafoods, nutraceuticals* (pp. 480-495). New York: Aspen.

Yamaguchi, T., Sato, H., & Kawamura, K. (2000). Nutritional status, activity pattern, and dietary intake among the baka hunter-gatherers in the village camps in cameroon. *African Study Monographs, 21*(2), 67-82.

Yazdanbakhsh, M., Kremsner, P. G., & van Ree, R. (2002). Allergy, parasites, and the hygiene hypothesis. *Science (New York, N.Y.), 296*(5567), 490-494.

Yohn, C. T. (2005). Lineage-specific expansions of retroviral insertions within the genomes of african great apes but not humans and orangutans. *PLoS Biology, 3*(4), e110.

Yost, J. (1981). People of the forest. In S. M. Acosta (Ed.), *Ecuador: In the shadow of the volcanoes* (pp. 96-115). Quito, Ecuador: Ediciones Libri Mundi.

Yost, J. (1983). Shotguns, blowguns and spears: The analysis of technological efficacy. In R. B. Hames, & W. T. Vickers (Eds.), *Adaptive responses of native amazonians* (pp. 189-224). New York: Academic Press.

Youdim, K. A. (2000). Short-term dietary supplementation of blueberry polyphenolics: Beneficial effects on aging brain performance and peripheral tissue function. *Nutritional Neuroscience, 3*, 383.

Young, F. A., Leary, G. A., Baldwin, W. R., West, D. C., Box, R. A., Harris, E., & Johnson, C. (1969). The transmission of refractive errors within eskimo families. *American Journal of Optometry and Archives of American Academy of Optometry, 46*(9), 676-685.

Zaki, E. A. (2004). Plant retroviruses: Structure, evolution and future applications. *African Journal of Biotechnology, 2*(6), 136.

Zhang, G. J. (2006). Predicting the effect of climate change on global plant productivity and the carbon cycle. In J. I. L. Morrison, & M. D. Morecraft (Eds.), *Plant growth and climate change* (pp. 187-208). Oxford: Blackwell.

APPENDIX A

IRB APPROVAL FROM ARIZONA STATE UNIVERSITY OFFICE OF RESEARCH INTEGRITY AND ASSURANCE

ASU ARIZONA STATE UNIVERSITY
RESEARCH AND ECONOMIC AFFAIRS

Office of Research Integrity and Assurance

To:	Takeyuki Tsuda MC
From:	Carol Johnston, Chair Biosci IRB
Date:	10/27/2009
Committee Action:	**Expedited Approval**
Approval Date:	10/27/2009
Review Type:	Expedited F4 F7
IRB Protocol #:	0909004392
Study Title:	Hunter-Gathers and Double-Edged Dietary Swords: Food as Medicine Among Waorani Foragers of Amazonian Educator
Expiration Date:	10/26/2010

The above-referenced protocol was approved following expedited review by the Institutional Review Board.

It is the Principal Investigator's responsibility to obtain review and continued approval before the expiration date. You may not continue any research activity beyond the expiration date without approval by the Institutional Review Board.

Adverse Reactions: If any untoward incidents or severe reactions should develop as a result of this study, you are required to notify the Biosci IRB immediately. If necessary a member of the IRB will be assigned to look into the matter. If the problem is serious, approval may be withdrawn pending IRB review.

Amendments: If you wish to change any aspect of this study, such as the procedures, the consent forms, or the investigators, please communicate your requested changes to the Biosci IRB. The new procedure is not to be initiated until the IRB approval has been given.

Please retain a copy of this letter with your approved protocol.

