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The Children of Amarna: Disease and Famine in the Time of Akhenaten

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By

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ABSTRACT

What is now known as Amarna, Egypt there once stood a grand city. Hastily built and quickly abandoned, this once capital city of Egypt was the brainchild of the Pharaoh Akhenaten. In 2002 the final resting place of the inhabitants who populated this ancient city were discovered. Since excavations began at the South Tombs Cemetery an unusual high number of individuals aged 3-25 have been excavated. Out of the 278 individuals excavated thus far, 45% of them fall to the adolescent and sub-adult category. Under normal circumstances this portion of the population tends to be the most robust and resilient, thus their representation in the archaeological record is generally very low. To determine why this was not the case for the communal population at Amarna the skeletal material was analyzed using the parameters set by *Standards* for the presence of certain features indicative of stress, such as, cribra orbitalia, linear enamel hypoplasias, and porotic hyperostosis. Out of 79 observable individuals aged 3-25, 68 show signs of cribra orbitalia and/or porotic hyperostosis, 33 have linear enamel hypoplasias, and at least four individuals show signs of possible scurvy, rickets, or folic acid deficiency. The result of such a high number of stress cases indicate a very unhealthy population who lacked access to proper nutrition, were malnourished, and diseased. This evidence completely contradicts the art of the time period, which depicts an abundance of food and resources.

ACKNOWLEDGEMENTS

Very special thanks are due to my wonderful advisor, Dr. Jerome C. Rose for all his encouragement throughout my undergraduate and graduate studies with him and especially for his belief in me. Special thanks are also due to Dr. Justin M. Nolan and Dr. Peter S. Unger for supporting me in this endeavor by being on my thesis committee, Carl Hitt for always having all of the answers and the right paperwork, and Ashley Shidner for her support and excellent editing.

DEDICATION

I dedicate this thesis to my wonderful mother and father, Denise and Bob Kuckens, who have always supported me in everything I have ever done and, I know, who are especially proud about this accomplishment. Thank you for always believing in me and for always loving me.

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Introduction

The archaeological site we know today as Amarna (el-Amarna, Tell el-Amarna), was once the location of the hastily built city of one of Egypt's most famous and controversial pharaohs, Akhenaten. Situated between a rocky cliff face and the Nile River, this bustling capital had an estimated population of around twenty to fifty thousand people and covered an area of about eighty square miles. The city of Amarna, named Akhetaten, was inhabited around 15 to 20 years and was abandoned approximately five years after its founding pharaoh died and only had minor occupations over the years. Since Amarna was only inhabited for such a small period of time, it is a fundamental snapshot of life during this period in Egyptian history (Kemp 2006). This short occupation period is unique and affords archaeologists an opportunity to look into the lives of past people during a specific period of time that are often not available. It is unusual that there exists a single level site consisting of a sole population, representing one moment in time. The importance of this fact is that we are able to see a city and its people exactly how it was at one moment in time without the degree of disturbances that we normally see from future generations. This allows for a clearer interpretation of the population existing at this time, because the data are not skewed by changing social, environmental, and biological circumstances over time, such as age of death, disease frequencies, body stature, and traumas.

The city of Amarna has been excavated since 1892, and although spectacular tombs of the elites have been cleared, the burial grounds of the inhabitants who populated the city had yet to be discovered (Rose 2006:73). This was a peculiar circumstance since many people inhabited the city. The result of this unfortunate circumstance was a gap in information about the non-elites living at Amarna in the time of Akhenaten. This all changed in 2002 when Dr. Helen Fenwick, lecturer in Archaeology at Hull University in Hull, England, discovered two cemeteries belonging to the residents of Akhentaten and in 2003 another cemetery was located. There are a total of five cemeteries belonging to the residents of Amarna. At this time, Professor Berry Kemp, the Amarna Project director since 1977, asked Dr. Jerome Rose to do a bioarcheological study of the remains in order to develop a picture of the people of Amarna. This led to a surface collection expedition in 2005 and consecutive excavation seasons from 2006-2013 at the South Tombs Cemetery.

The excavation site is located southeast of the city adjacent to the elite tombs, and is aptly named the South Tombs Cemetery. In the 2006-2007 seasons two 5 by 35 meter trenches were dug in order to retrieve specimens (Rose and Zebecki: 2007) and in 2008, excavation continued at lower levels within the trenches. In 2009 excavation continued at the 'upper' site while a new location further 'down' the *wadi* was started in order to see if the demographics from the previous seasons extended across the cemetery. In 2010 excavation continued at the 'upper' and ‘lower’ sites, and a new excavation area was started towards the mouth of the *wadi* with the intention of determining the western limit of the burials in the cemetery.

As you will see below in figure 1 and 2, these three excavation areas are just a small proportion of the cemetery. Due to the fact that only a small proportion of the cemetery has been excavated at this time what results is a subsample of a sample. In the archaeological literature there have also been concerns that archaeological specimens being excavated are not accurately reflecting the living population. Charlotte Roberts and Keith Manchester masterfully specify this idea in the book, *The Archaeology of Disease*:

> “The populations being studied in paleopathology are dead and therefore may not be representative of the living group; biological anthropologists are dealing

with a sample of a sample of a sample… of the original living population, and total excavation of the cemetery is unusual. Partial excavation of a cemetery is the most common occurrence in archaeology and therefore only a portion of the original buried population will be examined; the differential disposal of males, females, and subadults and their subsequent excavation means biases in the produced data is inevitable…" Roberts and Manchester (1995:9)

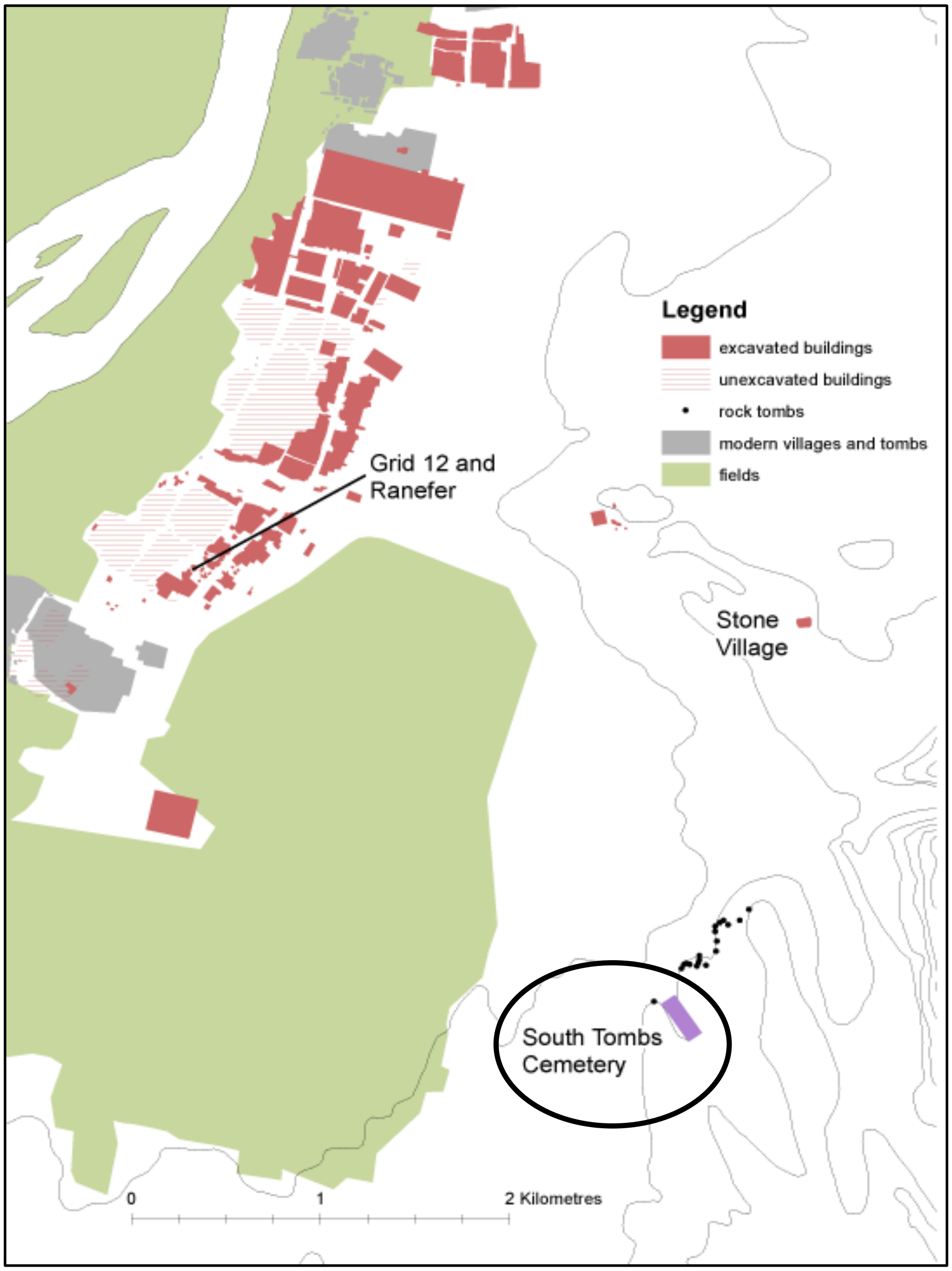

Figure 1. Excavation site for the City of Amarna, referencing the location of the South Tombs Cemetery in relation to the city proper (http://www.amarnaproject.com).

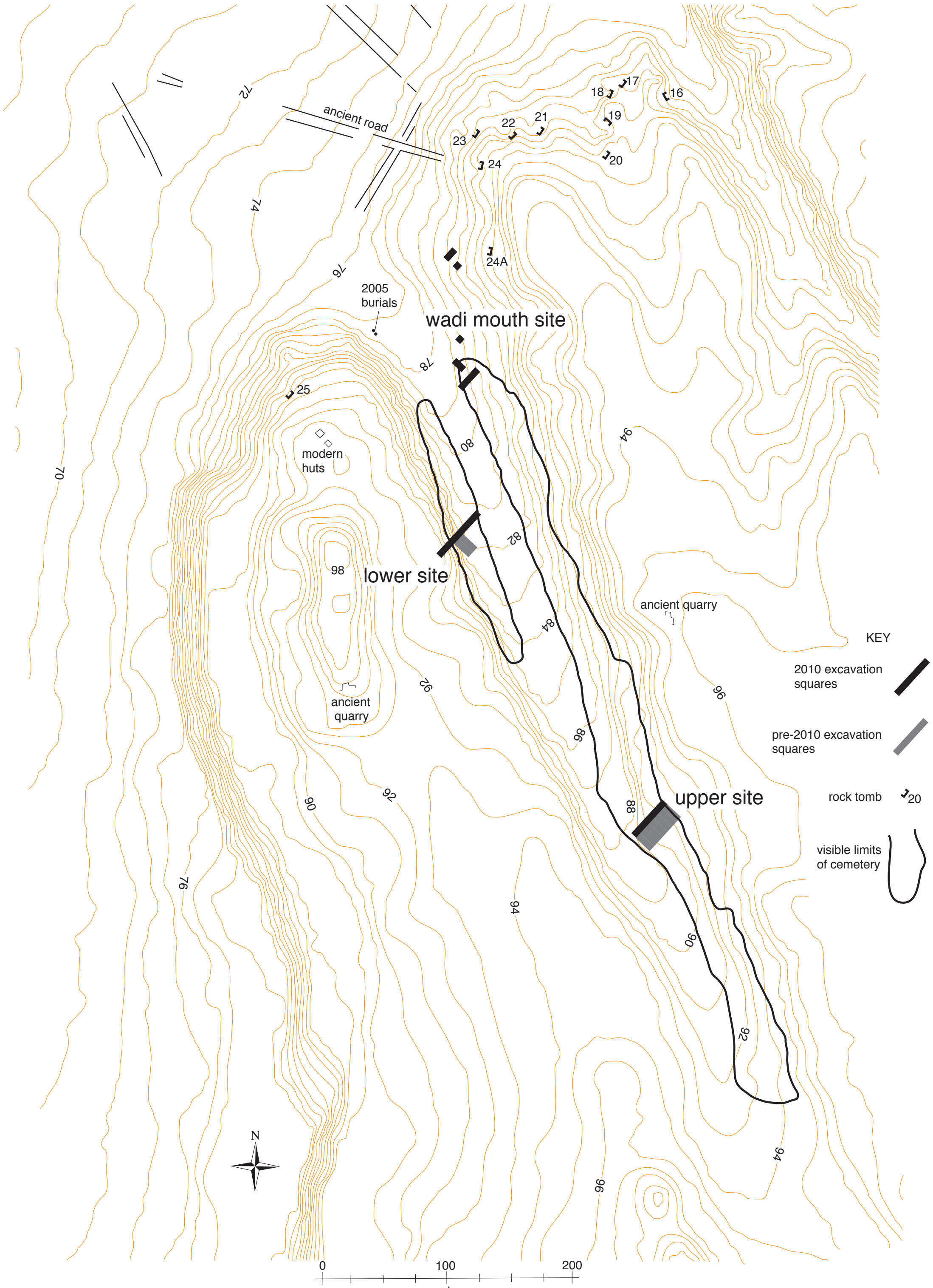

Figure 2. Excavation site for South Tombs Cemetery at Amarna, Egypt, excavation years 2006-2012 (http://www.amarnaproject.com).

While it is impossible to rectify the accurate representation of the living population conundrum it was possible, in this excavation, to rectify the subsample bias problem. In an interview with Barry Kemp, conducted on March 23, 2008 while I was at Amarna, Kemp assured me that a sample bias was not was not going to be a problem at this site. Kemp makes his assurances based on the random sample that was produced in the 2005 surface collection, which extended the length of the entire cemetery. Kemp believes that the cemetery extended into the Wadi and had expanded over time, which resulted in the washing away of an overall random portion of the cemetery down through the Wadi, producing the random sample of skeletal material that perfectly reflects what is being excavated (personal correspondence 2008).

Since the 2005 surface collection 278 ageable individuals have been recovered, in addition to isolated skulls and mandibles. 145 of these individuals were recognized as adults, those over the age of twenty-one, 26 were categorized as subadults, those whose ages ranged between sixteen through twenty years of age, 66 individuals fell in the three through fifteen year old aged ranged and were categorized as juveniles, and 41 individuals fell into the infant category of zero through two years of age.

Ageable Individuals	**Adults** **21+**	**Subadults** **16-20**	**Juveniles** **3-15**	**Infants** **0-2**
278	145	26	66	41

Figure 3. Breakdown of the South Tombs Cemetery (STC) populations into loosely defined socio-biological broad age categories.

In a conversation with the then head archaeologist at Amarna, Wendy Dolling pointed out that the standard in any ancient population, and other societies, contemporary with this time period, is an under representation of 0-3 year olds in the archaeological record as these societies have been known to bury their young in separate parts of a cemetery. However, the high rate of death seen in this age range is not unusual as they are more susceptible to mortality due to underdeveloped immune systems. On the other hand, a high rate of death for juveniles, those aged between 8-15, and sub-adults, those aged between 16-20, is very rare. Juveniles and sub-adults should be the least represented within the demography of the population for they are the most resilient of all age groups (Rose 2006: 76). It must be noted that juveniles and sub-adults are the most reliably aged group within a population due to consistent timely growth patterns in tooth development, so they are the easiest to identify (Cardoso 2007).

This Master's thesis will focus on finding the answer to why there are so many juveniles and subadults in the South Tombs Cemetery, as well as the possible explanation for their increased numbers. Could it have been an issue of malnutrition and poor health? Could it have been a case of recurrent infections and disease? Or could have it been a combination of them all? Chapter 1 will begin with a brief discussion of the history of Egypt and the Amarna period in order to put the people being studied into context. Chapter 2 will review the methods that were employed to correctly identify and analyze the skeletal material. Chapter 3 will explore the concept of population structure and demography and then analyze Amarna against four other ancient Egyptian demographic profiles in order to see if they are comparable. The chapter will conclude with an examination of Amarna's demographic profile by comparing it to epidemic profiles as I had previously done in my honors research thesis. The main hypothesis of the above-mentioned research was that an epidemic caused Amarna's distinct demography.

