The Amarna South Tombs Cemetery:

Biocultural Dynamics of a Disembedded Capital City in New Kingdom Egypt

by

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ABSTRACT

The Egyptian New Kingdom city of Akhetaten (modern: Tell el-Amarna, el-Amarna, or simply Amarna) provides a unique opportunity to study ancient biocultural dynamics. It was a disembedded capital removed from the major power bases of Memphis and Thebes that was built, occupied, and abandoned within approximately 20 years (*c*. 1352–1336 BCE). This dissertation used the recently excavated Amarna South Tombs cemetery to test competing models for the development of disembedded capitals, such as the geographic origin of its migrants and its demographic structure in comparison to contrastive models for the establishment of settlements. The degree to which biological relatedness organized the South Tombs cemetery was also explored. The results suggest that the Nile Valley into the New Kingdom (1539–1186 BCE) was very diverse in dental cervical phenotype and thus highly mobile in respects to gene flow, failing to reject that the Amarna city was populated by individuals and families throughout the Nile Valley. In comparison, the Amarna South Tombs cemetery contained the least amount of dental phenotypic diversity, supporting a founder effect due to migration from larger, more diverse gene pools to the city or the very fact that the city and sample only reflect a 20-year interval with little time to accumulate phenotypic variation. Parts of the South Tombs cemetery also appear to be organized by biological affinity, showing consistent and significant spatial autocorrelation with biological distances generated from dental cervical measurements in male, female, and subadult (10–19 years of age) burials closest to the South Tombs. This arrangement mimics the same orderliness in the residential areas of the Amarna city itself with officials surrounded by families that supported their administration. Throughout the cemetery, adult female grave shaft distances predict their

biological distances, signaling a nuclear family dynamic that included many females including mothers, widows, and unwed aunts, nieces, and daughters. A sophisticated paleodemographic model using simulated annealing optimization projected the living population of the South Tombs cemetery, which overall conformed to a transplanted community similar to 19th century mill villages of the United States and United Kingdom.

DEDICATION

To my lovely wife Rhonda, and my beautiful boys Aiden and Alexander.

ACKNOWLEDGMENTS

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Chapter 1:

INTRODUCTION

The main topic of this dissertation is the biocultural dynamics of a common

strategy used throughout history that the pharaoh Akhenaten (1355–1338 BCE) employed

to neutralize power bases: the creation of a disembedded capital. A disembedded capital

is a city created by a municipal entity to subdue competition among substantial bases of

political and religious influence by utilizing neutrality as its chief maneuver (Blanton

1976; Willey 1979; Joffe 1998). Many modern capitals developed in this manner, for

example, Brasília, Canberra, Ottawa, New Delhi, and even Washington, D.C. (Walton

1966; Epstein 1973:28–30; Knight 1977a,b; Fischer 1984; Bowling 1991). During his

reign the pharaoh Akhenaten constructed Amarna, a capital city in Middle Egypt

approximately equidistant between Memphis in the north – the political center containing

the high court – and Thebes in the south – the religious hub. This new city was key to the

institution of his new religion and centralization of control and authority of the empire.

The archaeological site of Amarna provides a unique opportunity for the study of

biocultural dynamics because it was built, occupied, and abandoned within approximately

20 years (*c*. 1352–1336 BCE). This dissertation is the first bioarchaeological study

specifically theorized in terms of a disembedded capital, particularly significant due to

Amarna's restricted time span of occupation.

This dissertation tests current, competing models for the development of

disembedded capitals, focusing on issues of population structure, specifically the

geographic origin of its migrants. It also explores the degree to which biological

relatedness organized Amarna's cemeteries, and the demographic structure of these

cemeteries in relationship to contrastive models for the establishment of disembedded

capitals. The recently excavated South Tombs Cemetery (STC) at Amarna allows

bioarchaeologists to address these historical research questions because of the limited

time frame associated with the mortuary assemblage.

This study focuses on the skeletal sample from the Amarna STC for several

reasons. One is the generally excellent preservation of archaeologically recovered human

remains. In addition, the sample size is large ($N = 357$) and the data originate from a

recent excavation (2006–2013) with extensive archaeological documentation (Kemp

2013; Kemp et al. 2013). As a documented disembedded capital with a short temporal

time span (15–20 years), the Amarna STC sample is used to test whether the Amarna

residents reflect diverse populations drawn from throughout the Nile Valley. This

research also explores the degree to which biological relatedness structured the

organization of the cemetery, and if the cemetery mimics the organization of the city

itself with clusters of small families around officials (Kemp 1977a, 1989:261–317; Kemp

and Stevens 2010a,b; Kemp et al. 2013). Additionally, the tight temporal resolution at

Amarna provides a rare opportunity for examining paleodemography and the application

of sophisticated mathematical modeling (Bonneuil 2005). The overarching significance

of this dissertation is its contribution to archaeology and bioarchaeology overall, but

specifically focusing on subjects such as kinship studies (Konigsberg 1987; Buikstra et

al. 1990; Stojanowski and Schillaci 2006; Johnson and Paul 2015; Larsen 2015:357–401)

and migration studies (Anthony 1990; Burmeister 2000; Cabana and Clark 2011;

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Campbell and Crawford 2012; Baker and Tsuda 2015), and impacting other disciplines like economic history, human biology, and urban ecology.

Research Questions

This dissertation project addresses three key research questions:

(1) *Does the gene pool of those buried in the Amarna STC reflect gene flow from a specific region(s) or, alternatively, from throughout the Nile Valley?* Not much is known about where populations originated from geographically when they migrated to ancient cities, let alone disembedded capitals (Blanton 1976; Willey 1979; Joffe 1998; Smith 2014). Like modern times, a common assumption for ancient city peopling is that rural-to-urban migration fueled them (Smith 2014), but other ideas are posited such as migration forced by the state or through coercion (Morris 1972; Hugo 2006).

(2) *Did biological relatedness structure the organization of this* de novo *urban center's cemetery?* Understanding the familial organization of ancient cemeteries illuminates the identity and ideology of ancient peoples and provides a foundation for other kinship studies in pre-industrial societies (Konigsberg 1987; Buikstra et al. 1990; Stojanowski and Schillaci 2006; Johnson and Paul 2015; Larsen 2015:357–401; Ensor et al. 2017), specifically our knowledge of how identities form in newly constructed settlements like cities and disembedded capitals.

(3) *Does the age structure of the Amarna STC conform to a specific migration scenario such as an accretional or transplantation?* Migration is poorly understood in antiquity since archaeological data makes predicting and identifying its occurrence challenging (Anthony 1990; Burmeister 2000; Cabana and Clark 2011; Crawford and Campbell 2012; Baker and Tsuda 2015). Enhancing our knowledge of the process of such migration, with particular usage of paleodemography in this dissertation, responds to the call to meet one of archaeology's greatest challenges (Kintigh et al. 2014a, b).

Organization

Chapter 2 provides a backdrop of biocultural dynamics in bioarchaeology. Though many aspects of archaeology and bioarchaeology are considered under the purview of biocultural dynamics (e.g., stable isotope analysis), this chapter focuses specifically on the methods employed to answer the research questions posed such as biodistance analysis and paleodemography, including a thorough history of scholarship. Biodistance analysis and paleodemography are two quantitatively intensive avenues of bioarchaeological inquiry and often require extensive elaboration concerning their assumptions and methodological implementation.

Chapter 3 contains a brief history of the Nile Valley in terms of Egyptology, geography, physiography, and bioarchaeology of the region. This chapter commences with a general overview of the geography and physiography of the Nile Valley from the Eocene epoch (~40 million years ago) to the concept of the *Green Sahara* and eventually the climatic medium that likely sparked Pharaonic civilization. The subsequent part of

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this chapter considers the field of Egyptology, including its origins arguably dating back to the ancient Egyptians themselves to the Graeco-Romans purveyors, Arab scholars seldom highlighted due to Eurocentrism, and eventually to the discovery and deciphering of the Rosetta Stone. The final section of this chapter supplies an archaeology and bioarchaeology of the Nile Valley.