APPENDIX B

LETTER OF INVITATION FROM KAWYMENO WAORANI COMMUNITY

COMUNIDAD HUAORANI DE KAWIMENO

COMUNIDAD DE KAWIMENO
RIO YASUNI
TERRITORIO HUAORANI

TELEFONO:
593-62382257
NUEVO ROCAFUERTE
(JUAN CARLOS CUENCA)

8 DE OCTUBRE, DEL 2009

A los comités fulbright a favor de Douglas Stuart London

La comunidad Huaorani de Kawimeno en el territorio Huaorani y ubicado en el rio Yasuni en Ecuador. Nosotros quisiéramos extender una invitación formal a Douglas Stuart London de Arizona State University, Medical Anthropology, School of Human Evolution and Social Change, Tempe, Arizona, los Estados Unidos de América (USA passaporte #457752577) para que el pueda trabajar en nuestra comunidad. Nosotros apoyamos sus esfuerzos para entender y estudiar los problemas relacionados con la dieta y salud que pertenece a la población Huaorani. Esto contribuirá a encontrar soluciones para mejorar el cuidado de salud para la gente Huaorani ya que nuestra comunidad está enfrentando fuertes obstáculos de mantener nuestra buena salud. Queremos trabajar con gente en quien confiamos para ayudarnos a construir nuestros propios recursos de salud. Douglas nos ha visitado y se ha quedado en nuestras comunidades algunas veces y nosotros estamos felices para dar una bienvenida oficial a su regreso. También estamos en d' acuerdo de dar a Douglas un lugar para hospedarse en nuestra comunidad, ayudar a Douglas si necesita traducir conversaciones (en caso de comunidades con diferente dialecto) además nosotros podemos introducir a Douglas a cualquier otra dirigente que se necesite para sus labores. Nosotros desde ya anticipamos trabajar juntos con Douglas para asegurar que el proyecto tiene éxito.

Atentamente,

1500285414

Presidente de comité de la comunidad de Kawimeno

Jack Jaramillo
Secretario
170254907-6

Miembros de la Junta Directiva del Comité de Kawimeno

APPENDIX C

LETTER OF SUPPORT FROM PEOPLE ALLIED FOR NATURE, LTD.

People Allied for Nature, Ltd.

225 WEST 34TH STREET, SUITE 1317
NEW YORK, NY 10122
(212) 279-7813
info@pansite.org

October 12, 2009

To the Fulbright Selection Committee:

I am the President of People Allied with Nature, Ltd. (PAN), a New York based not-for-profit corporation, which has been working with indigenous communities in Ecuador since 1994. I am writing this letter of support on behalf of Douglas London who is applying for a doctoral Fulbright research grant to study the anthropology of indigenous food systems in Ecuador. I had the opportunity to meet Douglas in Ecuador in January of 2009 and we talked about his research in the Amazon lowlands with the Huaorani.

I have also read his Fulbright proposal and believe that his research will prove invaluable to further develop our understanding of the medicinal value in food systems as a whole and be especially relevant to the diseases faced by indigenous people as they become part of the modern food system. Douglas focuses on a comparative approach across agricultural and foraging systems with a special focus on applied research of benefit to the people he studies. This topic deserves special attention because it can shed light on why indigenous populations have special issues with chronic disease beyond that experienced by the general population.

PAN is eager to see Douglas's project come to fruition and to make introductions to facilitate his work. Ecuador is an ideal place to study indigenous food systems because of the variety of food systems and environments. Our organization focuses on the relationship between the environment and the people living in it and we work in collaboration with local communities, universities as well as other Ecuadorian institutions. It is our strong belief that Douglas's Fulbright experience will not only provide an opportunity to develop a relationship with Ecuadorians working to improve the health and environment in Ecuador but also help foster links between Ecuador and the United States in the field of anthropology.