Although this idea seemed like a plausible theory at first, we now know that it only scratched the surface of what the people of Amarna really faced, but it is was what sparked the fires for further investigation. Chapter 4 examines indicators of stress, first in general, then detailing the ideas behind non-specific stress markers. Each non-specific stress marker; cribra orbitalia, porotic hypertosis, and linear enamel hypoplasias will be discussed thoroughly and then analyzed within the context of the South Tombs Cemetery skeletal material. Chapter 5 continues the discussion of indicators of stress with delayed growth where the ideas of malnutrition, undernutrition, and a high disease load lead to a state where the body lacks key vitamins and minerals in order to properly grow in a healthy and timely manner. Following the concepts of chapter 6; chapter 7 will discuss the ideas of diet and malnutrition and how they contribute to non-specific stress markers. In this chapter the Egyptian diet in the city of Akhetaten (modern day Amarna) will be specifically looked at, as well as the cultural reasons behind the populations lack of access to proper nutrition. Chapter 8 will look at some of the possible diseases that could have contributed to the unhealthy state of the populace of Amarna, as well as postulate upon the reasons for why those without skeletal markers of stress are in the archaeological record.

Chapter 1: A Short History of Egypt and Amarna

Egypt has a long and remarkable history filled with powerful pharaohs, beautiful queens, great works of art, and historical intrigue of war, desire, and power that began with Dynasties 1 and 2 in the Archaic Period *c*. 3100-2675 B.C.E. and continues on to today. In the midst of Egypt's rich history came a pivotal point during the New Kingdom period (*C.* 1539-1069 B.C.E.) when the controversial pharaoh, Akhenaten, ascended to the throne and dramatically changed the trajectory of Egyptian history. The Skeletons being studied derive form this period and the latter half of the 18th Dynasty.

Amenhotep IV, who changed his named to Akhenaten, was the eighth ruler of the 18th Dynasty and ascended to power after the death of his father Amenhotep III in *c.* 1353 B.C.E. Amenhotep III left Egypt "wealthier and more powerful than it had ever been before" (Van Dijk 2000: 272) and a time of peace reigned in the region. As in previous centuries, the sun god Ra ruled, and the pharaoh was his earthly representation. However, as we will soon see, this was about to change when Amenhotep IV took the worship of the sun god Ra to a whole new level. Nevertheless, Amenhotep IV cannot be considered the driving force or the sole creator of monotheism in Egypt for it was his father who paved the way for such thinking. As mentioned above, the sun god Ra ruled, but other deities existed and held sway and power. At the end of Amenhotep III's reign, Ra began to take on Osiris's aspects of darkness and the otherworld as well as incorporating the aspects of other gods and goddesses. This exacerbated the tide of thought to turn away from many creator gods to that of Ra as the supreme primeval creator.

Author Jacobus Van Dijk notes that although Amenhotep III's reign saw the beginnings of an increasingly solarized form of worship, he "appears to have tried to counterbalance this development by commissioning an enormous number of statues of a multitude of deities and by developing the cult of their earthy manifestations as sacred animals" (2000: 273). This, however, only intensified the importance of the sun god's role as it emphasized the idea that other deities were a part of Ra's creation alongside the animals and humans that they were sent down to protect. While these lesser deities were earthbound, Ra was alone and distant in the sky watching over his creations. It is around this same time that Ra became associated with Thebes, the most important religious center in Egypt, and its local god Amun. As a result, these two gods became one, making Amun-Ra the most important deity in all of Egypt and its priesthood politically and economically very powerful.

As detailed on some scarabs, it was Amun-Ra who "officially" crowned Amenhotep IV as the one chosen "to appear in glory for millions of years" (Van Dijk 2000: 274). There is, however, some controversy as to when exactly Amenhotep IV ascended to the throne or even if he was in fact his father's choice at all. One source states that Amenhotep IV was not originally intended to be his father's successor, but instead the crown prince Thutmose was. Fortunately for Amenhotep IV (Akhenaten) the original heir apparent died (Shaw 2000). Van Dijk also states that there was possible co-regency between Amenhotep III and Amenhotep IV lasting anywhere from two to twelve years. Another source states that the idea of a long co-regency between the two Amenhoteps' "cannot withstand serious scrutiny" and instead offers an alternative view that "[d]uring the early years of his (Amenhotep IV) reign, it was rather his mother, Teye, who, relying on seasoned officials of Amenhotep III, had a decisive influence on the affairs of the State" (Hornung 1999: 98). Nowhere does Hornung mention Thutmose being the preferred heir. Whatever the circumstances may have been that lead to his ascension to the thrown, the outcome was the same, Amenhotep IV became ruler and forever changed Egypt.

At first Amenhotep IV put in appearances and made offerings to the national god Amun-Ra while at the same time displaying his preference for the deity known as the Aten. The Aten was neither a new deity nor Amenhotep IV's creation but was in fact worshiped by his father and the pharaoh preceding him, Thutmose IV, as a sun disk manifestation of the sun god Ra-Harakhty.

Figure 3. Statue of Akhenaten, Egyptian Museum, Cairo, Egypt. (ancient-egypt.org)

Amenhotep IV did not immediately enact the one god rule, but instead planned his revolution slowly and carefully. Taking advantage of the absence of Amun-Ra's high priest, who was off on campaign, Amenhotep IV built a temple to the Aten at Karnak, replacing the falcon-headed Re-Harakhty with the sun disk and rays of the Aten. It is at this time that he also had himself depicted as the earthy representation of the Aten as both the "father and mother" of those he ruled (Hornung 1999). These representations showed Amenhotep IV with female attributes, which had never before been seen. The artistic style that emerged during the reign of Amenhotep IV was completely new and was immediately enacted into law for all palace workshops. This new style had an "extraordinary sense of movement and speed, a general 'looseness' and freedom of expression that was to have a lasting influence on Egyptian art for centuries after the Amarna Period had come to an end" (Van Dijk 2000: 282).

Along with enacting a new form of art and religion, Amenhotep IV also changed the political environment of Egypt by promoting "nobodies", his friends from the army and those he went to school with, into powerful positions (Hornung 1999). Additionally, he surrounded himself with foreigners and those from the lower classes, all to insure complete compliancy and loyalty. Guaranteed that there would not be any opposition to his plans by his loyal subjects, Amenhotep IV enacted a full reorganization of Egypt and its religion. “Above all, this included the founding of a new Residence on virgin soil ‘belonging to no god and no goddess’ and a change in the king’s personal name” (Hornung 1999: 100). In his sixth regal year, Amenhotep IV began preparations to move the religious capital of Egypt from Thebes to a new site in Middle Egypt, for which he named Akhetaten (Horizon of the Aten), by marking the borders of his new city with boundary stelae. It is also at this time that he officially changed his name from Amenhotep IV to Akhenaten, meaning pleasing to the Aten or the living spirit of Aten.

A year later the court settled in the new capital city, and it was at this time that Akhenaten began his full scale campaign to eradicate any traces of the old gods and the persecution of those who continued to worship them. He also designated himself the high priest of the Aten as well as positioned himself as the sole intermediary between his subjects and the deity. No longer were his followers praying to other gods or even truly to the one god, but rather they were worshipping at household altars that portrayed Akhenaten and his family being embraced by the rays of the sun-disk god. These depictions of the royal family were also a new development in the Amarna period for they “displayed an intimacy such as had never before been shown in Egyptian art even among private individuals, let alone among royalty. They kiss and embrace under the beneficent rays of the Aten, whose love prevails all of his creation” (Van Dijk 2000: 282). Other art depicted on the walls of tombs conveyed the idea that everything was bright, light, and plentiful. A propagandistic technique to hide what might have been really been going on, for Egypt was unstable politically with its neighbors close to home and abroad. “…Egypt’s fronts were again thrown in agitation…[Akhenaten] left foreign affairs to his officials…unrest soon spread from Syria to Palestine…Worse was the loss of the northern harbors, which robbed the Egyptians of their supply bases…"(Hornung 1999: 102). The art not only could have been used to cover unrest, but by the state of the skeletal remains it could also have been a way to represent a life that they were trying to achieve, but could not.

Towards the end of Akhenaten's reign, the god Amun-Ra returned and began to be worshipped alongside the Aten. Akhenaten's would be successor, Smenkhare, built his mortuary temple in Thebes, as well as dedicating it to Amun-Ra. It must have been at this time that Akhenaten realized his revolution had failed. Persecutions had stopped, and Akhenaten's subjects could once again pray to other gods without fear. It was not long after, in 1336 B.C.E., that Akhenaten died and a short time later so did his successor Smenkhare. Tutankhaten, later known as Tutankhamen, became pharaoh and with the leadership of Akhenaten's most influential counselor, Aya, began a nonviolent campaign of restoration. Two years later in 1331 B.C.E, the court moved to Memphis, officially ending the Amarna Period and Akhenaten just faded away. "…Akhenaten's twin vision of a monarchy worshipped for itself, and of a theology that was so simple as to release the king from the shrouds of mystery, failed to convince his contemporaries and died with him. After his death they [Egyptians] returned to intellectual compromise and wrapped again the nakedness of monarchy in the shrouds of high theology" (Kemp 1992: 280-281).

Although briefly recounting Egypt's and Akhenaten's history allows for one to put the time period being investigated in to context, it does not, however, tell us anything about the "regular" people that lived at Amarna at this time. This of course is due to the fact that ancient Egyptians only wrote about gods, pharaohs, and elites, with only a few exceptions such as at Deir el-Medina where inscriptions of everyday matters have been recovered. Generally, the laypersons' everyday life outside of the context of what they did for the pharaoh was not an important enough subject to recount. Egyptians may not have left many written accounts outside the worship of gods and the lives and building campaigns of kings, but all is not lost. The skeletal remains of Amarna populace left behind can tell us much about them: how they lived and how they died. It is with these skeletal remains that we can build a demographic profile, look for skeletal evidence of stress, and discover information once buried in history.

Chapter 2: Methods

The goal of this project is to examine skeletal stress markers in relation to the demographic profile to provide insight into the lives of the residents of the Akhetaten (modern day Amarna). Specifically, cribra orbitalia (CO), porotic hypertosis (PH), linear enamel hypoplasias (LEH), will be used as indicators of childhood stress. This chapter will discuss the methods used to age adult and juvenile remains as well as the techniques used to score these skeletal markers of stress.

Adult Aging Methods:

The methods employed to correctly identify the age of the skeletal remains at Amarna followed the procedure set forth by Jane E. Buikstra and Douglas H. Ubelaker in *Standards for Data Collection from Human Skeletal Remains*. When present, the os coxae were used to age an individual, as it is the best means to do so. One of the areas of the os coxae examined was the pubic symphysis, the area of the pubic bone that connects to the opposing side, using the degradation grouping stages of Todd (1921a, 1921b) and Suchey-Brooks (Brooks and Suchey 1990: Suchey and Katz 1986). Both scales incorporate phases based on the look and feel as well as the presence or absence of features. Once a phase has been determined, an age range and mean range are given to correspond with the description and pictures, or models, as is the case for the Suchey-Brooks method.

The other feature on the os coxa that enables one to determine age is the auricular surface. This is the surface that connects the os coxa to the sacrum and, as with the pubic symphysis, will show marked differences in the presence or absence of features due to aging. The details of each phase and subsequence age ranges were determined using the technique defined by Lovejoy et al. (1985) and Meindl and Lovejoy (1989: 165) as found in *Standards* (Buikstra and Ubelaker 1994).

In the absence of the pelvis, as well as in conjunction with it, the cranial sutures were also examined to identify age. This technique employs a scoring system of 0-3: 0 being completely open, 1 for minimal closure, 2 for significant closure, and 3 for complete obliteration of the suture. There are ten points on various sutures that are included in the score, seven in the composite score and seven in the vault score (the midcoronal and pterion points are used in both sets of scoring categories). Once all the scores are added up, they are compared to a chart that lists the mean age and age range for each score (Meindl and Lovejoy 1985: 63).

Juvenile Aging Techniques:

For those under the age of 23, pelvic changes and cranial sutures were also employed to age individuals. Unlike adult remains, the epiphyseal fusion process of the long bones can also more accurately age juveniles. The epiphyses lies at the end of the long bones and as humans grow and age these epiphyses fuse with the shaft of the long bone to make a complete structure. The epiphyseal fusion, non-union, intermediate state, and union are used to determine juvenile age, as each epiphyseal suture fuses in an almost regular and timely fashion. This method is scored from 0 to 2 (Buikstra and Ubelaker 1994).

The last method employed to determine age, was tooth development and wear. Mandibular and Maxillary molars tend to erupt in certain intervals: at six years old for the first molar, twelve for the second, and eighteen for the third. The amount of wear on each molar is a good indication of how long the tooth was in use between its eruption and death. These methods and procedures were employed and the technique used were Ubelaker's system for sequence of formation and eruption of teeth (Buikstra and Ubelaker 1994: 51) and Smith and Scott's method for attrition scores (Buikstra and Ubelaker 1994: 52-53) along with the atlas of tooth development published by AlQahtani et al. (2010).

Scoring Techniques for Skeletal Stress Markers:

Standards for Data Collection from Human Skeletal Remains were also employed to determine the presence and the appropriate scoring of cribra orbitalia, porotic hypertosis, and linear enamel hypoplasias. The number and percentage of occurrences for each age range were recorded for all three skeletal markers of stress. Percentages were then recorded for each age range that had at least one skeletal marker.

Scoring Technique for Cribra Orbitalia and Porotic Hypertosis:

Both cribra orbitalia and porotic hypertosis are scored the same way. Each individual would be given a number between 0-3 based on the presence or absence and activity level of the porosity. 0 indicates no presence of porosity, 1 equals porosity is barely discernible, 2 means porosity only, and 3 indicates porosity with coalescence of foramina. If porosity were present the observer would then circle the activity level, whether active, healed, or healing, based on its features.

Scoring Techniques for Linear Enamel Hypoplasias:

The scoring of linear enamel hypoplasias has been slightly modified from the *Standards* scoring technique. Instead of a scoring range from 0-7 that score different features, the technique employed at the bioarcheological field school has taken a much simpler approach and has only scored hypoplasias from 0-3 and only for presence and absence and number of incidences found on one tooth, which is numbered 0 1 2 3 or more.

These techniques coalesced to form the bases for the analysis of the population of Akhenaten's grand yet short-lived city. With the data an analysis of the demography was fully examined, each skeletal marker of stress was thoroughly investigated, and diet and disease was considered in context of cribra orbitalia, porotic hypertosis, and linear enamel hypoplasias.

Chapter 3: Demography

Demography is the study of vital events that affect human populations such as birth, mating and the production of offspring, and mortality. Demographers refer to these three events as vital statistics. For the purpose of this paper, the only vital statistic that will be used in order to examine the demography at Amarna is the last, mortality, since it is the only vital statistic to sustain the march of time. How mortality occurs in the population being studied is of extreme importance to the demographer. When death occurs in a certain segment of the population, it can tell a lot about that society. “The ages at which *age-specific* mortality is most likely to occur are indicators of how well a society is adapting to its environment and how successful its culture and economic practices are” (Swedlund and Armelagos 1976: 10). For the purpose of this paper, age-specific mortality will be looked at to investigate not Amarna’s ability to adapt to its environment or how successful its culture and economic practices were, but rather the reasons why it was not successful. “Age and sex data from skeletal collections can be used to better understand patterns of activity, disease, and diet…They form the basis for addressing demographic questions dealing with the life and death of a population” (Buzon 2005: 29). Using skeletal material as a primary source to construct a demographic profile has its drawbacks and can be problematic because of the nature of the material. Skeletal samples are just that, samples of a population, as generally a whole cemetery is not excavated so what a paleodemographer ends up with is a sample of a sample. There is also potential for misestimation of age and sex, as well as biases introduced by cultural and taphonomic factors (Chamberlain 2006).

Life Tables and Normal Profiles:

A normal demographic profile resembles a Nike swoop or a “U” shape. High mortality is most commonly seen at birth, and “declines rapidly towards a minimum around the twelfth year of age, and than increases slowly through adolescence and maturity until it reaches the second catastrophic maximum at the terminal period of senescence” (United Nations 1955: 1). Figure 4 is an example of “normal” demographic profiles taken from *Age and Sex Patterns of Mortality: Model Life-Table for Under-Developed Countries* published by the United Nations.