Chapter 4 explores the extensive history and archaeology of Amarna, including an introduction to the New Kingdom and the 18th Dynasty. It also comprises an in-depth summation of the concept of disembbeded capitals and population dynamics, as well as a detailed history of scholarship surrounding the discovery of the city of Amarna and excavations from the 18th century to the most recent excavations at the South Tombs cemetery.

Chapter 5 features the specific methods in biodistance and paleodemography used to investigate the previously outlined research questions, which are also termed Models 1–3. For biodistance analysis, dental cervical measurements were collected from individuals recovered from the Amarna STC as well as from relatively contemporaneous New Kingdom samples such as Memphis, Thebes, and Tombos (Petrie 1909; Buzon 2004, 2006). A large-scale biodistance analysis (Model 1) was conducted with these four samples using **R** matrix. A small-scale biodistance analysis (Model 2) used Mantel tests (Mantel 1967) to ascertain whether geographic distances predict biological relatedness in the Amarna STC. And for Model 3, a form of simulated annealing optimization (Bonneuil 2005) was applied to investigate the South Tombs cemetery age structure to evaluate whether the city of Amarna was populated via one of two migratory scenarios: accretion or transplantation.

Chapters 6 and 7 present the results and discussion surrounding these research questions (Models 1–3), and Chapter 8 contains the conclusion.

Chapter 2:

BIOCULTURAL DYNAMICS IN BIOARCHAEOLOGY

This chapter presents a brief overview of the bioarchaeological methods and theoretical foundations employed in biodistance analysis and paleodemography, the two primary analyses used to answer the research questions outlined in Chapter 1. This dissertation addresses biocultural dynamics such as human migration and settlement strategies, gene flow, and biological relatedness under the guise of bioarchaeological inquiry. The term "biocultural dynamics" used herein refers to a framework that stresses the importance of the influence of biological and cultural interactions within human societies of the past and the forces that drive change (Blakely 1977).

Bioarchaeology Defined

Bioarchaeology is the contextual analysis of human remains (Buikstra 1977:67; see also Buikstra and Beck 2006:xvii–xx). This type of analysis requires extensive knowledge of anthropological and archaeological principles, methods, and theories at both the local and global levels. It also requires expertise in biological anthropology with a specific focus on the analysis and interpretation of human skeletal remains and tissues. The term "bioarchaeology" began to appear in texts concurrently in both the United States and the United Kingdom in the 1970s. In the U.K., Grahame Clark's study at Starr Carr (1972) used the word "bioarchaeology" in its title, yet the type of bioarchaeology

Clark referred to is one that encompasses the study of archaeologically recovered faunal remains. By the late 1970s, a different meaning for the term "bioarchaeology" began to evolve in the United States. Buikstra (1977:67) defined a bioarchaeological perspective as one that used human osteology coupled with a multidisciplinary research program to focus on a number of research questions surrounding variation in burial programs, human activities and lifestyles, paleodemography, population migration and biological relationships, paleodiet, and paleopathology (see also Buikstra 2006:xviii). This type of bioarchaeological research program was heavily influenced by Binford's (1962) "New Archaeology," which challenged archaeologists to move away from simply building chronologies of human occupation, and to provide ideas about the processes of changes in human behavior over time and space (i.e., processual archaeology; see also Willey 1958; White 1959; Binford 1965; Clarke 1968). The field of bioarchaeology also originated in physical or biological anthropology, where many early works focused exclusively on typologies and reporting of quantitative and qualitative data on human remains (e.g., Morton 1839; Blumenbach 1865), with very little emphasis on collaboration with archaeologists and hypothesis testing (Buikstra 1991). In this way, bioarchaeology responded to the call of Washburn's (1951, 1953) "New Physical Anthropology" by shifting the discipline of biological anthropology from a strictly descriptive enterprise to integrated research designs to address a range of theoretical and historical questions (Buikstra 1977:67). It also championed carefully chosen archaeological contexts as "natural laboratories" for testing hypotheses about humankind's history.

Bioarchaeological inquiry has progressed significantly with new methodologies, technologies, and nuanced theoretical paradigms. Early critiques began to question the representativeness of archaeological human skeletal samples (Cook and Buikstra 1973, 1979), an idea that developed into the well-known "osteological paradox" (Wood et al. 1992) whereby human skeletal samples are paradoxical and heavily biased when comparing directly to data from living populations or modern phenomena. The four-field approach among American anthropologists (see Hicks 2013) is an important influence as well, with the implementation of a biocultural approach to interpreting human skeletal remains (Blakely 1977), that is, understanding the interplay between biology and culture, how they influence each other, and how they manifest as driving forces for change in human societies. Approaches to bioarchaeological research can also vary in scope, where a single burial or suite of burials are intensely described both within a biological and cultural framework, a technique often termed "osteobiography" (Saul 1972; Robb 2002), and more recently "biohistory" (Stojanowski and Duncan 2017); or, a large-scale approach that examines either one or more population samples to elucidate aspects of behavior (Larsen 2015). Other "bioarchaeologies" have emerged as well, including those that specifically focus on social issues (Agarwal and Glencross 2011) and identity (Knudson and Stojanowski 2008, 2009), but also as part of the archaeology of the human experience (Hegmon 2016) such as the bioarchaeology of pain and suffering (Martin et al. 2013; Martin and Harrod 2015) and care (Tilley 2015; Tilley and Oxenham 2011; Tilley and Schrenk 2017).

Biodistance Analysis

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Biodistance analysis (or *biological distance analysis*) is a method used in bioarchaeology to measure and interpret the degree of relatedness or dissimilarity using variation in phenotype (Buikstra et al. 1990; Konigsberg 2000). A major assumption in evolutionary biology is that all carbon-based lifeforms on earth are related in some way through time and space via common ancestry (e.g., coalescent theory; Kingman 1982; see also Wakely 2008). Individuals or groups (within and between species) that share a greater number of similar genes or phenotypes are likely to share a more recent common ancestor, while a lesser amount of biological similarity infers a common ancestor more distant in time. This concept is used to reconstruct genealogies and phylogenetic trees (Relethford 2013). Biodistance studies using DNA in both ancient and modern contexts inform about past population and demographic histories. An alternative approach to using DNA, which is most often invasive and costly, is to use phenotypic data as a proxy for genetic data to interrogate biological relatedness or divergence.

Phenetics and Heritability

When examining phenotypes, it is important to remember that a phenotype is the additive effect of a genotype plus the environment. In biodistance analysis, a critical assumption is that closer biological relatives are more likely to share genes that influence phenotype due to inheritance from a shared ancestor ("identical by descent") than genes that arose independent of familial ties ("identical by state") (Thompson 1986; Konigsberg 2000; Blouin 2003; Figure 1). Thus, closer biological relatives share more phenotypic

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traits (e.g., physical size/shape or other characteristics) since they share a similar

genotype than more distant relatives (Dempsey and Townsend 2001; Hughes et al. 2001;

Townsend et al. 2009). Under this assumption, skeletal and dental traits (e.g., metric and

non-metric traits) from human remains are considered proxies for genetic information

and are used to construct both genealogies from ancient cemeteries and indices of

relatedness or divergence among multiple mortuary contexts (Cheverud et al. 1979;

Sjøvold 1984; Devor 1987; Cheverud 1988; Konigsberg and Ousley 1995; Scott and

Turner 1997; Sparks and Jantz 2002; Stojanowski 2003, 2004, 2005; Carson 2006a,b;

Stojanowski and Schillaci 2006). Other important assumptions in biodistance are that the

phenotypic traits selected for analysis are: (1) minimally affected by environmental or

epigenetic factors across the groups sampled; and, (2) highly conserved genetically,

reflecting neutral variation.