Sincerely,

Claude Nathan

CN:nc

APPENDIX D

REQUIRED MINIMAL INFORMATION FOR EACH PLANT ENTRY FOR KAWYMENO WAORANI FOOD SYSTEM

(Note: Circle Y/N or box Y/N if filling on computer ex. [Y]) (note: Red letters mean incomplete)

Study Priority Classification: Very High High Medium Low Very Low

Photos: A B C ? (Key: A. complete file. B. Incomplete file. C. No photos yet. ?=unknown status)

1. Full Info sheet completed (required for key foods) (S): Y or N

2. Plant name(s) Wao:

3. Plant names: Spanish/Quichua:

4. Plant names: English/ Scientific:

6A. On Davis list = Y or N 6B.Original on Felipe list = Y or N

7. Used by Quichua study pop. regularly: Y or N

8A. Type/size of plant:

KEY: Small tree up to 20 meters high = ST, Large tree over 20 meters high = LT, Bush under 3 meters = B, Small plant (up to one meter) = SP,

8B. Other info: Vine, Palm etc:

9. Other Description: (continue back of page if nec):

10. Food Use (F)= Y or N 11. How often eaten?

KEY: $$$$$ = Eaten daily all year, $$$$ = Eaten daily in season available, $$$ = Eaten 2-3 times a week, $$ = Eaten once a week, $ = eaten once a month

0$*= Eaten once a year

12. Cultivated: Y or N

13. Recently imported or discovered food? Y or N

14. Fruit Eaten: Y or N

15. If fruit, what season is fruit available:

16A. Any other part of plant eaten? Y or N

16B. What part?:

17. Eaten raw = Y or N 18. Eaten Cooked = Y or N

19. If cooked how? (continue back of sheet):

20. Used to hunt/fish as a poison?: Y or N How?

21. Medicinal Use (M): Y or N 22. How often used?

(KEY: &&&&& = used daily, &&&& = used weekly, &&& = used once or twice a month, && = used a few times a year, & = used once every year or two)

23. Recently imported/ discovered medicinal? Y or N

24. Potency Storage time: DAYS

25. Briefly if medicinal what used for and how prepared (continue back of sheet):

26. Eaten by principal food source animals regularly (AF)? Y or N

27. Used by food animals medicinally (AM): Y or N

28. How used by animals medicinally? (continue back of sheet):

29. Additional uses Non-medicinal/food uses: Y or N (Continue Back of sheet)

30. Other Miscellaneous Information

APPENDIX E

DISSERTATION HEALTH DATA SHEET

Datos de Salud Arizona State University Study					
Fecha y Lugar:					
1. Apellido	Nombre	Edad/sexo	Peso	Talle	Circ brazo
Anemia/Hernia/Ojos	Hongos/Leish/Urinaria	Vista D/I	Temperat	Grasa Piel	Presion Sang
2. Apellido	Nombre	Edad/sexo	Peso	Talle	Circ brazo
Anemia/Hernia/Ojos	Hongos/Leish/Urinaria	Vista D/I	Temperat	Grasa Piel	Presion Sang
3. Apellido	Nombre	Edad/sexo	Peso	Talle	Circ brazo
Anemia/Hernia/Ojos	Hongos/Leish/Urinaria	Vista D/I	Temperat	Grasa Piel	Presion Sang
4. Apellido	Nombre	Edad/sexo	Peso	Talle	Circ brazo
Anemia/Hernia/Ojos	Hongos/Leish/Urinaria	Vista D/I	Temperat	Grasa Piel	Presion Sang
5. Apellido	Nombre	Edad/sexo	Peso	Talle	Circ brazo
Anemia/Hernia/Ojos	Hongos/Leish/Urinaria	Vista D/I	Temperat	Grasa Piel	Presion Sang
6. Apellido	Nombre	Edad/sexo	Peso	Talle	Circ brazo
Anemia/Hernia/Ojos	Hongos/Leish/Urinaria	Vista D/I	Temperat	Grasa Piel	Presion Sang
7. Apellido	Nombre	Edad/sexo	Peso	Talle	Circ brazo
Anemia/Hernia/Ojos	Hongos/Leish/Urinaria	Vista D/I	Temperat	Grasa Piel	Presion Sang

APPENDIX F

FAMILY DIET HISTORY DATA COLLECTION FORM

Grupo de Familia (nombre patriarco):

Fecha:

Lugar: Quichua Community, Santa Teresita, Rio Napo, Agua Rico, Ecuador.