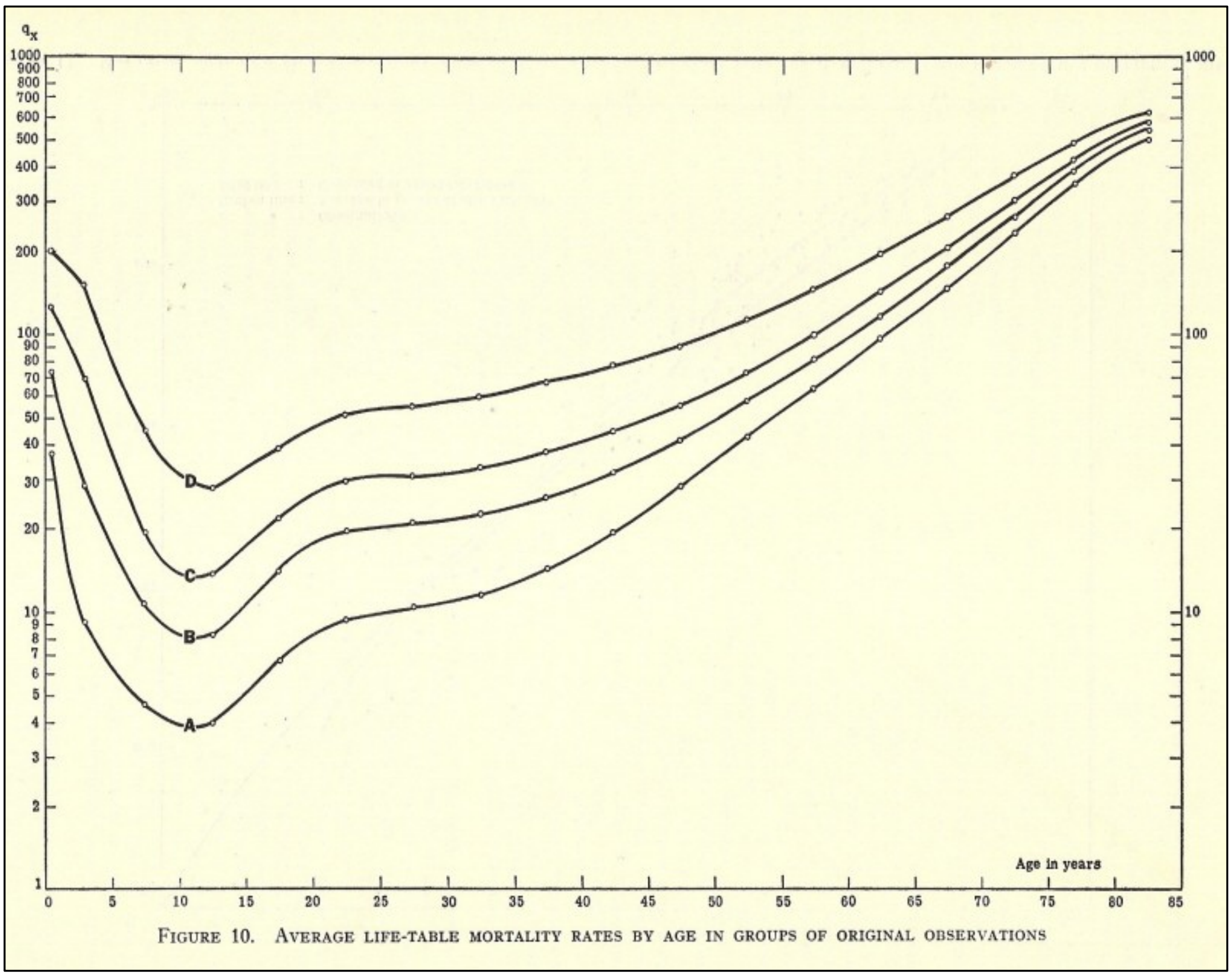

Figure 4. Average life-table mortality rates by age in groups of original observation from *Age and Sex Patterns of Mortality: Model Life-Table for Under-Developed Countries* the United Nations’ Department of Social Affairs Population Branch, New York: 1955.

The profile above is of a population that is constant and stable. Notice how the graph has a high mortality rate for those in the vulnerable ages of 0-2 and then begins a steady decline. The graph then dips down at around 10 to 13 years of age, begins to increase again around age fifteen, bumps slightly up again around the mid-twenties, and then slowly ascends up the chart. This is the normal flow that a population should follow.

The demographic profile of Amarna deviates from the “normal” pattern significantly and although figure 5 is not a life table, Amarna’s profile resembles a mountain range more than it does a Nike swoop. Take note how the more “vulnerable” ages from 0-2 are relatively positioned where they should be, as this age group is most susceptible to the causes of death then any other age group due to the fact that their immune systems have yet been given enough time to develop properly. The graph then does its “normal” slight dip down in the 3-7 age range, but it must be noted that even though the graph does a normal dip, the number of deaths in this age range is not normal. Here in the 8-15 age group through the 16-20 age group is where the Amarna demographic chart dramatically deviates from a “normal” demographic profile. Instead of continuing to decline in these two age groups, as seen in figure 4, the line shoots directly up in the 8-15 age range dipping down again in the 16-20 age group only to once again climb back up in the 21-25 and peaking in the 26-30 age range, only to once again fall almost to a minimum in the 31-35 age range. It rises once more in the 36-40 and again in 41-50 age group and then drops to its absolute minimum in 51+ group. It should be noted that the peak in the 26-30 age-range is probably not unusual as ancient populations life expectancies were only about 30 to 35 years (Eike-Meinrad 1991).

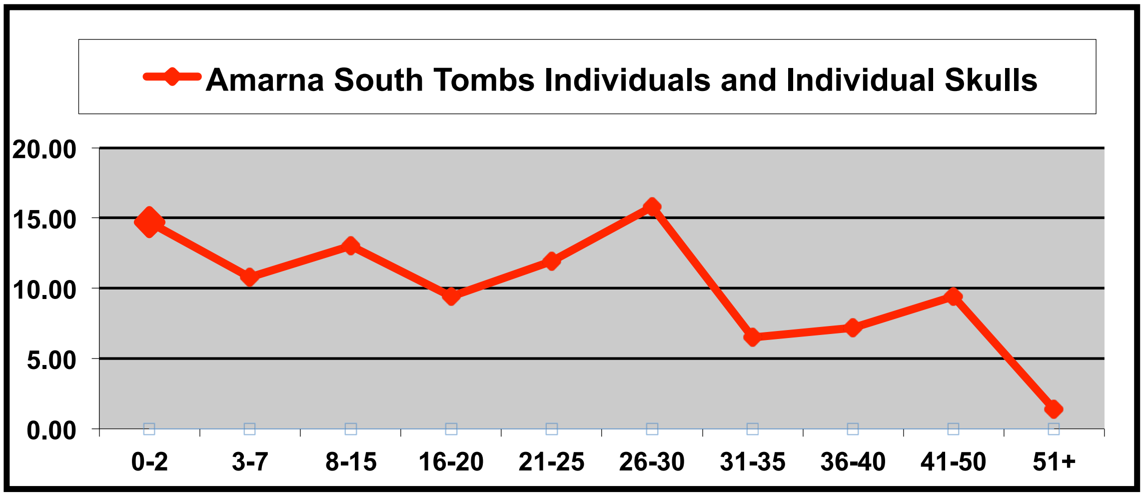

Figure 5. Amarna demographic profile of individuals, with and without skulls, each age range calculated as a percent of total individuals.

Comparison to Egyptian Skeletal Profiles

The materials used for comparison are two New Kingdom populations, Upper Egypt Qurneh and Lower Egypt Memphis, analyzed by Michele R. Buzon in her article "Health of the Non-Elites at Tombos: Nutritional and Disease Stress in New Kingdom Nubia", a Second Intermediate population from the Hyksos-Dynasties (15th and 16th) in Lower Egypt at Tell el-Dab'a (Winkler and Wilfing, 1991), and an Old Kingdom to New Kingdom Lower Egypt population at Qubbet el Hawa in Elephantine (Rösing,1990). All articles are primary sources published by the archaeologist who excavated each site.

Amarna's distribution, comparatively speaking, reflects the Second Intermediate Period population of Tell el Dab'a distribution more then it does either of the contemporary New Kingdom Samples. Both the Amarma and the Tell el Dab'a sample, as well as, the New Kingdom population of Qubbet el Hawa have individuals in the 0-3 age range, and except for Qubbet el Hawa, the numbers in this age range represent a relatively normal percentage rate due to the high mortality for this age group. Both present the highest mortality in the 4-12 and although there is a slight dip in number for the 13-17 age group the percentage overall is still extremely high compared to the three other populations. Starting with the 18-29 age group, both the Amarna and Tel el Dab'a populations begin to follow the same trajectories as the other three demographic profiles, and as noted elsewhere, the highest mortality should be seen in the 30-45 age range as this was a normal life expectancy for someone living in this time period. Although it should be noted that the percentage of deaths in the 18-29 age range is almost the exact same as the percentages for the 30-45 age group for all five populations.

Sample	0-3	4-12	13-17	18-29	30-45	46+
Amarna (New Kingdom)	52 (19%)	48 (17%)	20 (7.2%)	66 (24%)	84 (30%)	8 (2.9%)
Memphis (New Kingdom)	0 (0%)	2 (1.9%)	2 (1.9%)	37 (36%)	48 (47%)	14 (14%)
Qurna (New Kingdom)	0 (0%)	10 (5.7%)	3 (1.7%)	61 (35%)	84 (49%)	15 (8.8%)
Tell el Dab'a (2nd Inter. Period)	46 (18%)	54 (21%)	24 (9.3%)	59 (23%)	57 (22%)	18 (7%)
Qubbet el Hawa (New Kingdom)	14 (3.8%)	29 (7.9%)	19 (5.1%)	105 (28%)	104 (28%)	98 (27%)

Figure 6. Demographic distribution of the comparative samples (Kuckens 2008:14).

Compared to the distribution of the other New kingdom populations, Memphis, Qurna and Qubbet el Hawa, Amarna has the highest mortality in the 4-12 age range as well as the 13-17 one. The 18-29 age range is comparable for the sample size for all four, but where Amarna and Qubbet el Hawa drop in number of individuals represented in the 30-45 age range, Memphis and Qurna, like Tell el Dab'a and Qubbet el Hawa stay relatively high. Neither the Memphis nor the Qurna samples had any individuals represented in the 0-3 age range, which suggests that they were buried elsewhere: such as a separate cemetery as discussed earlier with Wendy Dolling (personal correspondence 2008) or in the cellars of the family's home (Friedman 1994: 96).

Comparison to Epidemic Profiles

The goal of my previous research, "Life and Death in Amarna: Osteology and the Demography of Egyptian Commoners in Akhenaten's Capital City", was to discover a reason why there were so many dead juveniles and sub-adults at Amarna, and with much investigation the demographic profile seen at Amarna directly reflected that of populations that suffered from sever epidemics such as smallpox, influenza, and the Bubonic Plague. Below are graphs taken from my undergraduate honors thesis of three populations that suffered the effects of devastating epidemics that were compared to Amarna's demographic profile in order to demonstrate the similarities. Note how all three follow the same trajectory as Amarna's curve, each showing a mountain range rather than a "normal" Nike swoop.

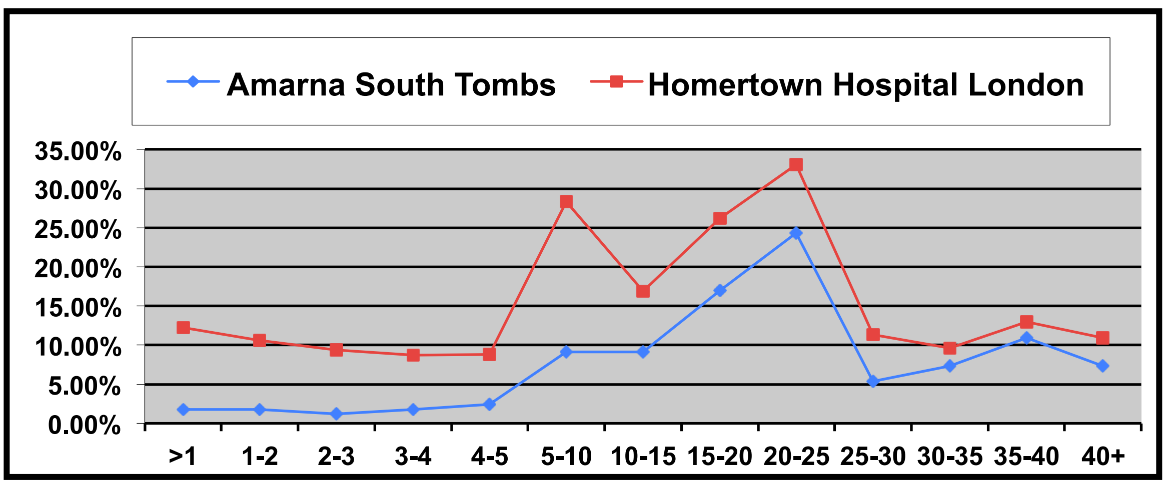

Figure 7. Comparison of age at death in Amarna South Tombs demography and Smallpox mortality at Homertown Hospital, London (Kuckens 2008:24).

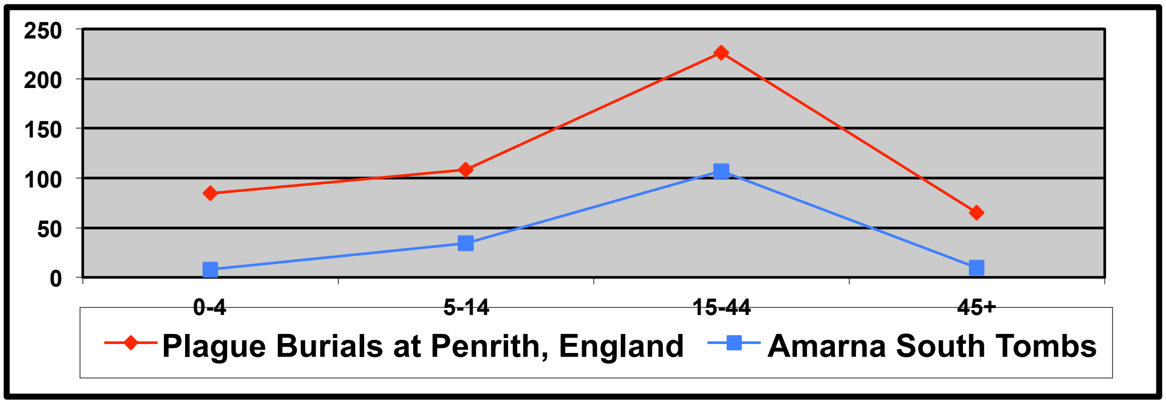

Figure 8. Comparison of plague deaths at Penrith, England and the Demography of Amarna, South Tombs (Kuckens 2008:27).

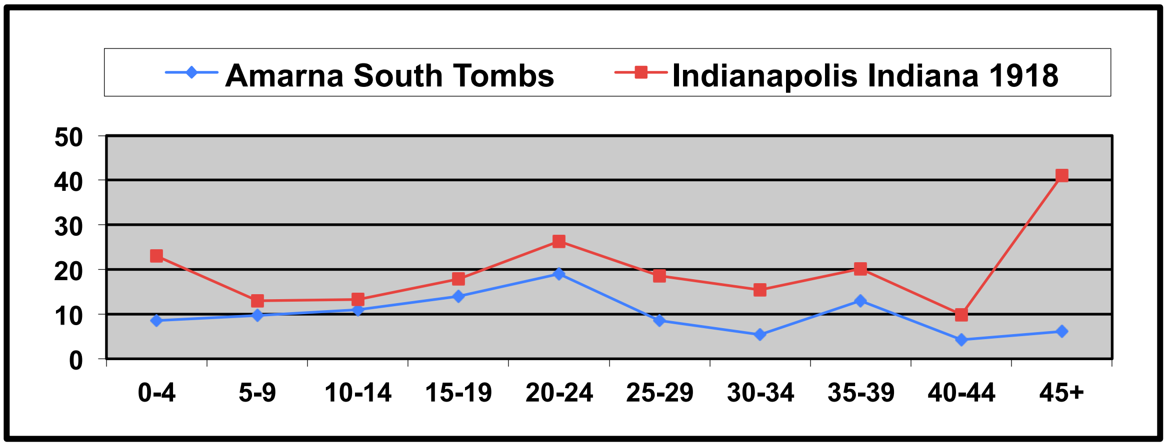

Figure 9. Comparison of age at death percentages for Amarna South Tomb individuals and the population of Indianapolis, Indiana during the 1918 Spanish Influenza Epidemic (Kuckens 2008:29).