Biodistance analysis uses quantitative skeletal and dental traits to reconstruct

genealogical histories at both intra- and inter-population levels. A quantitative trait is a

condition of size, shape, or otherwise recordable morphology conceived as the result of

two or more genetic loci, commonly referred to as the mechanism of polygenic

inheritance (Hartl and Clark 1989). Traits used in bioarchaeology are the sizes and shapes

of crania and teeth. Though many loci contribute to the phenotypes of crania and teeth,

their expressions among populations usually follow a gradient or normal distribution

(Konigsberg 2000). As the phenotypic expression of a quantitative trait is based on both

genetic loci and the effects of the environment, a phenotype is modeled as:

$$P = G + E$$

Figure 1. Cladistic Representation of Identical by State vs. Identical by Descent.
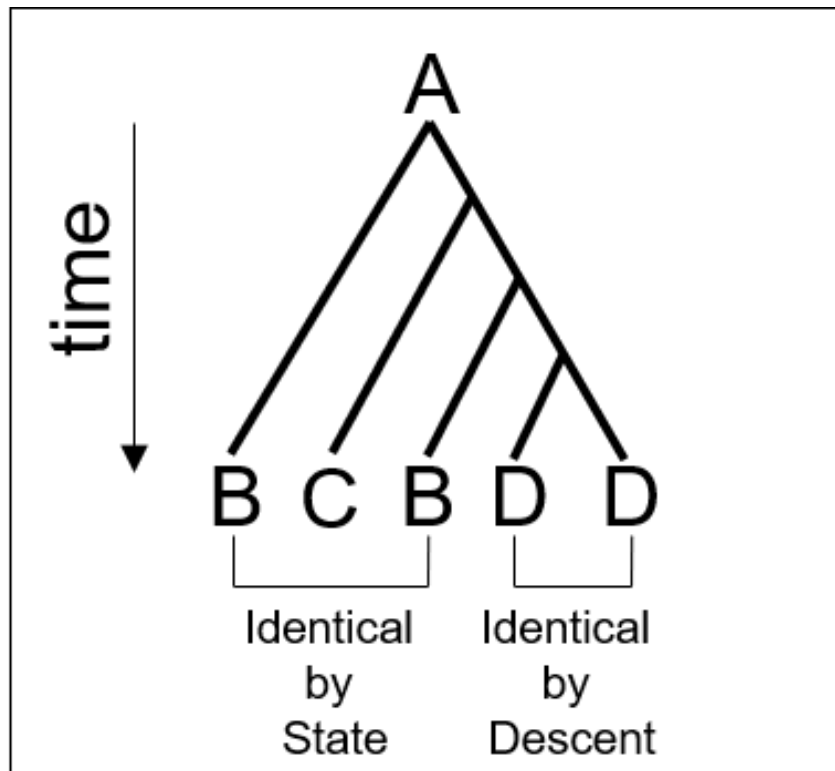
Note: Letters represent insertion sites for phenotypes in question. A is the common ancestor of all insertions, and B is the next insertion to evolve over time, then C, and lastly D. The fact that two B insertions exist is due to it evolving independently on separate lineages (identical by state); the fact that two D lineages exist is because they share a more recent common ancestor in time (identical by descent). Parsimony suggests that since both D insertion lineages are more recent in time, the simplest explanation with the least amount of assumptions is that the D insertion evolved via common ancestry.

where P is the phenotype, G is the genotype, and E is the environment. At a population level, the variance in a phenotype (Var[P]) is addressed as the sum of its effects, so that

$$\text{Var}(P) = \text{Var}(G) + \text{Var}(E) + 2\text{Cov}(G, E).$$

If the covariance of the genotype and environment (Cov[G,E]) is made constant at 0,

which is a relaxed assumption given that the traits in question are effectively neutral

(Relethford and Blangero 1990), then heritability (H^2) is expressed as:

$$H^2 = \frac{\text{Var}(G)}{\text{Var}(P)}.$$

The parameter H^2 denotes a broad-sense heritability index that demonstrates the

contribution of genes to the Var(P) for a population in question that also incorporates

phenomena such as additive effects and levels of dominance (Strachan and Read 1999).

Often, heritability is conducted by measuring the Var(P) between monozygotic (MZ) and

dizygotic (DZ) twins. Since MZ twins are genetically identical and DZ twins share

around 50% of their genes, Var(E) is considered negligible in MZ twins and the

difference in correlation between MZ and DZ twins would then be $2(R_{mz} - R_{dz})$ and

approximate H^2 (Griffiths et al. 1999; Silverman et al. 2002). High values of H^2 in twin

studies suggest that multiple genes contribute to Var(P). The Var(G) is the result of

additive genetic effects (Var[A]) and a narrow-sense heritability index (h^2) is proposed

for examining quantitative traits with

$$h^2 = \frac{\text{Var}(A)}{\text{Var}(P)}.$$

Quantitative traits for use in biodistance analysis appear as similar in variation along

regression lines provided that the h^2 is no less than 0.20 (Relethford and Blangero

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1990:15). Previous heritability studies for cranial and dental metric and non-metric traits usually converge on an h^2 of ~ 0.55 (Susanne 1975, 1977; Cheverud et al. 1979; Sjøvold 1984; Devor 1987; Cheverud 1988; Hauser and DeStefano 1989; Kieser 1990; Konigsberg and Ousley 1995; Scott and Turner 1997; Sparks and Jantz 2002; Stojanowski, 2001, 2005c; Carson 2006a, b; Stojanowski and Schillaci 2006). Carson (2006a), has, however, reported some craniometric heritabilities as low as 0.10, and many estimates that are not significantly different from zero. Dental metrics alone demonstrate a higher narrow-sense heritability index on average ($h^2 > 0.50$) than other cranial phenotypic variables (see Lundström 1948; Alvesalo and Tigerstedt 1974; Townsend and Brown 1978a,b; Townsend et al. 1986; Dempsey et al. 1995; Dempsey and Townsend 2001; Stojanowski 2001, 2004, 2005; Stojanowski et al. 2017). High levels of heritability in skeletal and dental traits justify their use as proxies for genetic variation and for studies of biodistance as these traits (such as permanent crown size) are strongly affected by genotype (see for example Townsend et al. 2003, 2006). Recent studies suggest that some heritability indices are overestimated due to flawed research designs (Paul and Stojanowski 2017; Stojanowski and Hubbard 2017; Stojanowski et al. 2017). The human dentition contains redundant variation as it is more pleiotropic than in primitive mammals (see Stojanowski et al. 2017). Redundancy and correlation of dental traits is known to skew the results of sophisticated mathematical models and increase error (Stähle 1959; Filipsson and Goldson 1963; Moorrees and Reed 1964; Garn et al. 1965a,b). Experimental studies with mice and other mammals also demonstrate substantial epigenetic effects (e.g., Cheverud 2003; Hallgrímsson et al. 2007; Hallgrímsson and Lieberman 2008), which are difficult to specify in humans and in biodistance models

(though see performance analyses by Paul and Stojanowski 2017). Even though current studies support the usage of dental phenotypes for reconstructing population histories and relatedness, these analyses should be used with contextual archaeological data (Rathmann et al. 2017; Stojanowski and Hubbard 2017).

Neutrality and Molecular Evolution

An essential concept that validates biodistance analysis in the interpretation of population structure and history stems from neutral (or nearly neutral) theory of molecular evolution (Freese 1962; Freese and Yoshida 1965; Kimura 1968; King and Jukes 1969; Ohta 1973; and more recently Kimura 1983, 1989; Ohta and Gillespie 1996; see Figure 2). The neutral theory states that most variation within and between species is manifested by genetic drift of neutral genes and not natural selection. First, genes under selection create phenotypes that are consistent among the same species and contribute little to phenotypic variation since genes under selection become fixed. Secondly, selection causes change over time that, if measurable and sufficiently variable across populations, represents a difference in the mutation-selection balance (or genetic equilibrium) and does not reflect a consistent phenotypic signal to reconstruct population histories. With neutral variation, population structure and histories are formulated by genetic drift and migration. As populations become isolated, they share fewer genes due to lack of gene flow and tend to differentiate in phenotypic variation due to genetic drift. The opposite also holds true. If populations are not isolated, then they tend to share more genes due to inheritance from a parent population or a more recent common ancestor.