(Clave de contestas abajo: A. Varias veces por dia. B. Diario. C. Poco veces cada semana. D. Poco veces por mes. E. Poco veces por an~o. F.Casi Nunca)

1. Cuantas frutas come ud. por dia, semana o mes?

Que tipos de fruta come mas?

2.Cuanto carne come ud. por dia, semana o mes?

Que tipos de carne come ud. (domestico y de selva)?

3.Cuanto verduras come ud. por dia, semana o mes?

Que tipos de verduras come?

4.Cuanto aves come ud. domestico y de selva (pollo, pavo de monte etc) por dia, semana o mes?

Que tipos de aves come ud.?

5.Cuantos huevos come ud. por dia, semana o mes?

6.Cuanto sal come ud. con su comida por dia, semana o mes?

Si solo consigue sal cuando ud va pueblo (Rocafuerte) a comprar, por cuanto tiempo duro el sal y por cuanto tiempo esta sin sal por mes?

7. Cuanto azuca come con su comida (azuca/caramelos/colas/cana de azucar/miel) por dia, semana o mes?

Si solo consigue azucar cuando ud va pueblo (Rocafuerte) a comprar, por cuanto tiempo duro el azucar y por cuanto tiempo esta sin azucar por mes?

8. Cuanto arroz come ud. por dia, semana o mes?

Si solo consigue arroz cuando ud va pueblo (Rocafuerte) a comprar, por cuanto tiempo duro el arroz y por cuanto tiempo esta sin arroz por mes?

9A. Cuanto pan come ud. por dia, semana o mes?:

Si solo consigue pan cuando ud va pueblo (Rocafuerte) a comprar, por cuanto tiempo duro el pan y por cuanto tiempo esta sin pan por mes?

9B. Cuanto fideos/tallarin come ud. por dia, semana o mes?:

Si solo consigue fideos cuando ud va pueblo (Rocafuerte) a comprar, por cuanto tiempo duro los fideos y por cuanto tiempo esta sin fideos por mes?

10. Cuanto maiz come ud. por dia, semana o mes?:

Si solo consigue maiz cuando ud va pueblo (Rocafuerte) a comprar, por cuanto tiempo duro el maiz y por cuanto tiempo esta sin maiz por mes?

11) Cuanto yucca come ud. por dia, semana o mes?

Cuanto platano come ud. por dia, semana o mes?

12) Cuanto pescado come ud. por dia, semana o mes?

Que tipos de pescado come ud mas?

12.A) Cuantos veces frita comida en aceite por dia, semana o mes?

Cuantos veces frita comida en manteca por dia, semana o mes?

B) Si solo consigue aciete cuando ud va pueblo (Rocafuerte) a comprar, por cuanto tiempo duro el aciete y por cuanto tiempo esta sin aciete por mes?

14) Que plantas siembren en el chakra/patio?

15) Que animales tienen domesticado para comer?

16) Cuantos de estas animales, fruitas y verduras domesticado comen y cuantos venden?

17) Hay algunas comidas que ayuda curar prevenir enfermidades que ud tenia? Cuales son y como ayuda?

18) Ponga ud ingredientes extra al comida para mejorar el sabor o preservar la comidad o da fuerza? Que son estos ingredientes? Come se utilizo?

19) Cuantos veces por dia/semana/mes come comida que viene de los tiendas y NO fue consiguido de selva o chackra? (por ejemplo comida que viene en costales, botellas de plastico u vidrio, latas, packetes de plasticos?)

20) Que comidas compra en el tienda/pueblo?:

21) Cuando ud va pueblo (Rocafuerte) a comprar comida, por cuanto tiempo duro el comida y por cuanto tiempo esta sin comida de tienda por mes?