Coupled with this and some convincing evidence proposed by Arielle P. Kozloff (2006) in her article, "Bubonic Plague During the Reign of Amenhotep III?", it is easy to understand how one can honestly believe the theory that an epidemic was the cause for such a high mortality rate for juveniles and sub-adults at Amarna.

In the article, "Bubonic Plague During the Reign of Amenhotep III?", eight characteristics are set forth that are seen and demonstrated in populations that suffer through plagues, including, but not limited to, the pre-Renaissance plague in 1347-1350 C.E, the Justinianic Plague in the mid-sixth century, the mid-third century C.E. plague in the Roman Empire, the Antonine Plague of the late 2nd century C.E, and the Athenian Plague in 430-426 B.C.E. These characteristics are; a period of international activity, the devastation of dense populations, the flight to clean areas, non-traditional burial methods, and poverty of grave goods, the advent of new cults and changes in religious affiliation, a change in artistic subject and style, and is the increase of marriages, family size, and the importance of women. Referring back to the short history laid out at the beginning of this paper will highlight all these characteristics.

The unusual 'mountain peak' demographic profile that the population of the South Tombs Cemetery is exhibiting suspiciously mirrors demographic profiles from populations affected by an epidemic. It was this anomaly that first suggested that life in Akhenaten's ancient city was not the grand abundance that is so artfully preserved on the walls of the tombs of the elite. A full-scale analysis of the skeletal material was then done to determine the presence and amount of skeletal indicators of stress, such as cribra orbitalia, porotic hypertosis, and linear enamel hypoplasias in order to ascertain the health status of the juvenile and subadult population.

Chapter 4: Indicators of Stress

The stress markers, or 'indicators of stress', such as cribra orbitalia, porotic hypertosis, and linear enamel hypoplasias are "abnormalities observed in skeletal and dental remains [that] represent the individual's adaptive response to stressors working on the body during his or hers growing years "(Roberts and Manchester 2007: 222). There are a number of factors that determine how an individual will respond to a stressor such as environmental constraints, the immune status of the individual, genetics, and the cultural system of the society. The result of so many factors influencing an individual's response to stress is that they will effect the population disproportionately (Schell, 1997). It must be noted, that even though an individual does not posses any indicators of stress it does not always mean that that individual was healthy, rather it could represent a person who died while in the midst of a stressful event never to recover, thus unable to leave those telltale skeletal markers.

In the late 1980's and early 1990's biological anthropologists, Alan Goodman and George Armelagos devised a model of the interaction of the three key factors that stress is a product of: (1) environmental constraints, (2) cultural systems, and (3) host resistance (Goodman, 1991; Goodman and Armelagos, 1989; Goodman et al., 1984; 1988). The model in these pivotal articles demonstrated that it is the environment that both provides the resources for survival, as well as, the stressors that affect health. The cultural systems in the model serves as a protective buffer against stressors allowing for adaptive behavioral change in order for the population to extract out of the environment important nutrients and resources.

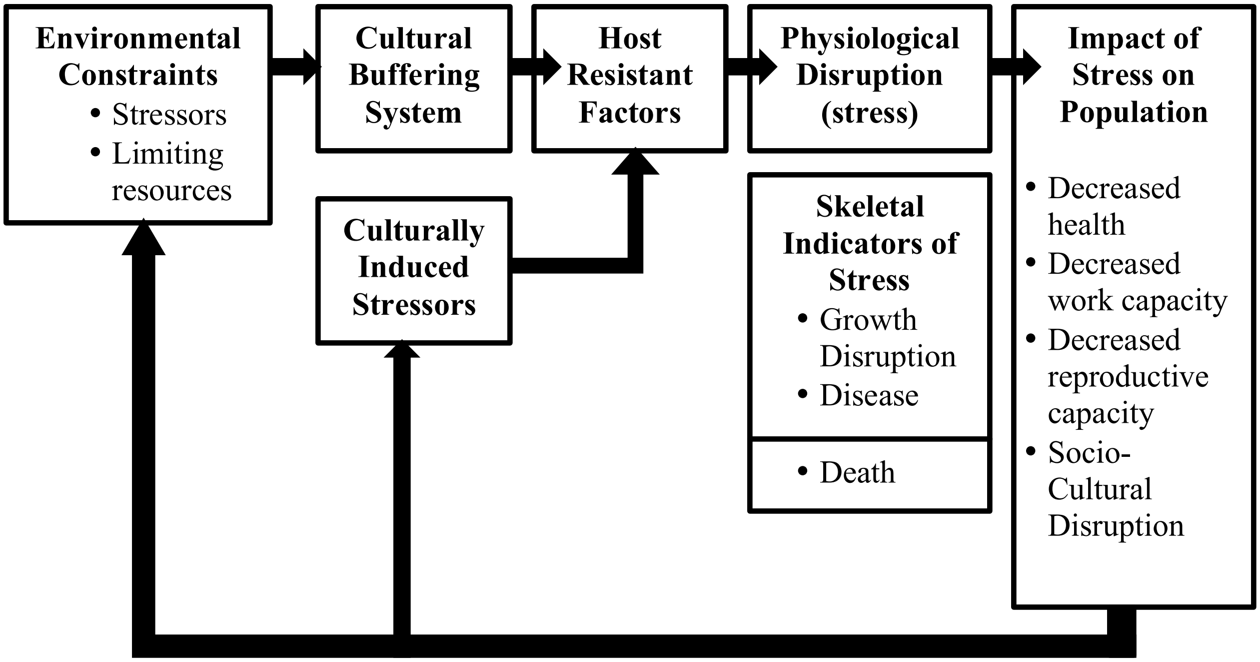

Figure 10. Alan Goodman and George Armelagos' model for inferring stress in archaeological populations interpreted by Clark Spencer Larsen (Larson 1997:7).

However, the buffer isn't foolproof and some people slip through the cultural system filter, thus leaving observable indicators of stress on the skeleton and teeth. The portion of the population that slips through is what is known as a disruption. These disruptions then cycle directly back into the cultural systems and environmental constraints causing negative impacts on the population. Goodman and Armelagos' model make it apparent that health is a reliable indicator of the adaptive process. However, stress has not only significant consequences to an individuals' health and mortality, but also their living functional status. "Elevated stress can lead to a state of functional impairment, resulting in diminished cognitive development and work capacity. The reduction in work capacity can be detrimental if it impedes the acquisition of essential resources (e. g., dietary) for the maintenance of the individual and the population (Larsen 1997: 6). Decreased fertility is another consequence of stress, which would have far reaching effects on the population. If a population as a whole mismanages their stress it could be very detrimental to its survival.

For a biological anthropologist studying disease, the subject matter inherently has some drawbacks. Unlike a clinical practitioner working with live humans an accurate diagnosis is almost impossible, as the subjects in bioarchaeology no longer possess their soft tissue where most diseases lay their claim. Only when an individual suffers from a disease, infection, or stressor for long periods of time do any skeletal markers appear. "When the aim is the biocultural study of disease in past societies, accuracy of diagnosis may be less imperative if the ultimate aim is not to study a particular disease but to obtain a more general picture of disease burden in a population. A key aspect of this latter approach has been the paleopathological conception of nonspecific stress." (Grauer 2012: 294).

Nonspecific stress indicators such as; cribra orbitalia, porotic hypertosis, and linear enamel hypoplasias may not point directly at a specific disease but the presence of said markers can tell the bioarchaeologist about the possible health and cultural circumstances of a population. “Indications of these skeletal manifestations, often caused by nutritional deficiencies and exposure to infectious pathogens, can be explored through documentation of several pathological conditions (e.g., cribra orbitalia/porotic hyperostosis, enamel hypoplasia, and osteoperiostitis)” (Buzon 2006: 29).

Cribra Orbitalia

"Cribra orbitalia (CO), which refers to porosity and hyperostosis of the superior wall of the orbit, is one of the most frequent lesions macroscopically found in archaeological skeletal collections and is frequently a topical subject of discussion in the bioarcheological literature." (Jatautis *el al.* 2011:57) The 'superior wall of the orbit' is the roof of the eye cavity and the porosity the authors refer to are small holes dotted along the surface of roof while the hyperostosis is an excessive growth of the bone as seen in figure 11.

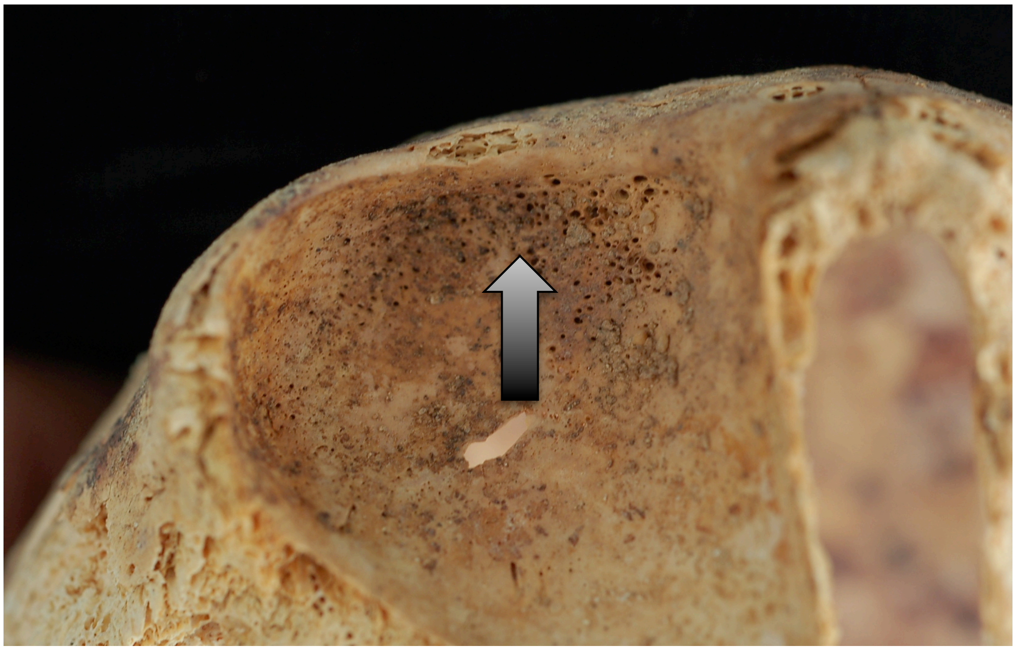

Figure 11. Example of cribra orbitalia seen in Individual 174 of STC aged 3-3.5.

Many explanations have been given for why cribra orbitalia occurs, such as, bone marrow hyperplasia, bone inflammatory process, and vestiges of hemorrhage, but the pervading theory that most believe is that it is a response to anemia, “[a]s early as 1500 B.C., an Egyptian manual of therapeutics, the *Papyrus Ebers,* described a disease characterized by pallor, dyspnea, and edema that may have been anemia of some type” (Stuart-Macadam and Kent 1992:1). In brief, anemia is a condition in which the body does not have enough healthy red blood cells to do their various bodily jobs. Red blood cells are mainly produced in the bone marrow and last between 90-120 days. When red blood cells die they are removed by other parts of the body and the kidneys signal the bone marrow to produce new red blood cells by secreting a hormone called erythropoietin. This process can only function properly with the aid of key vitamins, nutrients, and minerals, mainly iron, folic and, and vitamin B12. Without these key ingredients the kidneys are unable to secrete the erythropoietin hormone, the bone marrow does not know new blood cells are needed, thus the individual suffers from anemia.

Anemia comes in many forms. There is anemia due to deficiencies in B12, foliate deficiency, and iron. There are also anemia of chronic disease, hemolytic, idiopathic aplastic, megaloblastic, pernicious, sickle cell, and thalassemia anemia. Anemia also has many causes from: genetic predisposition, poor diet, mainly one with an insufficient consumption of red meat, blood loss, long-term (chronic) diseases or intestinal parasitism (e. g. diarrhea). Recently, however, the theory that iron deficiency anemia alone as the cause for CO has come into question (Walker et al. 2009) as it has been recognized that other causes, such as infectious diseases, scurvy (Ortner 2003:385-386), rickets (Ortner and Mays 1998), waterborne parasite hemoblastic anemia (see Walker et al. 2009), and even post-mortem changes produce similar effects in the skull. Whatever its causes may be, "CO in (pre)historical studies is very often considered as a general index of poor health as well as an indication of poor dietary and poor sanitary conditions and high incidence of infectious diseases (Jatautis *et al.* 2011:58).

Cribra Orbitalia at Amarna

Cribra orbitalia (CO) is the number one non-specific stress indicator seen at Amarna. In the 0-2 age group 82.4% (14 out of 17) of the individuals that exhibit skeletal markers have cribra orbitalia. Seven of those have CO alone while four have CO in conjunction with scurvy, one has CO, scurvy and porotic hypertosis (PH), one has CO with just PH, and one has CO with PH and linear enamel hypoplasia (LEH). The state of activity indicated for cribra orbitalia in this age group have all been measured as active or slight active, but one, which was indicated as being slight, minor, and healed.

In the 3-7 age group 80% (15 out of 19) of those with skeletal markers have cribra orbitalia. 12 out of the 15 have CO alone while only one has CO with PH, one has CO and scurvy, and another has CO, PH, and scurvy. Most of the cribra orbitalia is indicated as active, ranging from severe to slight, but 4 out of the 15 cases are healed or healing.

Cribra orbitalia makes up 80% (15 out of 19) of the indicators of stress manifested on the skeleton in the 8-15 age group. In this age group we see CO coinciding with other indicators of stress more often then alone then in any of the previous age groups. There are only 5 cases of CO that occur alone, while CO and LEH's occur together 9 times (once with possible signs of scurvy) and one case of CO is seen with PH in this age group.

In the 16-20 age group 62.5% (10 out of 16) of those with skeletal markers have cribra orbitalia. Seven have CO alone, while only three have it in conjunction with LEH's. Three of the cases are recorded as active or slight while the remaining seven are indicated as healing or healed. In the age group 21-25 we are again only seeing around a 60% occurrence of cribra orbitalia. In this age range 64.3% (9 out of 14) of the indicators of stress is cribra orbitalia. Five times CO occurs alone, three times with LEH, and one time with porotic hypertosis. All cases of cribra orbitalia are indicated as healing or healed.

Cribra orbitalia makes up only 50% (10 out of 20) of the skeletal markers of stress seen in the 26-30 age group. Cribra orbitalia occurs by itself six times in this age group, twice with linear enamel hypoplasia, once with Porotic Hypertosis, and once with both LEH and PH. In this age range we see almost equal amounts of healed (7) and active (5) cases of cribra orbitalia. In the 31-35 age range there is only 3 out of 9 cases of cribra orbitalia (33.3%), two occur alone, while one in conjunction with LEH's. Two are indicated as healing, while one is indicated as mild, whether this is a mild active state or mild healing state is unclear.

The 36-40 age group has the lowest cases of cribra orbitalia of all the age groups with only 1 case out of 7 individuals who had the presence of skeletal markers of stress (14.3%). Individual 49 is aged 35-45 and was diagnosed with active CO in the right eye orbit only in conjunction with linear enamel hypoplasia's. In the 41-50 age group 33.3% (2 out of 6) of the individuals that have the presence of skeletal markers of stress have cribra orbitalia. One by itself and one in conjunction with LEH, both are healing or healed. Although there are 2 out of 3 (66.7%) occurrences of cribra orbitalia in the 51+-age range there are only four individuals total in the group so the sample size is too small to say anything significant or accurate, so from hence forth this age group will not be considered in the analysis.