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Figure 2. Neutral Theory of Molecular Evolution (modified from Bromham and Penny [2003]).
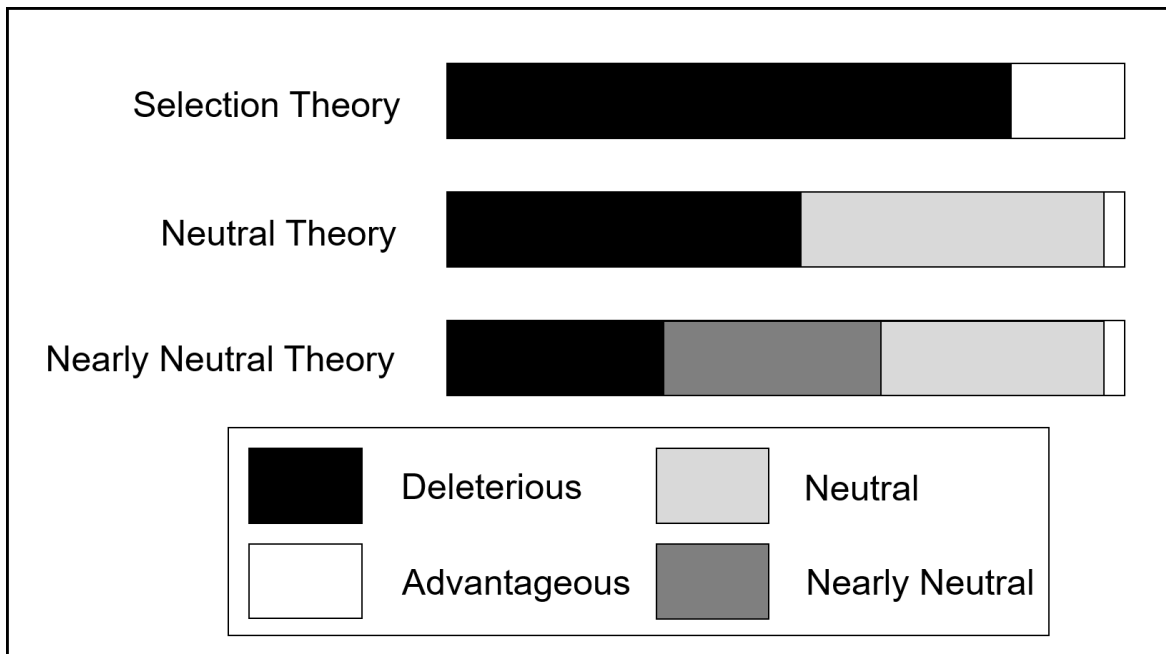
Note: Selection theory: assumes all mutations affect fitness with no neutrality and thus mutations are either deleterious or advantageous; neutral theory: neutral mutations outnumber advantageous ones and the ratio of neutral sites in comparison impact the rate of change (i.e., more neutral sites increase rate of change); nearly neutral theory: effective population size determines the outcome of mutations that have slightly advantageous or deleterious effects on fitness.

The process of migration (or gene flow), whereby groups immigrate into new populations or emigrate out of parent populations, would then reflect convergence or divergence in phenotype. Thus, neutral variation is not affected by the mutation-selection balance and variation in phenotypic traits are shaped by the evolutionary forces of genetic drift and migration (or gene flow). It must follow that in biodistance analysis the dimensions and morphology of crania and teeth are highly conserved and under robust genetic control (Goose 1971; Alvesalo and Tigerstedt 1974; Townsend and Brown 1978a,b; Kabban et al. 2001; Townsend et al. 2009).

The concept of neutral variation is essential to several models of variation in quantitative traits. There are a number of models to choose from in the field of population genetics (Wright 1943, 1951; Kimura and Weiss 1964; Boyce et al. 1967; Bodmer and Cavalli-Sforza 1968; Wright 1969), but Wright's island or isolation by distance model (1943, 1951) provides a robust conceptual framework for examining drift and migration under a neutral (or nearly neutral) paradigm (Figure 2). As previously mentioned, if populations are isolated, they will diverge as a result of genetic drift. If populations are not isolated and exchange migrants or mate with one another (gene flow), then the propensity to diverge is reduced. There is also a compromise between drift and migration since larger populations are less susceptible to the effects of drift and resist the tendency to diverge. Additionally, greater amounts of migration or gene flow increase the tendency to converge. With this in mind, the migration-drift equilibrium (f) is evaluated in terms of a fixation index. If the probability $1/(2N)$ that two alleles are identical by descent in the preceding generation $t-1$ and the probability $1 - 1/2N$ that they were descendants from dissimilar alleles in the previous generation, where N is the effective population size (also written as N_e), the expected homozygosity in generation t is written as

$$f_t = \frac{1}{2N} + \left(1 - \frac{1}{2N}\right) f_{t-1}$$

and the probability of homozygosity by the probability that both alleles are not migrants using $(1-m)^2$ is modified so that

$$f_t = \left[\frac{1}{2N} + \left(1 - \frac{1}{2N}\right) f_{t-1}\right] (1 - m)^2.$$

This formula is similar to the infinite allele model (Kimura and Crow 1964) except that

migration rate (m) replaces mutation (μ). Using the assumption of equilibrium between

gene flow bringing in new variation and drift reducing variation, it follows $f = f_t = f_{t-1}$. If

it is assumed that f is equal to the equilibrium fixation index F_e or F_{ST}, then under

migration-drift equilibrium

$$F_{ST} = \frac{(1 - m)^2}{2N - (2N - 1)(1 - m)^2}$$

when $m = 0$, $F_{ST} = 1$, and when $m = 1$, $F_{ST} = 0$. If the terms with m^2 are ignored, then

$$F_{ST} = \frac{1 - 2m}{4Nm + 1 - 2m}.$$

And when $2m$ is ignored in both the numerator and the denominator, then

$$F_{ST} \approx \frac{1}{4Nm + 1}.$$

With a two-allele model, if $2Nm > 1$, the distribution of allele frequencies shows a bell-

shaped curve (i.e., normal distribution), and populations tend not to diverge from one

another. If $2Nm < 1$, the distribution of allele frequencies is bowl-shaped (i.e., binomial distribution), in which case populations tend to diverge from one another.

Advancements in Method and Theory

Though Wright's island or isolation by distance model (1943, 1951, 1969) was available to researchers since the mid-20th century, the theoretical framework for bioarchaeology was not formally introduced until the late 1980s and early 1990s (Konigsberg 1988, 1990a,b; Relethford and Blangero 1990). The genetic distance between subpopulations or islands, F_{ST}, is calculated under the assumption of a migration-drift equilibrium using genetic markers. An equivalent distance for phenotypic markers is the probability of identity by descent within subpopulations (see Hartl and Clark 1989). Therefore, F_{ST} can be approximated as the ratio of between-group and within-group variance of quantitative traits (Relethford 1991). Others, like Relethford and Blangero (1990), developed numerous ways to calculate F_{ST} specifically from the phenotypic variance-covariance matrix (otherwise known as **R** matrix; see Chapter 5). Traditional approaches to biological distance often included a distance measurement such as Mahalanobis's (1936), which is essentially a Euclidean distance, but accounting for the variance-covariance of the data (see also Chapter 5). The Mahalanobis distance, or D^2, as a measure of biological differentiation between groups, is criticized for its lack of robustness and poor attention to local variation (Relethford and Blangero 1990; Relethford et al. 1997; Relethford 2003). A major difference between D^2 and **R** matrix theory is that **R** matrices are built by a "codivergence" matrix (often termed as **C**).