22) Cuantos veces por semana/mes come comida que fue consiguido de selva? Que comidas?

23) Cuantos veces por semana/mes come comida que fue consiguido de chakra? Que comidas?

Tome café?

APPENDIX G

KICHWA MEDICAL EXAM DATA COLLECTION FORM

Datos de Salud Arizona State University Study

Santa Teresita Fecha:

1. Apellido	Nombre	Edad/sexo	Peso	Talle	Circ brazo
_	_	_	_	_	_
Urina	Heces	Vista D/I	Temperat	Grasa Piel	Presión Sang

2. Apellido	Nombre	Edad/sexo	Peso	Talle	Circ brazo
_	_	_	_	_	_
Urina	Heces	Vista D/I	Temperat	Grasa Piel	Presión Sang

3. Apellido	Nombre	Edad/sexo	Peso	Talle	Circ brazo
_	_	_	_	_	_
Urina	Heces	Vista D/I	Temperat	Grasa Piel	Presión Sang

4. Apellido	Nombre	Edad/sexo	Peso	Talle	Circ brazo
_	_	_	_	_	_
Urina	Heces	Vista D/I	Temperat	Grasa Piel	Presión Sang

5. Apellido	Nombre	Edad/sexo	Peso	Talle	Circ brazo
_	_	_	_	_	_
Urina	Heces	Vista D/I	Temperat	Grasa Piel	Presión Sang

6. Apellido	Nombre	Edad/sexo	Peso	Talle	Circ brazo
_	_	_	_	_	_
Urina	Heces	Vista D/I	Temperat	Grasa Piel	Presión Sang

7. Apellido	Nombre	Edad/sexo	Peso	Talle	Circ brazo
_	_	_	_	_	_
Urina	Heces	Vista D/I	Temperat	Grasa Piel	Presión Sang

APPENDIX H

STATISTICAL CALCULATIONS

Age- and Sex-Stratified BMI Statistical Calculations						
Kawymeno Waorani Males						
Age	18-28	29-39	40-49	50-59	60-69	70-79
n =	3	5	5	3		1
STDEV	1.70	3.71	0.84	3.52		n/a
MEDIAN	23.62	25.32	26.19	25.59		25.64
VARP	1.92	11.01	0.35	8.25		n/a
MEAN	23.47	25.26	26.19	23.69		25.64
Santa Teresita Kichwa Males						
Age	18-28	29-39	40-49	50-59	60-69	70-79
n =	6	3	5	4	7	4
STDEV	1.89	1.47	1.92	1.91	6.82	3.76
MEDIAN	24.49	24.39	26.08	25.30	23.27	25.30
VARP	2.98	1.43	2.93	2.75	10.07	10.59
MEAN	24.69	24.46	25.47	24.66	24.06	26.50
Kawymeno Waorani Females						
Age	18-28	29-39	40-49	50-59	60-69	70-79
n =	7	3	3	0	1	0
STDEV	2.59	4.42	0.90		n/a	
MEDIAN	23.96	23.62	25.68		21.62	
VARP	5.75	13.02	0.54		n/a	
MEAN	25.26	23.64	25.34		21.62	
Santa Teresita Kichwa Females						
Age	18-28	29-39	40-49	50-59	60-69	70-79
n =	5	4	5	3	5	2
STDEV	2.56	4.45	1.90	1.78	3.12	7.27
MEDIAN	23.31	21.40	21.08	22.57	21.37	25.82
VARP	5.25	14.87	2.88	2.12	7.78	26.42
MEAN	23.70	22.69	21.69	21.62	22.52	25.82