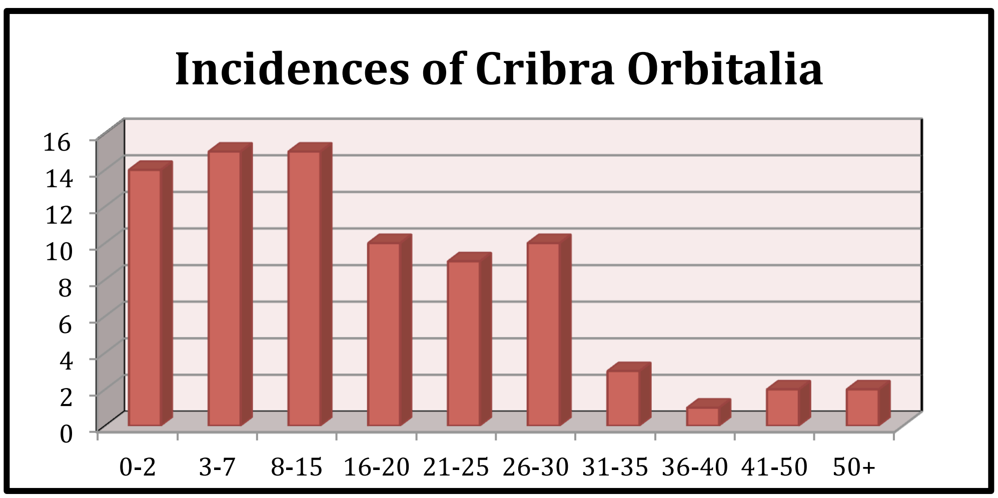

Figure 12. Frequencies of cribra orbitalia on the skeletal remains of the STC population at Amarna occurring in each age-range

Porotic Hypertosis

Like cribra orbitalia, porotic hypertosis (PH) is macroscopic circumscribed areas of porosity and pitting as seen in figure 13. Unlike cribra orbitalia, which is seen on the superior orbital wall, porotic hypertosis occurs on the cranial vault bones, both are the most common lesions found in the skeletal remains of archaeological collections. Both porotic hypertosis and cribra orbitalia are often thought of as being the result of an expansion of the diploë, or spongy bone, of the skull in response to marrow hypertrophy.

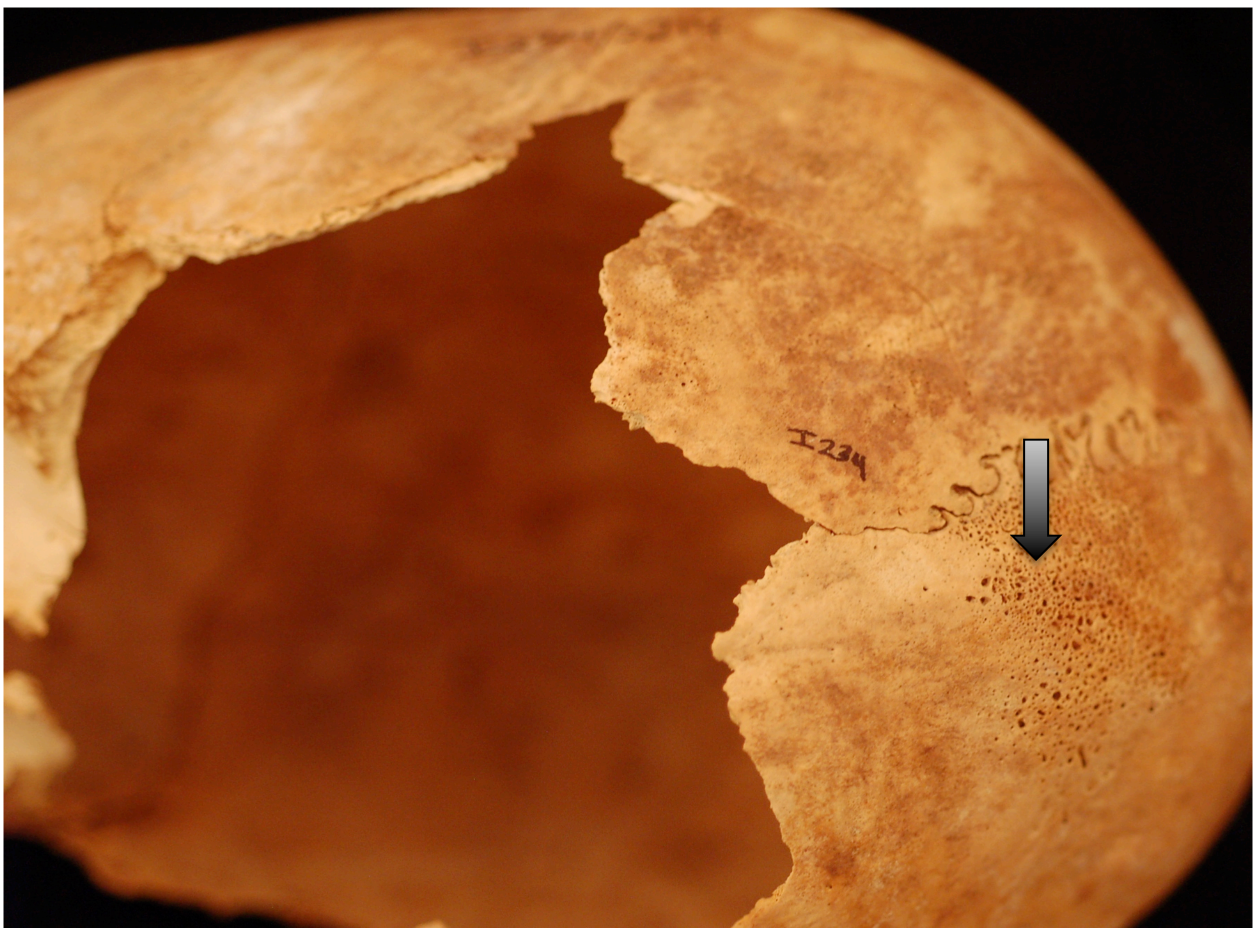

Figure 13. Skull of individual 234 from STC aged 2.5 years old possessing an example of porotic hypertosis.

The diploë is composed of red, hemopoietic marrow in children and the hyperplasia of this red marrow is an erythropoietic response to anemia. In adults, a fatty yellow bone marrow replaces the hemopoietic red type of youth and a reconversion of the yellow to the red is used when there is a need for an increase in red blood cell production. Usually no hyperplasia of the marrow space occurs, thus porotic hypertosis found in adults is typically a holdover from an anemic episode from their childhood (Stuart-Macadam 1985). Again, one must be advised not to jump to conclusions about diagnosis, as pointed out above, porosity of the cranial vault and orbital walls can be the result of many different factors (Ortner 2003), although, "Since the 1950's iron-deficiency anemia has gained acceptance as the most likely cause of the marrow hypertrophy that produces porotic hypertosis. This inference is based principally on analogies with modern clinical cases in which hematological evidence of iron-deficiency anemia and radiographic evidence of cranial vault marrow hypertrophy co-occur" (Walker et al 2009:109).

Larry Angel coined the term porotic hypertosis in 1966 in his article, "Porotic Hyperostosis, Anemias, Malarias, and Marshes in the Prehistoric Eastern Mediterranean", feeling that it was descriptively more appropriate than the term osteoporosis symmetrica as it was known as, and previously used by other scientists and researchers. In Angel's article he noted the similarities between radiographic images of patients with congenital anemias and the visible lesions on archaeological specimens and "noted similarities in the probable etiologies of the cranial vault and orbital roof lesions and suggested porotic hypertosis as an overarching term that could encompass both conditions" (Walker et al 2009:109).

Although Angel made the first connection between congenital anemia and the porosity lesions of both porotic hypertosis and cribra orbitalia, it was clear by the shear number of both lesions that are recorded in the archaeological record that congenital anemia could not be the only cause, hence its continued debate in the literature about its etiology. Patricia Stuart-Macadam (1992; 1998) concluded that the lesions left as a result of the hypertrophy of the diploë was an adaptive response to a parasitic infection. This author believes that the resulting anemia is a trade off as the host (in this case humans) withholds iron to reduce its availability to pathogenic microbes, thus effectively making the "environment" for the parasite inhospitable. Disputing Stuart-Macadam claim, Thomas D. Holland and Michael J. O'Brien (1997) argued that the presence of these lesions signified a chronic condition, which would have extensive biocultural consequences for the health of an individual, both mind and body. "The crux of the debate therefore, was not only lesion etiology but also the interpretive weight given to evidence of plasticity: short-term survival or long-term survival and reproductive success. In essence, the authors (see Goodman 1994) argued that analyses of survival have to incorporate a consideration of physiological well-being and quality of life; that living is more than simply not dying" (Grauer 2012:44). Both porotic hypertosis and cribra orbitalia have been widely documented by Bioarchaeologist in historic and prehistoric contexts all over the world and is a common factor used in assessing the health and nutritional status of a population.

Porotic Hypertosis at Amarna

Although they reportedly seem to have the same probable etiologies, porotic hypertosis is not as pervasive in Amarna as cribra orbitalia as there are only fourteen total cases compared to eighty-one cases of cribra orbitalia, but this is not unusual. "The thinness of the orbital lamina means that hyperplasia of the diploë may more readily result in surface porosity here than in the cranial vault bones" (Grauer 2012:292). Most of the manifestations of porotic hypertosis co-occur with cribra orbitalia, which, indicative of the literature, is as it should be and is illustrated in figure 14.

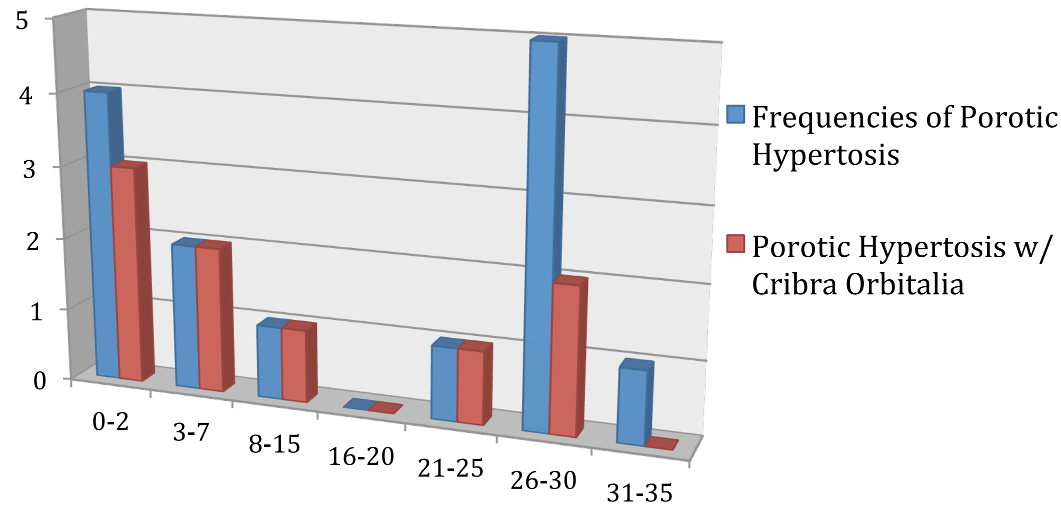

Figure 14. Number of occurrences of porotic hypertosis co-occurring with cribra orbitalia in each age-range of the STC population.

In the 0-2 and 3-7 age ranges the porotic hypertosis is active. The one incidence in the 8-15 age group is healed, but the PH in the 21-25 is active. In the 26-30 age group only one occurrence of PH is active, all others are noted as healed or healing. The one case of porotic hypertosis in the 31-35 age range is recorded as well healed. As noted above, porotic hypertosis and cribra orbitalia are often thought to have the same etiology so it is only reasonable that we would see that 64.3% (9 out of 14) of porotic hypertosis cases would coincide with cases of cribra orbital. Figure 15 illustrates the number of porotic hypertosis cases in the Amarna population for each age group.

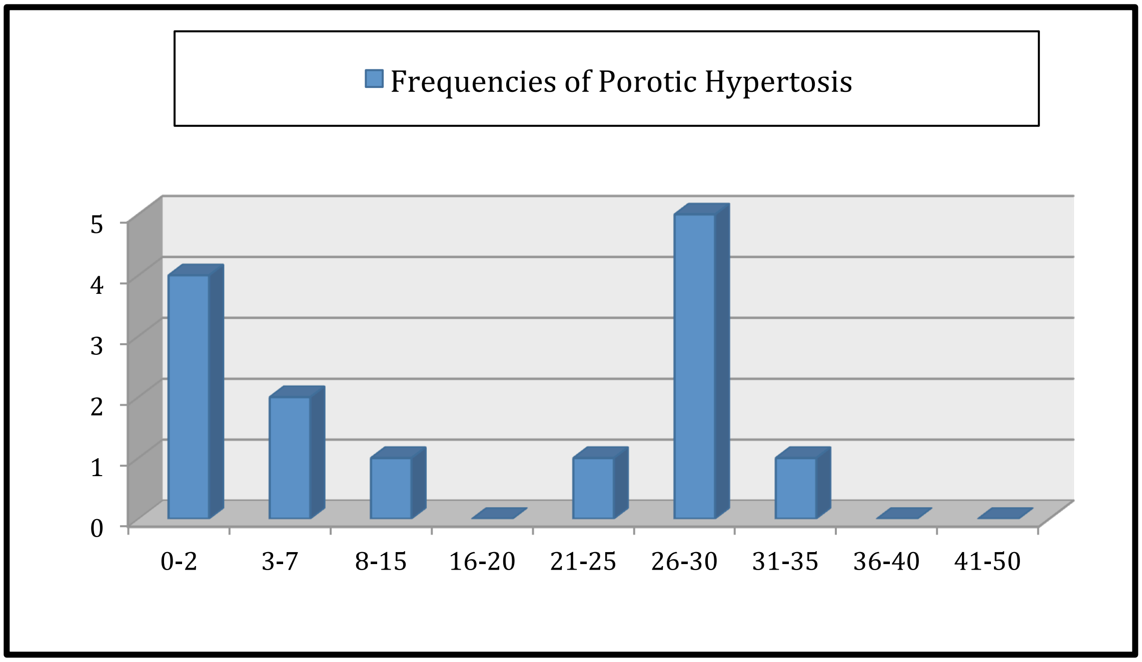

Figure 15. Frequencies of porotic hypertosis occurring in each age-range of the STC population.

Linear Enamel Hypoplasias

Linear enamel hypoplasias are bands that form around the circumference of the tooth during crown formation. These bands follow the trend of the perikymata, which are regular incremental lines on the crown surface of the tooth, and represent a disruption of the matrix deposition in the growing dentition in response to systemic psychological stress. In 1746 Robert Bunon discovered hypoplasias on the unerupted teeth of children with scurvy, rickets, smallpox, and measles, determining that they were formed during crown formation. It wasn't, however, until 1893 that this phenomenon got its own name. Otto Zsigmondy was the first to employ the term hypoplasia when he named the feature *hypoplastische emaildefecte* (hypoplastic enamel defects). Figure 16 is an example of a linear hypoplasia from individual 124 of the STC at Amarna.

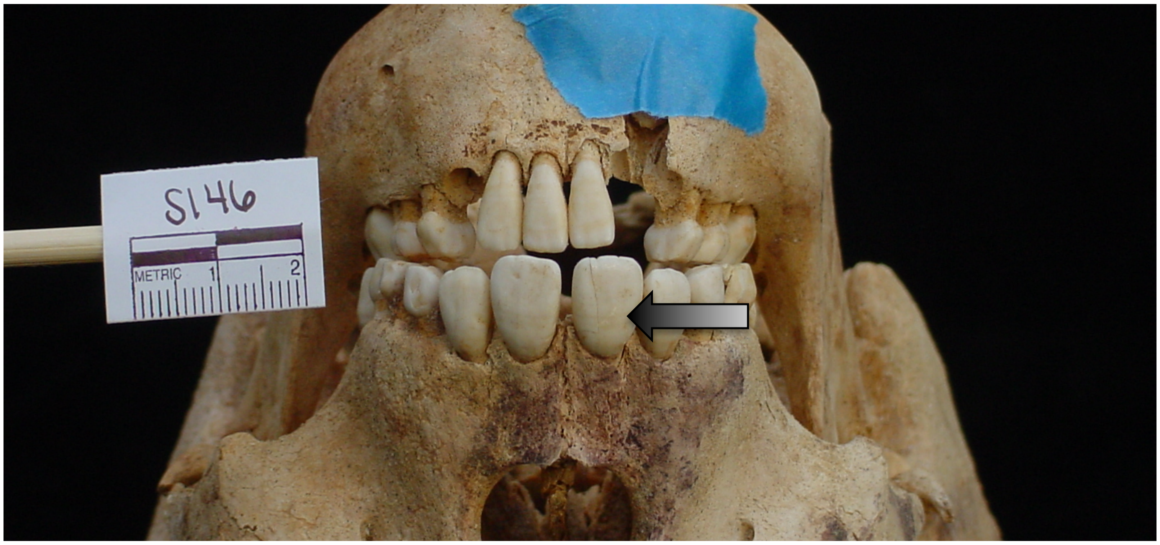

Figure 16. Skull from Individual 124 of the STC aged 8.5 detailing linear enamel hypoplasias on the maxillary central incisors.