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However, Mahalanobis distances are converted to **R** matrices with ease (see Konigsberg 2006:278–279). This dissertation uses the Mahalanobis distance as the basis for biological distance within populations, specifically for the Amarna STC intracemetery model, since D^2 is, in fact, robust at the within-population level (see Defrise-Gussenhoven 1967). In contrast, **R** matrices and **R** matrix theory are most appropriate for regional biodistance analysis or among group comparisons between the Amarna STC and other contemporaneous New Kingdom populations.

Relethford and Lees (1982) described two main approaches in biodistance analysis: model-bound and model-free. Model-bound approaches emphasize concepts in population genetics and evolutionary theory while model-free approaches explore population history and contextual information to explain patterns in data (Relethford and Harpending 1994; Konigsberg 2006; and more recently Relethford 2016). Biodistance analysis also operates at various scales. For example, regional inter-population studies can delineate past affinities, inform on migratory and settlement processes, as well as explore the origin of populations (Buikstra 1980; Turner 1986; Howells 1995; Konigsberg and Buikstra 1995; Relethford et al. 1997; Steadman 2001; Stojanowski 2004, 2005a,b). Other inquiries such as intracemetery analysis examine the biological affinities of a single cemetery to test whether burial placement was determined by biological relatedness (Alt and Vach 1992; Pietrusewsky and Douglas 1992; Byrd and Jantz 1994; Corruccini and Shimada 2002; Stojanowski 2003, 2005a; Stojanowski and Schillaci 2006; Kron 2007; Pilloud and Larsen 2011; Paul et al. 2013; Stojanowski 2013; Sciulli and Cook 2016; Prevedorou and Stojanowski 2017). This dissertation uses

biodistance analysis to examine the Amarna STC at both the intra-cemetery (small-scale) and regional (large-scale) levels.

Biodistance analysis has benefited from recent methodological and theoretical advancements in both statistical analyses and sociocultural theory (see Pilloud and Hefner 2016 for the most current review). The implementation of new methodologies such as geometric morphometrics ushered in a new era of 3-D applications using landmarks to create point clouds and the utilization of laser scanning technology. The introduction of **R** matrix theory and matrix decomposition models have influenced relational and geospatial approaches in bioarchaeology such as social network analysis (Johnson 2016), and other similar implementations such as artificial neural networks (ANN), and lattice theory (Merrill and Read 2010; Sosna et al. 2012; see also Merrill 2015). Johnson and Paul (2015) have advanced the field of biodistance by emphasizing the application of sociocultural anthropology at both the intra-cemetery and regional levels in bioarchaeology. All too often researchers equate kinship with biological distance whereas kinship can take several forms of relatedness that are not exclusively biological in nature (e.g., fictive kinship, see Ensor et al. 2017). Though this dissertation does not use 3-D applications for data capture, it does apply the most current computational techniques (**R** matrix theory and geospatial analysis) as well as sociocultural approaches in Egyptology to interpret collected and synthesized data from the Amarna STC and comparative New Kingdom samples (e.g., McDowell 1998; Toivari-Viitala 2001; Meskell 2002; Toivari-Viitala 2002).

Paleodemography

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Paleodemography is the study of ancient populations using death profiles (d_x) or age-at-death data to understand the factors that explain varying age structures of the past (Milner et al. 2000; Hoppa and Vaupel 2002; Chamberlain 2006; Frankenberg and Konigsberg 2006; Bocquet-Appel 2008; Séguy and Buchet 2013). A major difficulty in paleodemography is that, unlike in modern and historical demography, no census data is available. Without census data, paleodemographers must use the age-at-death profiles from skeletal samples to model age structures.

Life Table Approach and Ensuing Critiques

Earnest Hooton pioneered early work in paleodemography at the sites of Madisonville (1920) and Pecos Pueblo (1930). In retrospect, some of Hooton's analysis at Pecos Pueblo was antiquated, even for his time, since Lotka (1922) had published his initial ideas of stable population theory a decade before, and the use of life tables in mortality analysis were employed much earlier (see Smith and Keyfitz 1977; Newell 1988). Hooton's student, Lawrence Angel (1947), was the next bioarchaeologist to examine life expectancy (e_x, in truth, mean age-at-death), this time in ancient Greece. Like Hooton, Angel abandoned the life table approach, though his awareness of this type of mortality analysis was more straightforward since he cited life table research (e.g., Dublin and Lotka 1936), but he preferred his own calculations that were essentially life table tabulations.

Later, Angel (1969) published his landmark paper, "The Bases of Paleodemography," which outlined his disdain for the life table approach. Though Angel's own mathematical analysis in the publication was inadequate, his critique of paleodemography was significant. Angel (1969) aptly recognized that life table construction in paleodemographic studies violated a number of assumptions of stable population theory, and he chastised those who took such a static approach to paleodemography, since populations, are rarely static in reality. Yet, Angel (1969) provided no solution to the problem mathematically and the stability assumption is still a considerable problem in the discipline since most mathematical models currently available are still constructed using stable population parameters. Stable population theory (or ecological stability) states that populations become "stable" over time when they converge on a constant birth rate, death rate, and population growth rate (see Figure 3; Lotka 1922, 1956; McFarland 1969; Keyfitz 1977). The phenomenon of population stability (as well as semi- and quasi-stability; see Bourgeois-Pichat 1958, 1971, 1978) is observed in modern and historical populations with census data, but without census data for populations in antiquity, it is assumed that ancient populations experienced similar demographic patterns as modern ones (i.e., the uniformitarian hypothesis; see Lyell 1830; Howell 1976; Hammel 1996; Paine 1997). Even the geological or generational time necessary to converge on constant population parameters is contentious (see Angel 1969; Weiss 1973; Weiss and Smouse 1976; Keckler 1997). However, without accepting this assumption, no comparison of model life table data from contemporary populations (e.g., Coale et al. 1983) with ancient ones is possible.

Other efforts to examine age structures of the past existed before Angel's 1969

Figure 3. Schematic of the Demographic Transition Model Showing Phases of Relative Constancy in Population Parameters (after Haggett 1975).
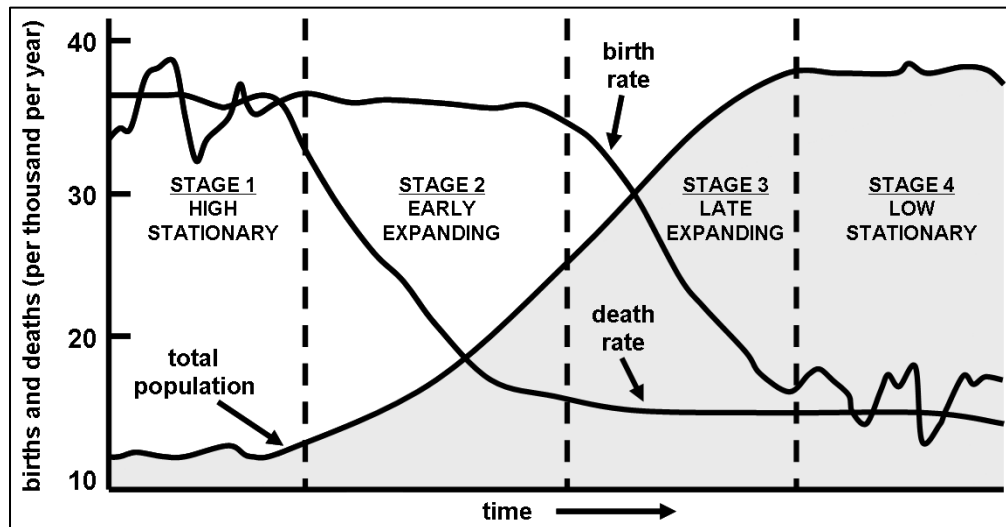
treatise (Howells 1960; Vallois 1960; Johnston and Snow 1961), but the first formidable application of the life table approach and associated calculations was a monograph by Acsádi and Nemeskéri (1970). However, Weiss (1973) popularized the life table approach for American biological anthropologists, bioarchaeologists, and archaeologists. Well into the 1970s, bioarchaeologists applied life tables without acknowledging Angel's (1969) critique to evaluate the age structures of past populations (e.g., Ubelaker 1974; Asch 1976; Buikstra 1976), and life table construction was routine in paleodemography (see Bennett 1973; Weiss 1973; Moore et al. 1975; Asch 1976 for calculations; Meindl and Russell 1998; Milner et al. 2000 for further reviews)