Age Stratified Blood Pressure Statistical Calculations						
Kawymeno Waorani						
Age	18-28		29-39		40-49	
n =	12		8		5	
BP	Diastolic	Systolic	Diastolic	Systolic	Diastolic	Systolic
STDEV	9.15	9.90	5.57	12.04	10.52	3.56
VARP	76.75	89.89	27.11	126.86	88.56	10.16
MEDIAN	55.00	97.00	58.00	91.50	61.00	91.00
MEAN	53.50	96.67	58.13	95.13	60.20	91.80
Age	50-59		60-69		70-79	
n =	3		1		1	
BP	Diastolic	Systolic	Diastolic	Systolic	Diastolic	Systolic
STDEV	3.46	6.08				
VARP	8.00	24.67				
MEDIAN	65.00	100.00	55.00	91.00	61.00	89.00
MEAN	67.00	103.00	55.00	91.00	61.00	89.00
Santa Teresita Kichwa						
Age	18-28		29-39		40-49	
n =	12		9		14	
BP	Diastolic	Systolic	Diastolic	Systolic	Diastolic	Systolic
STDEV	14.43	14.50	8.47	12.10	11.84	15.71
VARP	190.91	192.74	63.73	130.17	130.10	229.07
MEDIAN	70.00	115.00	70.00	108.00	70.00	111.00
MEAN	71.42	108.58	70.78	108.22	73.57	110.93
Age	50-59		60-69		70-79	
n =	9		9		4	
BP	Diastolic	Systolic	Diastolic	Systolic	Diastolic	Systolic
STDEV	3.91	8.84	6.50	15.24	12.91	9.00
VARP	13.58	69.43	37.51	206.40	125.00	60.75
MEDIAN	70.00	110.00	70.00	117.00	75.00	130.00
MEAN	70.56	110.11	68.78	117.22	75.00	129.50

Statistical Results	

MUAMC	
T-test	1.42375E-05
Kawymeno Waorani	
STDDEV	5.27
VARP	27.44
MEDIAN	24.25
MEAN	22.53
Santa Teresita Kichwa	
STDDEV	4.12
VARP	16.73
MEDIAN	26.75
MEAN	25.96

Tricep Skinfold	
T-test	4.58746E-20
Kawymeno Waorani	
STDDEV	3.24
VARP	10.35
MEDIAN	18.00
MEAN	17.32
Santa Teresita Kichwa	
STDDEV	3.11
VARP	9.52
MEDIAN	11.00
MEAN	11.77

Body Temperature	
T-test	1.44691E-05
Kawymeno Waorani	
STDDEV	0.77
VARP	0.58
MEDIAN	35.10
MEAN (C˚)	35.17
MEAN (F˚)	95.30
Santa Teresita Kichwa	
STDDEV	0.61
VARP	0.37
MEDIAN	36.00
MEAN (C˚)	35.92
MEAN (F˚)	96.66

Statistical Results			
Urine pH		Urine Density	
T-test	0.0012	T-test	0.0057
Kawymeno Waorani		Kawymeno Waorani	
STDDEV	0.90	STDDEV	7.04
VARP	0.76	VARP	46.22
MEDIAN	5.00	MEDIAN	1020.00
MEAN	5.33	MEAN	1019.33
Santa Teresita Kichwa		Santa Teresita Kichwa	
STDDEV	1.34	STDDEV	2.52
VARP	1.76	VARP	6.27
MEDIAN	6.00	MEDIAN	1015.00
MEAN	6.36	MEAN	1013.39

Mean IgE Levels	IU/mL	n =
Kawymeno Waorani Hunter-Gatherers	11,850	31
Westernizing Waorani	4,850	8
Santa Teresita Kichwa Sustinence Farmers	2,964	16
Modern US Populations	100	

(Source: Kron, et al. 2000)

Month of Birth for All Kawymeno Waorani born from 1995 to 2010	
Chi-square	26.87
p-values	0.005
alpha	0.05
degrees of freedom	11

Number of Monkeys Consumed per Month	
Chi-square	
p-values	
alpha	
degrees of freedom	

Note: All food system comparison figures are only total numbers of groups, thus food system analyses are descriptive in nature rather than quantitative and thus have no statistical analysis done on them.