Like porotic hypertosis and cribra orbitalia, linear enamel hypoplasias (LEH) are indicative of a non-specific stress indicator, and much research has been done to find its many etiologies. Various animal experiments, both dietary and non-dietary related, have been conducted throughout the decades. Mellanby (1929; 1930; 1943) and Klien (1945) found that a deficiency in vitamin A or D caused hypoplasias in rats while Kreshover and various colleagues, between the years 1944 and 1953 found that diabetes, fever, viruses, and bacteria also caused them (Hillson 1996).

Linear enamel hypoplasias are also associated with the neonatal line when a child suffers from a severe birth injury, which is most prominent on the labial surface of the deciduous incisors. In the article, "Linear Hypoplasia of Deciduous Incisor Teeth in Malnourished Children", by Edward A. Sweeney *et al.* (1971), found similar defects in 73% of children recovering from third degree malnutrition, as well as, 43% of those with second degree malnutrition. 22% of the rest of the population studied also suffered from hypoplasias as well, in which Infante and Gillespie (1977) relate to economic factors relating to malnutrition. Allergies, congenital defects, neonatal haemolytic anemia, maternal rubella, diabetes, and syphilis are all pre- and neonatal conditions that have been linked with the presence of hypoplasias. Linear enamel hypoplasias have also been linked with later childhood diseases such as, severe rickets and malnutrition (Goodman *et al*., 1991), diarrhea (Pindborg, 1982), chickenpox, diphtheria, measles, pneumonia, scarlet fever, and whooping cough (Sarnat and Schour, 1941; 1942). "In a review paper, Kreshover (1960) concluded that 'abnormal tooth formation is a generally nonspecific phenomenon and can be related to a variety of local and systemic disturbances" (Hillson 1996: 166).

The Neolithic Revolution, when ancient humans transitioned from hunter/gatherers to agriculturalist and pastoralists, beget another transition, the epidemiological transition where the human relationship with pathogens changed dramatically. The domestication of animals changed the pattern of human health and disease, bringing humans closer to zoonotic pathogens than they ever had been before, "there also appears to be a concomitant increase in the frequency and intensity of general stress indicators, such as enamel hypoplasias" (Grauer 2012:198). Many scholars have written on the dramatically different levels of psychological stress between hunter/gatherer societies and sedentary agricultural societies including Smith et al. (1984), Ubelaker (1984), Allison (1984), and Starling and Stock (2007). "All of these studies noted that the occurrence of enamel hypoplasias in humans rose with increased agricultural intensification, implicating the linked increase of factors such as disease and malnutrition with this major biocultural transition" (Grauer 2012:198).

Linear Enamel Hypoplasias at Amarna

As seen in figure 17, the total number of enamel hypoplasias that occur at Amarna is 63 out of 130. 58% of individuals who possess at least one stress marker have a LEH with most co-occurring with either cribra orbitalia or porotic hypertosis. Only one LEH can be found in the 0-2 age group, four in the 3-7 age group and thirteen in the 8-15 age range. The 8-15 age group possess the most hypoplasias relative to the number of stress indicators detected (19) and observable individuals (22). The 16-20 age group possess eight individuals with hypoplasias while the 26-30 age range has ten. There are seven hypoplasias in both the 31-35 and 36-40 age groups and five in the 41-50 age-range.

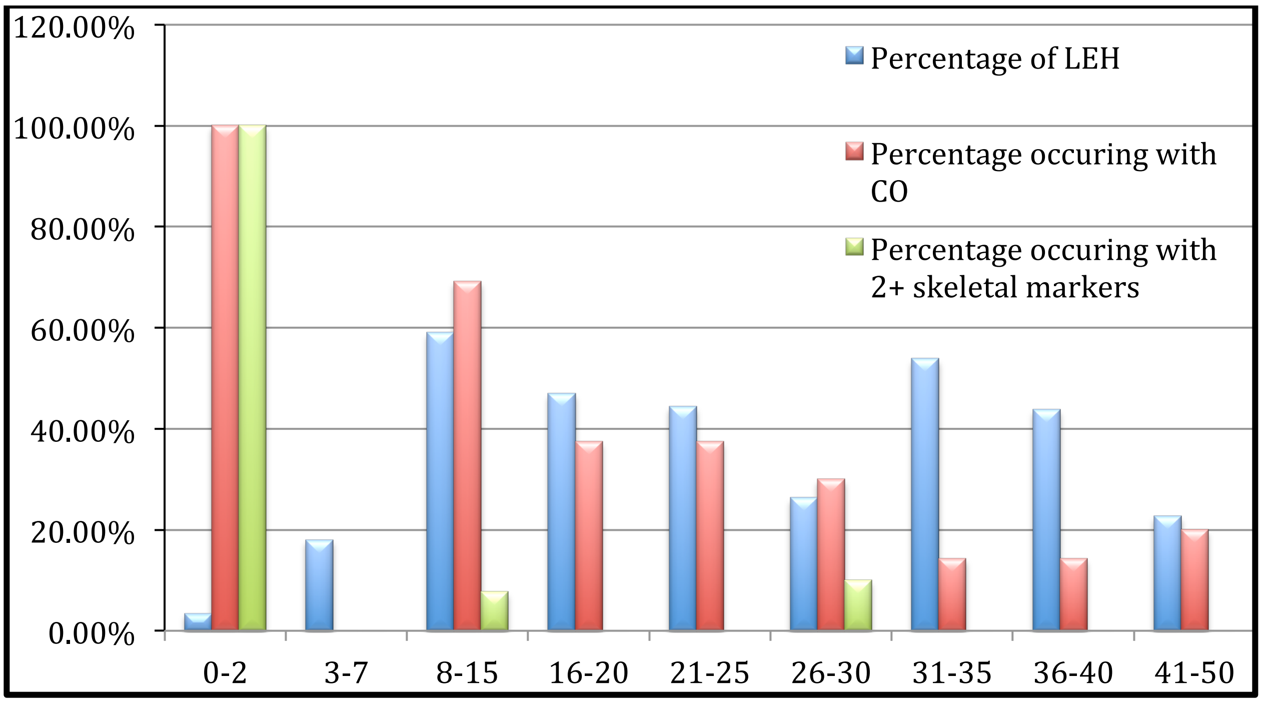

Figure 17. Percentages of linear enamel hypoplasias for the STC population, percentages of LEH occurring with cribra orbitalia, and percentages of LEH occurring with two or more skeletal markers aged 0-50.

Discussion of All Stress Markers

Upon further inspection of the skeletal material, it became obvious that the previous idea that an epidemic swept through the population killing indiscriminately was simplistic at best. This is not to say that Amarna was not suffering from some type of disease or a combination of diseases only that the answers to the problem that we are seeing at Amarna is a lot more complicated then first believed. What had not been noted in the previous findings were the skeletal markers of stress, such as cribra orbitalia, porotic hypertosis, linear enamel hypoplasias, signs of scurvy, and delayed growth. What is important about this is, that if an epidemic swept through a relatively healthy population and killed indiscriminately we would not see evidence of long term disease and stress, instead we would see skeletal material that looked relatively pristine, meaning no evidence of long-term disease and stress, or relatively low levels. Instead, what we are seeing at Amarna is quite a different story.

In figure 18 we see that out of the twenty-nine observable individuals aged 0-2, 58.6% had at least one stress marker. Out of twenty-three observable individuals aged 3-7, 86.4% had at least one stress marker. 95% of those aged 8-15 had signs of at least one stress marker, while 93.8% of those aged 16-20 did, and 77.8% of those aged 21-25 did as well. Of those aged 26-30, 52.6% showed signs of stress markers, while 66.7% of those aged 31-35 had at least one sign. Out of the twelve observable individuals aged 36-40, 43.8% had at least one stress marker, while only 27.3% of observable individuals aged 41-50 showed signs of stress. In the book *The Archaeology of Disease* by Charlotte Roberts and Keith Manchester (2005), the authors state, "…it should be remembered that only around 15 per cent of burials in a typical archaeological skeletal sample will have evidence of disease (Ortner, 2003), and 80-90 per cent of those individuals will show evidence of trauma, infection or joint disease" (2007:29). It is clear by the above numbers that Amarna far exceeds the "normal" percentage rate of what is typically seen in an archaeological skeletal sample. It is this high percentage of stress markers, which is indicative of poor health and disease that will get us closer to finding out what went wrong at Amarna.

Age	Everyone	Observab le	Stress Markers	Non e	1 Stress Marker	2 Stress Markers	3 or more stress markers
0-2	41 (14.7%)	29	17	12	9	7	2
3-7	30 (10.8%)	22	19	3	15	4	1
8-15	36 (12.9%)	22	19	3	9	10	1
16-20	26 (9.4%)	17	16	1	13	3	0
21-25	33 (11.9%)	18	14	4	9	4	0
26-30	44 (15.8%)	38	20	18	15	4	1
31-35	18 (6.5%)	13	9	4	6	3	2
36-40	20 (7.2%)	16	7	9	6	1	0
41-50	26 (9.4%)	22	6	16	5	1	0
51+	4 (1.4%)	3	3	0	2	1	0

Figure 18. Breakdown of the number of individuals represented in each age group found in the South Tombs Cemetery (STC) at Amarna, number of individuals observable, the number of stress markers observed in each age-group, the number of individuals observed with no indicators of stress, the number of individuals with one stress marker, the number of individuals with two stress markers, and the number of individuals with three stress markers

Chapter 5: Stress: Delayed Growth

> "Final achieved height is determined to a great extent by genetic factors and by the influence of hormones, most importantly growth hormone and thyroxin, … the state of nutrition during the period of active growth during puberty is the most significant factor. Thus, it is often taken as a surrogate for the comparison of nutritional status in different skeletal assemblages" (Waldon 2009:191).

"Growth and development is an area to which the study of skeletal assemblages is able to make significant contributions" (Waldron 2009:191). When attempting to extrapolate the health status of a past population it is important to understand patterns of human physical growth and development. Because of the nature of archaeological material and the lack of standardized techniques, comparisons between other archaeological groups and/or modern populations have had its share of controversy. However, it can still provide us with important information on the timing and degree of growth faltering of one population compared to another, as general consensus in the bioarchaeology community believes that the general pattern of juvenile growth in the past broadly reflects what we see in living populations today. "The congruence of growth in past and living groups suggests that there have not been major shifts in the general pattern of growth in recent human evolution…Thus, stress in past populations can be inferred on the basis of the identification of deviations in growth from 'normal' modern populations" (Larsen 1997:9).

For the past 300 years there has been a formal study of human growth and development, for as humans, we tend to be, as paleoanthropologist, David Pilbeam, has been quoted as saying, "fascinated by humanity". During these past 300 years the human growth and development field has gone through three distinct areas of interest. The first area of interest is called 'the social' as it focused on the study of growth to facilitate social reform or social-economic history. The second area is called 'the medical/educational'. It is in this area where we see growth studies being done that focused on individual children with the idea of promoting proper development and treating disorders. The third and final area of interest is called 'the intellectual/scientific' where growth studies were conducted "in service of the 'truth', to understand the form, the mechanism and the evolution of the human growth curve" (Ulijaszek et al. 1998:3). It is in this last phase where we get the standards laid out by Dr. Marion M. Maresh, in what is known by The Maresh Standard.

In 1943 a preliminary report on the growth of the major long bones of healthy children was published as part of the Child Research Council study of physical growth in order to ascertain what the normal growth rate should be for children. It is this standard that doctorial candidate at the University of Arkansas, Ashley Shidner, is using in her growth and development study of the Amarna skeletal remains, which I will employ in order to facilitate the malnourished/undernourished and overly diseased hypothesis. "Growth rate is widely recognized as a highly sensitive indicator of heath and well-being of a community or population" (Larsen 1997:8).

Although normal growth of the human skeleton does not proceed the same way for every individual, everybody does experience two major growth spurts during their youth. The first growth spurt is from birth to two years of age with a growth rate of 18-25 centimeters in the first year and 10-13cm in the second. The second growth spurt happens around puberty and is a more prolonged stage where most of the individual's height is gained at 6-13cm a year. The rate of growth is affected by a number of different components such as proper amounts of calcium, phosphorus, iron, zinc, and copper, but total energy and protein content are the most important components for growth to proceed at a normal rate. "Adequate secretion of growth hormone and thyroxin are also required for growth to proceed at a normal rate, while a number of childhood diseases, including infectious diseases and rickets will slow down growth if only temporary" (Waldon 2009:193).

In the article, "The Levels of Calcium and Magnesium, and of Selected Trace Elements, in Whole Blood and Scalp Hair of Children with Growth Retardation*",* Ozmen *et al* analyze the whole blood and scalp hair of both children with retarded growth and "normal" children in order to ascertain whether their exists different levels of copper (Cu), zinc (Zn), iron (Fe), calcium (Ca), and magnesium (Mg) in the two groups to prove their hypothesis that, "Trace element deficiencies and excesses are known to affect numerous biological functions in humans, including physical growth, psychomotor development and immunity" (2013:126). In the article mentioned above, the authors also conclude that growth retardation has been linked to systemic conditions such as iron deficiency anemia, which could explain the high prevalence of CO found in the Amarna population, growth hormone deficiency, which as pointed out above it essential for normal growth rate, and constitutional growth delay, among other things. The authors point out that the use of hair in a study such as this has many advantages. First, hair remains isolated from the metabolic activities of the human body, second, it indicates an individuals element profile at the time period, third, unlike bodily fluids hair provides historical information on both the body's concentration of trace elements and nutritional condition, and lastly, hair can also tell us about an individuals intracellular accrual of trace elements.

What Ozmen *et al*. (2013) discovered was that the 27 children with growth retardation aged 4-12 had significantly lower levels of iron and zinc in their whole blood and of iron, zinc, calcium, and magnesium in their scalp hair ($p<0.05$) when compared to the 21 children aged 4-12 in the control group, which is illustrated in figure 19. It should be noted that calcium and magnesium did not indicate a significant difference in the whole blood levels between the two groups, which demonstrates that the hair is more sensitive to the accumulation of trace elements. The authors also point out that the children in the growth retardation group come from a lower socio-economic order than the control group, are uneducated, and have a diet that consists mostly of carbohydrates.

	Children with growth retardation	Control	
	Mean (SD)µg/g	Mean (SD) µg/g	*P* value*
Age	8.59 (2.78)	8.31 (2.88)	0.370
Ca	1168 (231)	1417 (245)	0.001
Mg	168 (50)	206 (40.00)	0.005
Fe	14 (4.14)	18.03 (4.33)	0.004
Zn	157 (25.10)	218 (42.29)	0.001
Cu	9.97 (3.99)	11.83 (2.53)	0.488

*Student's *t*-test (p=0.05)

SD: standard Division

Figure 19: The mean and Standard Deviation values of the hair Fe, Zn, Cu, Ca and Mg in children with Growth Retardation and controls. (Ozmen *et al* 2013:4)

Many of the above concepts discussed above must be taken into consideration when analyzing growth and development at Amarna. In 2011 a reanalysis of the long bone length versus the dental age of the juveniles and sub-adults at Amarna found there was an inconsistency between the two, "The dental age estimates average 20 months in advance of the long bone age estimates based on the Maresh standards." (Dabbs and Zabecki forthcoming). It was at this time that the issue of delayed growth became a major factor in the analysis in the health of the remains at Amarna.