An important contribution during this time was by Moore et al. (1975), who discussed the problem of under-enumeration of subadults apparent in archaeological skeletal samples. For example, often the highest mortality is observed in individuals less

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than one year old, but skeletal samples rarely demonstrate this pattern. This fact is due to skeletal preservation, as juvenile bones of this age class are very small, brittle, and highly sensitive to bioturbation and diagenesis (see Scheuer and Black 2004; Baker et al. 2005). Furthermore, some cultural practices among human societies show that individuals in the 0–1 age class are not interred in cemeteries with older juveniles and adults (Hoppa 1999). The initial observation by Moore et al. (1975) brings up another underlying assumption in paleodemography: that age-at-death profiles from archaeological skeletal samples are representative, analogous, and acceptable for use in comparison with modern population death profiles (d_x), an idea that later became known as the "whopper assumption" (see Ruggles 1993). Accepting the whopper assumption grants validity for the use of age-at-death profiles from skeletal samples for use in statistical modeling. Moore and colleagues (1975) also showed how to convert life table data using nonzero growth rates. Constructing life tables with zero growth rates, which along with constant birth and death rates, assumes a special type of stable population known as a stationary population. Whereas the stable structure applies to most populations, the stationary assumption is even more restrictive in terms of analysis and interpretation. Despite the awareness of the issues with using zero growth rates, life table construction assuming stationary population parameters was common among researchers during the late 1970s, early 1980s, and even more recently (Green et al. 1974; Owsley et al. 1977; Lovejoy et al. 1977; Owsley and Bass 1979; Lallo et al. 1980; Green et al. 1986; Lanphear 1989; Mensforth 1990; Benedictow 1996:36–41; Alesan et al. 1999). Life table construction is impractical since many of the calculations are derived from census data that are most often unavailable for archaeological populations, many skeletal samples are very small and lack good

representation in each age class, and it presents an unquantifiable amount of error (Moore

et al. 1975; Sattenspiel and Harpending 1983; Johannson and Horowitz 1986; Wood et al.

1992; Konigsberg and Frankenberg 1994; Wood et al. 2002). Additional critiques of

paleodemography emerged in the early 1980s (Bocquet-Appel and Masset 1982; Howell

1982; Sattenspiel and Harpending 1983). Of particular note is the Bocquet-Appel and

Masset 1982 publication "Farewell to Paleodemography," which emphasized that the

inaccuracies and biases involved in chronological aging methods of skeletons were

insurmountable and that the field should be abandoned altogether (*contra* Bocquet-Appel

2008). Skeletal aging in bioarchaeology is clearly an important issue. Skeletal age-at-

death is determined by pace and manner of development for juveniles (< 20 years of age)

and degenerative changes in the skeleton for middle to late adults (> 35 years of age).

Dental ages for juveniles contain smaller margins of error (e.g., Al Qahtani et al. 2010),

but long bone measurements and epiphyseal union are also used (see Scheuer and Black

2004). The latter are more susceptible to growth retardation and more sensitive to

environmental and physiological effects (Garn et al. 1959; Lewis and Garn 1960;

Widdowson and McCance 1960; Garn et al. 1965a,b; Niswander and Sujaku 1965;

Eveleth and Tanner 1976; Murchison et al. 1988; Smith 1991; Bowman et al. 1992;

Saunders et al. 2000; Cardoso 2007; Šešelj 2013). Adult aging techniques for individuals

30–35+ are often based on degenerative changes in the skeleton (e.g., Lovejoy et al.

1985; Brooks and Suchey 1990), which are influenced not only by chronological age, but

activity-levels, body mass, hormones, and genotypes (Mays 2015; Merritt 2015).

Although numerous aging techniques are developed in the field each year, general age

categories such as young adult (21–34 years), middle adult (35–49 years), and

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older/mature adult (50+ years) are applied since the existing techniques bear large margins of error (see Buikstra and Ubelaker 1994 for a detailed review). These adult age categories are difficult to use in mathematical modeling since many demographic models employ five-year age categories (see Keyfitz 1977). Also, poor resolution for individuals past 50+ years of age using aging techniques poses problems when examining age structure distributions. Moreover, age-at-death distributions can mimic the distributions of the reference sample (known as "age mimicry") used in degenerative adult aging techniques (see Mensforth 1990; though described earlier in other fields, see Kimura 1977; Westrheim and Ricker 1978), further complicating the true age structures of skeletal samples. Other important revelations in the field were made during the 1980s, such as the finding that the mean age-at-death of a skeletal sample is not identical to life expectancy at birth (e_0) and that additional population parameters such as population growth are required to estimate life expectancy, but also that birth rates have a greater influence on mean age-at-death than death rates (Sattenspiel and Harpending 1983). The latter conclusion influenced many researchers in that the usage of age-at-death ratios (e.g., $D_{5-14}/D_{20-\omega}$, $D_{30-\omega}/D_{5-\omega}$) was a platform to interpret solely fertility (Bocquet 1979; Bocquet-Appel and Masset 1982; Buikstra et al. 1986).

Numerous responses to the Bocquet-Appel and Masset (1982) critique ensued, and it is still an active subject of present-day inquiry (Van Gerven and Armelagos 1983; Bocquet-Appel and Masset 1985; Buikstra and Konigsberg 1985; Masset and Parzysz 1985; Bocquet-Appel 1986; Bocquet-Appel and Masset 1996; Greene et al. 1986; Konigsberg and Frankenberg 1992; Masset 1993; Konigsberg and Frankenberg 1994; Piontek and Weber 1990; Bocquet-Appel and Masset 1996). Most researchers fell into

one of three groups: (1) those who bid farewell to the field altogether (Bocquet-Appel and Masset 1996; *contra* Bocquet-Appel 2008), (2) those who sought remedies to improve the field (e.g., Gage 1988; Gage and Dyke 1986; Konigsberg and Frankenberg 1992; Wood et al. 1992; Konigsberg and Frankenberg 1994, see also the "Rostock Manifesto" [Hoppa and Vaupel 2002]), and, (3) those who dismissed the critique as erroneous entirely (e.g., Van Gerven and Armelagos 1983).

Improvements in Mathematical Modeling

A major improvement in paleodemographic research was the application of parametric models of mortality as an alternative to the life table approach (Gage 1988; Gage and Dyke 1986; Wood et al. 1992, 2002). These models of mortality are functions that parameterize available age-at-death data and allow the observed data to be shaped as a mortality curve to follow a general "law of mortality" for human populations (see Figure 4; Mode 1985:35–74; Gage 1989; Gavrilov and Gavrilova 1991; Wood et al. 1992; Konigsberg and Frankenberg 2002). There are many models to choose from, such as Gompertz (1825) and Gompertz-Makeham (1860), Weibell (1951), Siler (1979, 1983), and semi-parametric Heligman-Pollard (1980) models (see Wood et al. 2002 for a thorough review).

One of the first scholars to conceive of a parametric model to illustrate the force of mortality that depicted the adult aging component was Benjamin Gompertz (1825). Today the approach by Gompertz (and later coupled with the ideas of William Makeham [1860], i.e, Gompertz–Makeham) is often termed the "law of mortality" in that most

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modern demographers agree that the model estimates mortality curves quite precisely even though the forces that underlie this variation are not fully understood. This "law" states that there is some inherent resistance to death at birth followed by an elevated level of resistance to death during most of childhood, then a steady increase in the risk of death into adulthood and senescence. Gompertz modeled the force of mortality as

$$\mu(x) = \alpha e^{\beta a} .$$

The variable α represents the level of mortality for adults as a positive scale parameter whereas variable β is a positive shape parameter to visualize how the risk of death increases with age. The primary assumption of the Gompertz equation is that the increase in adult mortality is the consequence of deteriorating physiological capacity modeled as a negative exponential curve (Gage 1989). Makeham (1860) later amended the Gompertz equation to include the risk of mortality due to forces seemingly unassociated with aging such as disease with the force of mortality as:

$$\mu(x) = \alpha_1 + \alpha_2 e^{\beta a}.$$

The Gompertz-Makeham model includes the parameter α_1 as a constant, age-independent factor of mortality and $\alpha_2 e^{\beta a}$ approximates the Gompertz function, which factors for the senescent component or increasing risk of death with increasing age (Mode 1985; Gage1989; Gavrilov and Gavrilova 1991; Wood et al. 1994, 2002). Yet another parametric model of mortality is the competing hazards model proposed by Siler (1979,

Figure 4. Schematic Demonstrating the Goodness of Fit to Demographic Data Using the Gompertz-Makeham Function (adapted from Stauffer 2004).
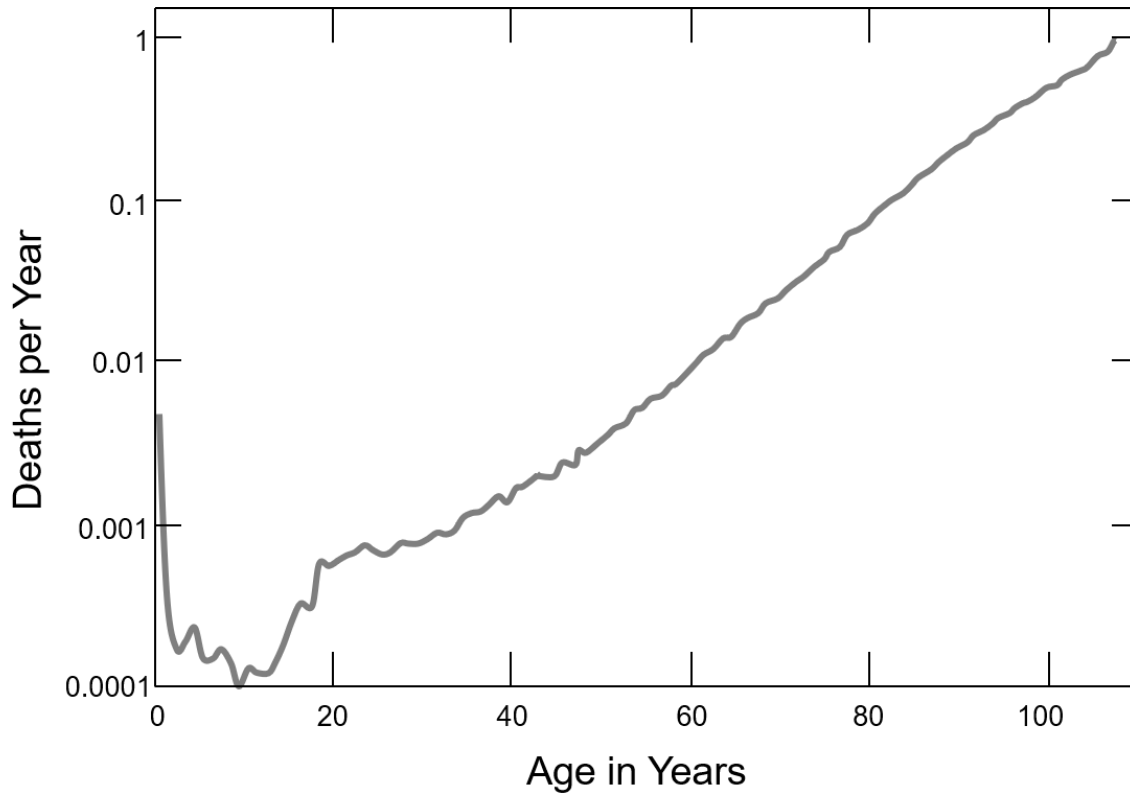
1980), which provides a more exact fit to human mortality data (Gage and Dyke 1986;

Gage 1988, 1989; Gage and Mode 1993) by including a juvenile mortality risk

component as:

$$\mu(x) = \alpha_1 e^{-\beta_1 a} + \alpha_2 + \alpha_3 e^{\beta_3 a}.$$

In this expression, α_1 represents neonatal mortality with β_1 modeled as the level of

decline in childhood mortality with age. The next two terms are the constant of Makeham

and the senescent component of Gompertz. Gage (1988) described a Siler competing

hazards model for anthropology that integrates growth rates to compute more accurate

age structures. Hazard models provide future direction of the field due to their ability to

parse age-specific components of mortality and the ease of calculating additional output

such as survivorship curves.

Other advancements in the field addressed more directly the original critiques of

Bocquet-Appel and Masset (1982), and publications thereafter (Bocquet-Appel and

Masset 1985; Bocquet-Appel 1986; Masset 1989; Masset 1993; Bocquet-Appel 1994;

Bocquet-Appel and Masset 1996). Konigsberg and Frankenberg (1992) used an approach

from the fisheries literature known as the "iterated age-length key" (Kimura and Chikuni

1987). The age-length key is a technique to estimate the age class of fish based on their

lengths (i.e., otolith rings) from a known reference sample. An unbiased age estimate is

generated using an iterative approach of the age-length key, essentially an Expectation-

Maximization (or EM) algorithm or maximum likelihood method (MLE) (Dempster et al.

1977; Kimura and Chikuni 1987). The age-length key is similar to chronological aging

techniques employed in bioarchaeology; it is a Bayesian method that uses an age

distribution from a reference sample as a prior to determine the age distribution of a

target sample. An age estimation that is not iterative is biased and susceptible to age

mimicry (Kimura 1977). An important contribution by Konigsberg and Frankenberg

(1992) is an EM/MLE algorithm for use in bioarchaeology to minimize biased results

from chronological aging techniques, and these formulaic expressions can be directly

incorporated into mathematical hazard functions.

Yet another recent contribution to the field is the product of a set of workshops held at the Max Planck Institute for Demographic Research dubbed the "Rostock Manifesto" (Hoppa and Vaupel 2002). In this edited volume, European and North American researchers reached a consensus regarding the major issues facing paleodemography and how to best combat them. Among the notable contributions is the emphasis on the dependency of Bayes' theorem for chronological age estimations (Hoppa and Vaupel 2002), albeit troubled with the issue of bias and age mimicry – a problem foreseen by Konigsberg and Frankenberg (1992), and with the EM algorithm, a solution proposed. A chapter by Wood et al. (2002) provides some of the most comprehensive ideas about model selection in paleodemography, ranging from relational models to the various hazard models previously described. Other creative applications also surfaced such as the usage of Markov chain Monte Carlo methods to estimate parameters of hazard functions (Konigsberg and Herrmann 2002). Perhaps the most innovative contribution was a new method to make more accurate chronological age estimates with aging techniques that are based on stages or phases by using logistic and probit regression (Boldsen et al. 2002; and mentioned in earlier works, Skytthe and Boldsen 1993; Milner et al. 2000). This method, termed "transition analysis," was a significant step in helping resolve the obstacle of poor resolution with chronological adult aging techniques in individuals 50+ years of age-at-death.