Figure 20 is just a fragment of the Amarna population that shows the incongruences between dental age and long bone length, but it is reflective of what is also being seen in the 0-2 age range as well as the 3-7 age group. “A basic assumption in human osteological research is that dental development is less influenced by environ- mental insults than skeletal development, and thus considered the best indicator of chronological age…” (Cardoso 2007:223). While skeletal growth is highly affected by the environment, thus providing a measure of growth faltering and health status, dental development is on a timed and fixed schedule that is typically used to judge whether skeletal growth corresponds to the ‘‘normal’’ rate of development.

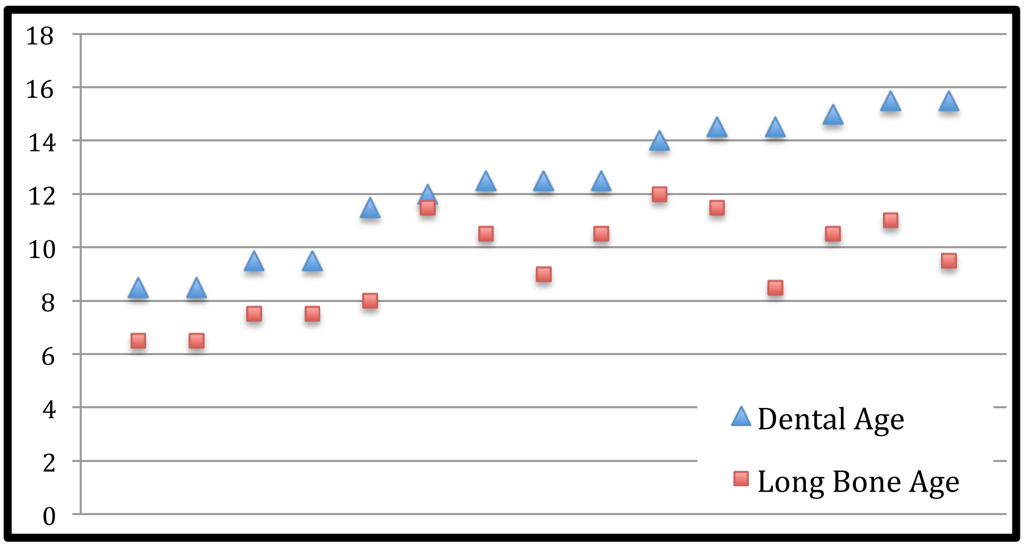

Figure 20: Dental age versus long bone age of Amarna STC Individuals aged 8.5-15.5

Figure 21 is a table of the individuals who where charted above in order to illustrate not only the age differential between the dental age and the long bone age, but also the incidences of non-specific stress indicators that these individuals possess. Only two (individuals 149 & 159) show no outward signs of stress other than growth faltering while only one individual’s long bones (individual 64) were aged the same as his dentition. Individual 206 and Individual 86 have the most extreme age difference between their dental and long bone age therefore it is not surprising that Individual 206 has cribra orbitalia, hypoplasias, and possible scurvy and individual 86 has three separate incidences of linear enamel hypoplasias.

ID	Dental Age	Long Bone Age	Pathology	CO/PH state	# of LEH
Ind124	8.5	6.5	CO, LEH	CO healed	LEH 1
Ind129	8.5	6.50	CO, LEH	CO severe healing	LEH 2
Ind109	9.5	7.5	LEH		LEH 3
Ind187	9.5	7.5	CO, LEH	CO severe active	LEH 2
Ind160	11.5	8.00	CO, LEH	CO slight healed	LEH 1
Ind64	12	11.50	CO, LEH	CO active	LEH 1
Ind41	12.5	10.00	CO, LEH	CO mild healed	LEH 1
Ind111	12.5	9	CO, LEH	CO severe healed	LEH 1
Ind149	12.5	10.50			
Ind159	13	12			
Ind170	14.5	11.50	LEH		LEH 1
Ind206	14.5	8.50	CO, LEH, possible scurvy	CO active	
Ind13	15	10.50	CO	severe	
Ind51	15.5	11.00	LEH		LEH 1
Ind86	15.5	9.50	LEH		LEH 3

Figure 21. Chart of STC individuals aged 8.5-15.5 and their corresponding dental age versus long bone age and incidences of non-specific stress indicators.

In “Growing up in Akhetaten: A Bio-Cultural Approach to Childhood Growth” Shidner (2013) has shown “that 87.7% of the subsample falls below the line of unity and that 64.6% of the subsample is below 0.90”. The line of unity represents the average for The Maresh Standard with a value of 1, anything below .09 means that the individual did not meet the average height for their age. Although it should be noted that the children used in this study were individuals from a middle class socio-economic subset of the population from Denver, Colorado *c.* 1943.

Shidner compared Amarna's juvenile and sub-adult population to Hierakonpolis' in order to correctly assess whether or not the children where if fact "short for their age". Hierakonpolis is a population from the Predynastic period of Egyptian history. The majority of the individuals in the Hierakonpolis subsample are still indeed "short for their age" with 77.1% below the line of unity and 37.1% of the subsample below 0.90, yet Amarna still has remarkably higher percentages in both categories and well below Hierakonpolis.

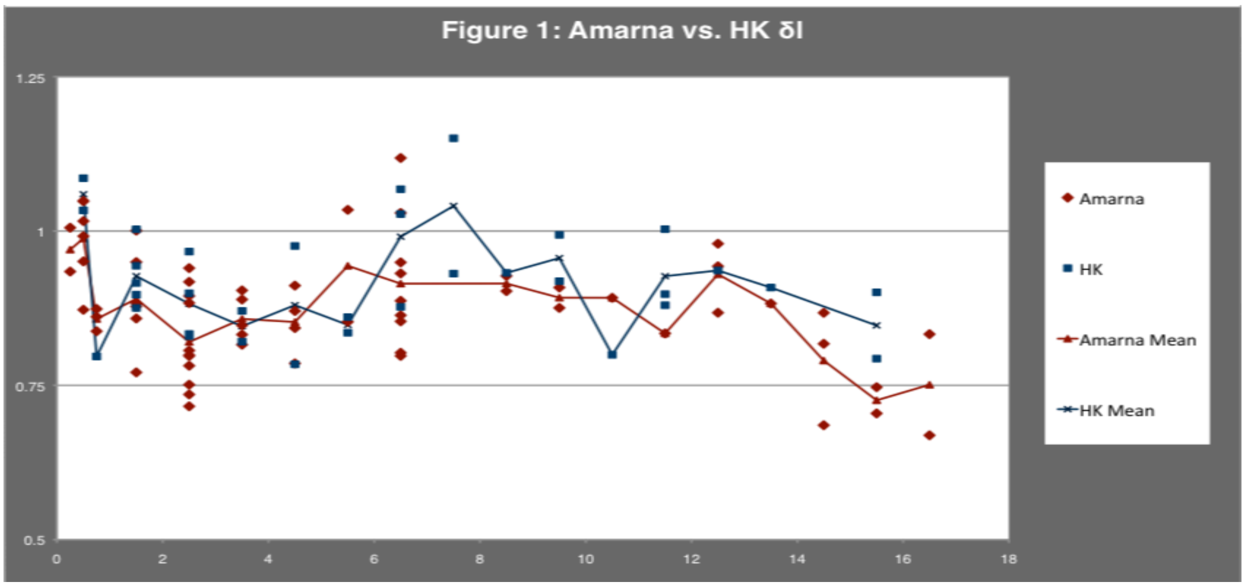

Figure 22 is a scatter plot of Individual δl values and dental age means for Hierakonpolis (HK43) and South Tombs Cemetery (STC) at Amarna and how they fall relative to the line of unity (Shidner 2013).

One of our secrets to success as a species is our growth plasticity in response ecological and environmental stress. Our bodies are able to reduce or stop growth altogether under extreme conditions and "catch-up" again when conditions are more favorable. The growth retardation that we are seeing at Amarna, coupled with the high prevalence of cribra orbitalia, porotic hypertosis, and linear enamel hypoplasias is obviously a response to an ecological and environmental stress, however the population is never recovering. There is never a "catch-up" period for the juvenile/sub-adult population at Amarna suggesting that conditions were never favorable. “If very early developmental events program abnormal growth to occur during a particular period, there may not be the capacity or stimulus to catch up when the child enters a later period” (Zakrzewski 2003:219)

Chapter 6: Diet and Malnutrition

> "Human growth is an outcome of complex interactions between genes and the environment…of which nutrition and infection are the most important components" (King & Ulijanszek, 1999:161).

Akhenaten wanted his city to portray the epitome of abundance and wealth, "[t]he two Aten temples acted as giant food displays. The art of the Amarna period exhibits something of an obsession with victuals" (Kemp 2013: 110). When Akhenaten is depicted in life and in adoration to the Aten he is accompanied by visuals of food and drink in abundance along with floral bouquets and flowing incense. Akhenaten and the Aten are not the only times food is represented in copiousness, pictures of the palace, images of the Aten temples, and other buildings are also depicted with a profusion of food. Aten temples are depicted with a plethora of offering tables piled high with food and bowls of smoking incense. The images of the palace and other buildings are illustrated with wooden tables loaded down with food and other offerings. The types of foods that these pictures depicted where whole loaves of bread, large joints of meat from cattle, and whole geese, plus other raw materials used in meal preparation (Kemp 2013).

These images of abundance are in direct contrast to what is being seen on the skeletons at Amarna. Cribra orbitalia, porotic hypertosis, linear enamel hypoplasias, and at least eleven cases of scurvy all indicate a lack of key nutrients that are indicative of malnutrition. Malnutrition is a condition that occurs when there is an insufficiency of key dietary elements in an individual's diet such as, protein, vitamins, and minerals. The insufficiencies of these key nutrients fail to meet the needs of the human body, which leads to negative effects on growth, health, behavior, mood, and other bodily functions. There are a number of causes of malnutrition. These include an inadequate or unbalanced diet, problems with digestion or absorption, certain medical conditions, and even from a diet deficient of a single vitamin. Malnutrition has varying degrees of severity from very mild with no symptoms to very severe where, although survivable, permanent damage is done to the body. Poverty, natural disasters, political problems, war, and epidemics all contribute to the conditions that cause malnutrition.

Malnutrition does not necessarily mean a total lack of food as it also involves conditions where a diet contains the proper amount of food, but does not contain the right balance of nutrients. What this means is, an individuals diet is calorically high but deficiently low in vitamins and minerals. Thus a person can have a lot of food in their diet or even be obese yet still be considered malnourished because they are not receiving the proper amount of key nutrients and minerals. On the other end of the spectrum is undernutrition, which is an insufficient caloric intake to support human health. In undernutrition an individual is not getting enough to eat so not only are they not getting all of the key dietary elements required for proper development and survival they are also not getting enough calories for energy and vitality.

Some of the diseases associated with malnutrition are protein-calorie malnutrition, in the form of kwashiorkor and marasmus, pellagra, and scurvy. Kwashiorkor is caused by a chronically low intake of protein. An individual suffering from kwashiorkor can be eating a normal amount of calories, but not getting enough protein. People suffering from marasmus on the other hand not only suffer from a chronically low intake of protein but also a low caloric intake. Some of symptoms of kwashiorkor are a swollen abdomen, called edema, which is the result of an enlarged liver, and diarrhea. The symptoms of marasmus are, failure to gain weight, stunted growth, and thin limbs and baggy skin. Both diseases cause lethargy, apathy, and irritability, and can eventually result in death. Pellagra is caused by a deficiency of niacin, or vitamin B3, vitamin B1, and the amino acid tryptophan and is usually the result of a diet with too much reliance on corn as niacin in corn is bound up in a form that isn't bioavailable for humans. Niacin is important to the proper functioning of the human body as it is necessary to release energy from proteins, fats and carbohydrates. Some of the symptoms of pellagra are diarrhea, dermatitis, and dementia. Scurvy is caused by a deficiency of vitamin C. Vitamin C is required to make collagen and a deficiency can cause a break down of ligaments, tendons, blood vessels, and bones. Some of the symptoms of scurvy are: easy bruising and bleeding, loss of hair and teeth, and painful and swollen joints. “Rickets and scurvy are both associated with malnutrition and provide insight into an important component of health in archaeological human skeletal populations” (Grauer 2012:264).

Cribra orbitalia and porotic hypertosis are considered non-specific indicators of stress, and although they have been linked to malnutrition they can also be indicative of other stressors such as disease and anemia (which has also been linked to malnutrition). Growth faltering is almost always the result of inadequate nutritional intake. As indicated above the juvenile and sub-adult population at Amarna suffered from a growth delay of at least two years, which is most likely the result of insufficient key vitamins and minerals such as, copper, zinc, iron, calcium, and magnesium, elements that would be lacking in a diet with little or no protein. How can a population that depicts tables overflowing with breads and meats be so malnourished?

The depictions of food found on the walls of tombs and other ancient buildings are not the only evidence available to us; there is also other archaeological evidence of the types of food that existed in Akhenaten’s city. Amphorae labels have been found impressed with hieroglyphic designations of duck, honey, grapes, beer, and dates. Bones of cattle, sheep, goats, pig, and hyena have been excavated in and around Amarna. “In archaeological samples from the main residential part of the city, pig is the most numerous mammal species, making more than half of those that were killed, although the majority were young animals and therefore not large" (Kemp 2013:219). Plant remains and an abundance of remnants of personal bakeries and broken bread molds hold testimony to the main source of the Egyptian diet; cereals. The populace of Amarna had a diet that consisted mostly of cereals, in the form of bread and beer. There were two kinds of cereals from which the bread and beer were derived; barley for the beer and emmer, a type of wheat, for the bread.

The link between cereals being the staple of the Egyptian diet and malnutrition is that cereals lack the required vitamins and minerals essential to the maintenance of health, most specifically iron, vitamin B_{12}, calcium, and zinc. The most recently available USDA data indicates that animal products provide 19% of the iron, 29% of the magnesium, 56% of the zinc, 16% of the copper, and 77% of the calcium content in a diet. Another important component besides mineral content is mineral bioavailability. Mineral bioavailability may be inhibited by certain factors in different plant foods, as well as enhanced by other factors (Hunt 2002). As an example iron from sources such as wheat, rice, maize, soybeans, and black-beans is poorly absorbed by the body, "[i]n fact, only 1 to 7 percent of the iron in vegetable staples…is readily absorbed when consumed alone, i.e. without meat" (Holland and O'Brien 1997:184).

Since much of the literature pertaining to porotic hypertosis and cribra orbitalia link the presence of these skeletal indicators of stress with iron deficiency anemia it is important to note that the chemical form of iron is an important factor affecting dietary iron availability:

> "…a plant- based diet alters the distribution of dietary iron between the efficiently absorbed heme form that is approximately 40% of the iron in meat, poultry, and fish, and the less well absorbed nonheme form present in all foods. Absorption of nonheme iron is substantially affected by both body iron status and by dietary enhancers and inhibitors. Reducing meat consumption decreases dietary heme iron, which accounts for approximately 2 mg (10 –12%) of the iron in a diet with substantial amounts of red meat" (Hunt 2002:128)

Hunt also points out in her article, “Moving Toward a Plant-based Diet: Are Iron and Zinc at Risk?”, that certain foods or factors such as; phytic acid (6-phosphoino- sitol) in whole grains, legumes, lentils, and nuts inhibit nonheme iron absorption as does polyphenols (the tannic and chlorogenic acids) in tea, coffee, red wines. There are also a variety of other cereals, spices, and vegetables that inhibit nonheme iron absorption.

Mineral content and mineral bioavailability of protein are, as important as it may be, not as important as the total intake of protein. According to the WHO Technical Report Series #935 titled, *Protein and Amino Acid Requirements in Human Nutrition: Report of a Joint WHO/FAO/UNU Expert Consultation* (2007) the amount of protein required to maintain weight and health is .66 grams per kilogram of body weight per day (.023 ounces per 2.2 pounds). Depending on sex and age an additional amount arranging from .09 to .01 grams per kilogram of body weight per day is needed for required growth. For example; a female aged 15 weighing 43.09 kilograms (95 pounds) requires 28.44 grams (1 ounce) of protein a day for maintenance and 29.73 grams (1.05 ounces) in order to sustain proper growth as seen in figure 23.

29.73 grams, or a little over an ounce a day, of protein appears to be an amount easily attainable by a population whose archaeological remains show an abundance of cow and pig bones, so the question remains; how can the skeletons present such high percentages of indicators of stress and growth faltering that are indicative of poor nutrition? Beyond the inefficiency of nutrient absorption and total intake requirements is cultural availability and the effects of disease on the body.

Age (years)	Maintenance requirement[a]	Growth requirement[b]	Average requirement	Safe level[c] (+1.96SD)	1985 report
	(g protein/kg body weight per day)				
Girls					
11	0.66	0.07	0.73	0.90	1.00
12	0.66	0.06	0.72	1.89	0.98
13	0.66	0.05	0.71	1.88	0.98
14	0.66	0.04	0.70	0.87	0.94
15	0.66	0.03.	0.69	0.85	0.90
16	0.66	0.02.	0.68	0.84	0.87
17	0.66	0.01	0.67	0.83	0.83
18	0.66	0.00	0.66	0.82	1.80
Boys					
11	0.66	0.09	0.75	0.91	0.99
12	0.66	0.08	0.74	0.90	0.98
13	0.66	0.07	0.73	0.90	1.00
14	0.66	0.06	0.72	0.89	0.97
15	0.66	0.06	0.72	0.88	0.96
16	0.66	0.05	0.71	0.87	0.92
17	0.66	0.04	0.70	0.86	0.90
18	0.66	0.03	0.69	0.85	0.86

[a]Calculations and notes as in Table 33a.

Figure 23. Amount of protein required for proper growth and maintenance per day per kilogram of body weight for boys and girls aged 11-18 from *Protein and Amino Acid Requirements in Human Nutrition: Report of a Joint WHO/FAO/UNU Expert Consultation.* WHO, 2007.

According to *The City of Akhenaten and Nefertiti Amarna and Its People* (2013) by Barry Kemp, cattle were thought to be the sacred property of the Aten and they held a special place within temple ceremonies. The Great Aten Temple was specifically designed to accommodate the slaughtering of the garland-laden cattle. Fresh joints were specifically cut only for the Aten while preserved meats were for private consumption and royal banquets. Archaeological finds included pottery jars with ink labels identifying the context as ‘meat for the festival’ or ‘for the daily offering’. But this meat was not for everyone, “[t]he food handouts that were traditionally at the centre of Egyptian temples and their cults were not, however, charitably for the poor. The beneficiaries were temple employees, officials and people involved in private funerary cults" (2013:116).

Even if the population of Amarna is supplementing their cereal-based diet with meats such as pig, cattle, duck, fish, and even hyena, but they are also suffering from chronic disease then they are still not getting the recommended daily requirements needed for proper health maintenance. There is a multifactorial cause of malnutrition that includes both a reduced intake of proper nutrition and the metabolic effects of underlying disease. "Nutrition and infection interact with each other synergistically. Recurrent infections lead to a loss of body nitrogen and worsen nutritional status; the resulting malnutrition, in its turn, produces a greater susceptibility to infection" (WHO 2007: 196).

Chapter 7: Diseases of the Nile Valley

The microbes of disease and their vectors have had a long and symbiotic relationship with humans and their genetic ancestors so it should come to no surprise that that the ancient population at Amarna suffered from various maladies of their own. As previously discussed, one of the potential causes for the non-specific stress indicators cribra orbitalia, porotic hypertosis, and linear enamel hypoplasias to develop on the bone, besides poor diet and unsanitary conditions, is a high incidence of diseases especially infectious disease (Jatautis *et al.* 2011). Incidences of disease is also a factor in growth faltering and in the maintenance of key vitamins and nutrients in the body, so it is imperative to investigate the types of infections a population might be suffering from in order to fully understand their health status. Potential diseases and afflictions that have already been discussed that could have been plaguing the population of Akhenaten's ancient city are: several types of anemias, ranging from low iron intake to B12 deficiency, scurvy, kwashiorkor, and marasmus. However, there are potentially many more vectors afflicting the population, such as malaria, hookworm infection, and schistosomiasis.

Due to DNA tests done on a number of mummies between September 2007 and October 2009 by Zahi Hawass, former Minister of State for Antiquities Affairs in Egypt, and other investigators from Germany and Italy, malaria can unequivocally be said to have existed in Egypt during the reign of Akhenaten as his alleged son, Tutankhamen, was a victim of the disease (Markel 2010). There are many elements that factor into the presence of malaria in an area, which are a mixture of socioeconomic factors, cultural practices, and behavioral aspects. There are climatic variations such as rainfall, temperature, and humidity, as well as natural variations such as, bodies of water, vegetation and soil type, natural disasters, and mosquito species. There are also human factors that affect the presence of malaria and their vectors the mosquito, such as: developmental projects, irrigated agriculture, mining, dams, and conflict. As a brand new city built on the Nile, Akhetaten possessed many of the factors that are required for the presence of malaria. It had a large body of water (the Nile), on going development projects (the city itself), irrigated agriculture (intensive agriculture in the form of emmer and barley), and mining (stone quarries for the continuing development of the city).

There are four kinds of malaria parasites that can infect humans: *Plasmodium falciparum, P. vivax, P. ovale*, and *P. malariae,* which is transferred to humans by the *Anopheles* mosquito. *P. falciparum* is the most common form and the deadliest. It is postulated that *P. falciparum* is a very ancient disease that has evolved over the past 100,000 years (Sallares *et al.* 2004). Once the infected *Anopheles* mosquito bites their victim the parasite, *P. falciparum,* quickly makes its way into the cells of the liver where it begins to divide rapidly into around 30,000 daughter parasites called merozoites. After about a week the merozoites burst out of the enlarged liver cells and enter the blood stream where they then rapidly enter the host's red blood cells. Inside the red blood cell, protected from the host's immune system, they begin the cycle of growth, release, and reinvasion again. Unchecked this repeated cycle can destroy most of the host's red blood cells within 12 to 14 days. The destruction of the red blood cells is what causes anemia in the human body, which is a likely suspect for the presence of cribra orbitalia and porotic hypertosis.

Malaria is not the only infection that can cause anemia; a single hookworm can remove between 0.02ml (*Ancylostoma duodenale*) and 0.05ml (*Necator americanus*) of blood a day. When coupled with a low protein intake and high parasite infection, blood loss is even more substantial. *Ancylostoma duodenale* is the most common form of hookworm infection in modern Egypt with a prevalence of 0.2 to 17.5 per cent and theoretically also affected earlier generations as well due to similar environmental circumstances (Holland and O'Brien 1997). Hookworms thrive and proliferate in environments with an abundance of standing water and large human settlements, which is the product of intensive irrigation agriculture.

The *A. duodenale* hookworm infects its human host either by ingestion of the larvae or penetration of the skin by the larvae. The larvae then makes its way to the upper and middle sections of the small intestine where they lay their eggs to later be removed with the hosts stool. The anemia is caused because the hookworm continuously consumes the blood of the host as food, "the severity of the iron-deficiency anaemia… are related to the duration of infection, number of worms, the iron content of the diet and iron reserves of the host" (Keita 2003:214). Keita also notes that children are more severely affected than any other part of the population and that one of the effects of infection is growth retardation. Hookworm infection is not only known to cause anemia, but it also causes an increase of susceptibility to other infections as well. Hookworm infection can also cause a malabsorption of vitamins A, B-12, and folic acid and cause intestinal protein loss. It can also cause an overall incapacity that manifests as anorexia.

According to Michele Buzon in her article, "Health of the Non-Elites at Tombos: Nutritional and Disease Stress in New Kingdom Nubia", "research using autopsy and immunological methods indicates the presence of schistosomiasis in predynastic and dynastic Egyptian remains" (2006:34). Schistosomiasis, like hookworms thrive in watery conditions. There are two species of schistosomiasis currently present in the Nile Valley, *Schistosoma mansoni* and *S. heamatobium*. The degree of exposer depends on the presence of the *Biomphalaria or Bulinus* species of snails in fresh bodies of water. Infection happens when the snails release parasite larvae into the water, which then infect human hosts by penetrating the skin to enter the blood vessels. Infection is more likely when the host does not dry completely when completing occupational or recreational activities such as, washing wheat, irrigating, playing (children), or bathing. Schistosomiasis can cause anemia as one of it key symptoms is blood in the urine and in its more extreme form bleeding colonic polyps. Schistosomiasis also causes a deficient immune system allowing for the host to become more susceptible to disease and it is theorized that it also causes growth faltering due to malnutrition (Keita 2003).

A high disease load and an inefficient diet all contribute to and explain the large number of cases of cribra orbitalia, porotic hypertosis, and linear enamel hypoplasias, but it doesn't explain those individuals without any of those skeletal markers of stress. Figure 24 illuminates the individuals in the archeological record with no skeletal stress markers. As pointed out in the pivotal article, "The Osteological Paradox: Problems of Inferring Prehistoric Health from Skeletal Samples", the absence of skeletal markers does not automatically mean a healthy individual, in fact it could mean the exact opposite; that the individual died quickly of an infectious disease thus not allowing the time it takes for skeletal lesions to form (Wood *el al.* 1992). The numbers in figure 24 are relatively low compared to the presence of skeletal indicators of stress, but their presence must still be noted especially in light of cultural evidence coming out of Hittite history that may explain the reason for these individuals for ending up in the archaeological record.

Age	Observable	Stress Markers	None	Age	Observable	Stress Markers	None
0-2	29	17	12	26-30	38	20	18
3-7	22	19	3	31-35	13	9	4
8-15	22	19	3	36-40	16	7	9
16-20	17	16	1	41-50	22	6	16
21-25	18	14	4	51+	3	3	0

Figure 24. Breakdown of the number of observable individuals represented in each age group found in the South Tombs Cemetery (STC) at Amarna, the number of stress markers observed in each age-group and the number of individuals observed with no indicators of stress.

The Hittite plague prayers mention a plague ravaging the Hittite population coming from Egypt during the reign of Akhenaten (Singer 2002). A Hittite king named Mursili pleads with his gods and goddesses in several separate prayers to take the plague away that have afflicted them for years. In Mursili's "Second" Plague Prayer to the Storm-god of Hatti he recounts the events leading up to the capture of Egyptian prisoners of war and ends saying, "…a plague broke out among the prisoners of war, and [they began] to die. When the prisoners of war were carried off to Hatti, the prisoners of war brought the plague to Hatti. From that day on people have been dying in Hatti" (Singer 2002:58).

The term plague is misleading as it often leads one to think of the Black Plague of Europe in the 14th century, but we must remember that these are translations using modern vernacular and not necessary the term that was used in the time of writing of the actual text. Plague could also have had a different or many meanings then how it is used today. It is clear, by how Mursili discusses the subject, no matter what its original meaning was, the 'plague' he talks about is highly infectious and deadly, so it is not in the realm of impossibility that some unknown epidemic was also ravaging Egypt on top of other vectors and malnutrition.

Conclusion

The hot Egyptian sun bakes the light brown skin of an eight-year-old boy playing with his six-year-old brother in the Nile to cool off from the Aten's relenting heat. Giggling the older boy splashes his brother and then sighs heavily as he gazes on his younger brothers taunt cheeks and back so bony he can count each separate vertebrae. But what makes him even sadder is his little brother's swollen belly and its rumblings of hunger and he knows that no matter how many beautiful pictures surround them of the bountiful fruitfulness of the Aten they will go hungry again tonight. And tomorrow, rather than playing in the Nile with his brother he may be making a trek out into the desert to bury him next to his sister instead.

A poor diet and a high infection load comprised a wretched life for the populace of the city of ancient Akhetaten (modern Amarna). The first indication of this was the unusual demography of the population of Amarna, which looks more like a 'mountain peak' then a 'Nike swoop' that a normal population represents. A normal population generally has a high number of fatalities in the infant stages of life, between the ages of 0-2, but then drops off considerably only to start slowly rising again after the age of fifteen. At the South Tombs Cemetery, Amarna, the fatalities for those aged 3-21, the juveniles and subadults, stay consistently high. In the early stages of investigation the demography of Amarna was compared to populations that were affected by various epidemics: small pox, influenza of 1918, and the Bubonic Plague. The demographic profiles of Amarna and those affected by epidemics matched up almost exactly. It was then that the idea that an epidemic was the cause of the unusually high number of deaths found in the juveniles and subadults population and the initial theory was born (Kuckens 2008).

Although the epidemic theory seemed like a plausible explanation the need for a more in-depth investigation was in order to see if the epidemic theory held up. The skeletal material was then analyzed for certain skeletal markers of stress such as cribra orbitalia, porotic hypertosis, and linear enamel hypoplasias to ascertain the health of the population of the South Tomb Cemetery. What was discovered was that 65% of the total observable population had at least one skeletal marker, which meant that a large portion of this population was suffering from some type of long-term bodily stress. Cribra Orbitalia makes up 59.2% of the stress markers found on the skeletons while porotic hypertosis makes up 10.8% of all the stress markers and linear enamel hypoplasias makes up 48.5% of all the stress markers found on the skeletal material of the STC population. Both cribra orbitalia and porotic hypertosis are theorized to be the result from various forms of anemia caused by numerous sources such as diet and disease. Linear enamel hypoplasias etiology is also thought to be dietary and disease related in nature.

Another indicator of stress that the skeletons of the South Tombs Cemetery possess is growth faltering. Growth is a recognized indicator of health and when it is stunted, malnutrition, undernutrition, and infections are generally known as the reasons for said stunting. An appropriate diet is key for proper growth and health and it is the essential vitamins and minerals in a diet that insure good health. When a diet lacks certain vitamins and minerals the body cannot function properly and 'shuts down' resulting in growth faltering. When the human body lacks the key vitamins and minerals of iron, vitamin C, and vitamin B12 it also attributes to the skeletal markers of stress such as cribra orbitalia, porotic hypertosis, and linear enamel hypoplasias.

Although the ancient city of Amarna, known during the reign of Akhenaten as Akhetaten, was decorated abundantly with pictorial tombs murals of bountiful food in the form of meat and bread piled high on lavish tables the food was not for public consumption. Instead the food was for the Aten and only those in the higher echelon were allowed to partake in the feasts laid out for the god. Instead the main source of nourishment for most of the population came from cereals in the form of bread and beer. Bread and beer have low nutritional value and the chemical make-up of vegetable based foods is also known to inhibit absorption of key vitamins from protein such as iron. Poor nutrition also makes the body more susceptible to disease and recurrent infection pulls vital nutrients out of the body such as nitrogen, thus leaving it even more susceptible to disease. Some of the effects of malnutrition are scurvy, kwashiorkor, and marasmus.

Besides a poor diet, cribra orbitalia, porotic hypertosis, and linear enamel hypoplasias are a result of a high disease load. Some of the potential diseases that the population at Amarna could have encountered are, malaria, hook worm, and schistosomiasis. All three vectors thrive in the type of environment that would have existed in the city of Akhetaten such as, irrigated water, standing water, and a bustling city thriving with people. All three infections cause anemia, which is thought to produce the skeletal porosities of cribra orbitalia and porotic hypertosis. And then there is the possibility of an unknown highly infectious disease, which was alluded to by the Hittite's in a plague prayer written by Mursili during the reign of Akhenaten, and could explain those individuals who are in the archaeological record who have no indicators of stress.

As alluded to in the brief prose at the beginning of this chapter, life in Akhetaten was filled will hunger, deprivation, and turmoil and was not the paradise in the desert that Akhenaten wanted so much for everyone to believe it to be. In order to truly test the theories laid out above some further test should be done. One thing that is available in abundance from the skeletal remains coming from the South Tombs Cemetery excavation site is hair. Test could be done on the hair to test for the presence and amount of vitamins and minerals as was done by Ozmen *et* *al.* in "The Levels of Calcium and Magnesium, and of Selected Trace Elements, in Whole Blood and Scalp Hair of Children with Growth Retardation" (2013) so we can say for sure if the population was in fact deficient in key nutrients or not. This type of test could definitively tell us about the state of health of the population at the South Tombs Cemetery at Amarna, Egypt.

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