Combating Violations of Assumptions

Though vast improvements in reducing bias with chronological aging techniques and more sophisticated statistical models emerged over the last 20 years, the key assumptions in mathematical demography still present risks when interpreting paleodemographic data. First and foremost, it is clear from historical scholarship that without accounting for bias or parameterizing raw age-at-death data, interpretations are highly speculative. Secondly, imputation of demographic parameters such as age-specific mortality and fertility rates to create models still rely on historical or modern census data (e.g., Coale 1969; Coale and Demeny 1983), as these parameters are unknown for archaeological populations. Weiss (1973) provided this type of data using the direct-historical approach, but his datasets are still incomplete and require similar imputation. Additionally, demographic parameters such as life expectancy at birth (e_0) require estimates of population growth rates and population size; again, parameters that are often unknowable unless accurate settlement data is available for archaeological sites. The aforementioned statements highlight two key assumptions in paleodemography: the whopper and uniformitarian assumptions. As noted previously, the whopper assumption states that archaeological skeletal samples are sufficiently representative for use in mathematical demography (see Ruggles 1993). This assumption is often universally accepted, or even ignored, though, bioarchaeologists must consider the nature and composition of their skeletal samples in terms of age class representation (e.g., under-enumeration of subadults aged 0–1 and 1–5 years, poor resolution in aged individuals 50+ years or older), or comparisons among samples may only reflect archaeological recovery strategies and not real patterns of difference (see for example Baitzel and Goldstein 2016). The uniformitarian assumption – where ancient populations are

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presumed to have similar demographic signatures as modern ones (Lyell 1830; Howell 1976; Hammel 1996; Paine 1997) – appears to be unconditionally accepted as well, mostly because it is deemed untestable (Frankenberg and Konigsberg 2006).

The uniformitarian assumption illustrates an important concept often overlooked in paleodemography, which is that populations in the past conformed to the parameters of stable population theory (or ecological stability; see Figure 3; Lotka 1922, 1956; McFarland 1969; Keyfitz 1977). One can simplify the concept of population stability as a population that is closed to migration with birth rates, death rates, growth rates, and age structures that are independent of time (Coale 1987). An even more stringent assumption is a stationary population, which has the same constant parameters of a stable population, with the addition of assuming a growth rate of zero. How are we to model populations of the past if these parameters are independent of time? A settlement with a cemetery used for thousands of years or more, given that it is in fact representative, might conform to stable population parameters since sampling a population over long temporal units likely characterizes equilibrium (Weiss 1973; Weiss and Smouse 1976). Weiss (1973) and Weiss and Smouse (1976) suggested that small populations reach equilibrium over a few generations given that population density is consistent, though the validity of this statement has yet to be verified, and the definition of "small" is ambiguous. Still, demographic research suggests that most human populations maintain stable age distributions even with slight changes in birth, death, and migration rates at any one point in time (Keyfitz 1968:89–94; Parlett 1970; Bourgeois-Pichat 1971; Coale 1972:117–161). Lopez (1961:66–68) defines this property as "weak ergodicity," validating the use of stable population models, which typify models employed in mathematical demography

and paleodemography. There are other concepts such as semi-stability defining those populations with a static age structure, but only some properties of stable population theory. Other phenomena, such as quasi-stability, is observed in many developing countries, where fertility is more or less constant, but mortality is more variable (Bourgeois-Pichat 1958, 1971, 1978). Quasi-stable models are of applicable interest to paleodemography, but simulations by McCaa (2002) and previous work by Sattenspiel and Harpending (1983) imply that it is fluctuations in fertility that affect age structures more prominently.

How then do bioarchaeologists model comparatively large populations at settlements with relatively short occupations? How can we examine the age structures of migrant communities of the past that effectively violate the premise of stable population theory? These questions emphasize the inherent difficulty of examining age-at-death data from the Amarna STC. Bonneuil (2005) has developed a new method that relaxes the stable assumption and uses a dynamic approach by varying mortality and fertility rates with a generalized version of a Monte Carlo method known as simulated annealing optimization (Kirkpatrick et al. 1983; Press et al. 1992). In this way, the distribution of deaths from a cemetery is utilized as a target in large space and the route or path closest to stable population parameters that generates this distribution of deaths over the depositional period is calculated (along with confidence intervals). The method proposed by Bonneuil (2005) is ideal for addressing the population dynamics for the peopling of the city of Amarna because of its restricted time span of occupation (less than 20 years) and since it was occupied by newly settled migrants (see Chapter 5).

Summary

This chapter provided a brief yet wide-ranging overview of the history of method and theory in biodistance analysis and paleodemography, the two primary techniques used in this dissertation to address the research questions presented in Chapter 1. Like many other disciplines, while many innovations in methodology advance the analytical aspects of both biodistance analysis and paleodemography in bioarchaeological inquiry, the assumptions that underpin our interpretations require careful consideration. The goal for Chapter 2 was to highlight the availability of resources for the application of both techniques, but also to emphasize how critical assumptions are to any scientific enterprise. With a solid foundation of these techniques in bioarchaeology, the next chapter covers a history of the bioarchaeology in the region of the Nile Valley.

Chapter 3:

A BIOARCHAEOLOGY OF THE NILE VALLEY

This chapter provides a history of the bioarchaeology of the Nile Valley. As previously stated, bioarchaeology is the contextual study of human remains (Buikstra 1977:67; Buikstra and Beck 2006:xvii–xx). Bioarchaeology, as a discipline of archaeology, effectively means that as it is the study of human remains and tissues within archaeological contexts, such that the bioarchaeology of a region is inextricably linked to its archaeology; and, archaeology as a discipline integrates several related fields such as geology, hydrology, and physiography.

The Nile Valley has a storied history with many stakeholders from several countries and disciplines, not just archaeologists but artists, geologists, historians, photographers, linguists, explorers, cartographers, and countless others. No other ancient culture in the world captivates the hearts and minds of Arabian and Western civilization more than the peoples who lived in the areas of the Nile Valley in the present-day countries of Egypt and the Sudan (see Figure 5). This fascination stems from the unique ways in which the ancient Nile Valley peoples venerated their noble dead with artificial mummification and elaborate grave furniture including the grandiose monuments that enveloped them to their concepts of the afterworld and pictographic language. The ancient Egyptians are among the oldest civilizations to invent canal irrigation and evolve state-level society congregating in aggregated villages as urbanites (see Childe 1950; more recently Trigger 2003). As a thorough bioarchaeology of the Nile Valley is

Figure 5. Map of Present-day Countries of Egypt and the Sudan with Ancient Egyptian and Nubian Borders (modified from Schrader et al. 2014:269).

extensive, not only because of multiple scholars interested in ancient Egypt and Nubia, but also the diverse topics addressed, such as mummy studies, paleopathology, ancient DNA, and mortuary archaeology, as a few examples (e.g., Pettigrew 1834; Mummery 1870; Ruffer 1920, 1921a,b; Rose et al. 1993; Rose and Burke 2006; Baker and Judd 2012). Therefore, for the sake of brevity, this chapter concentrates on topics related to the history of the development of bioarchaeology in the Nile Valley with select studies that emphasize major advances in the field for this region (see also Baker and Judd 2012; Rose 2018). This chapter begins with a backdrop of the geography and physiography of the Nile Valley, followed by a brief introduction to Egyptology and a history of archaeology and bioarchaeology in the Nile Valley.

Geography and Physiography of the Nile Valley

The Nile River is one of the longest rivers in the world (second only to the Amazon River) stretching nearly 4,800 km with its primary headwater deriving from the largest freshwater lake in Africa, Lake Victoria, in northern Uganda. The tropical precipitation in the summer gives the Nile its south-north flow from Ripon Falls in Jinja in Uganda as the Victorian Nile, then to other lake beds such as Lake Kyoga and the northern shoreline of Lake Albert along the border of the Democratic Republic of the Congo. As the White Nile passes north into the Sudan from Juba, it meets its secondary source at Khartoum that originates in the Ethiopian highlands of Lake Tana as the Blue Nile. The term 'Nile Valley' then specifically refers to the area formed by the Nile River from the confluence of its southern tributaries, the White and Blue Niles, near the

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modern-day city of Khartoum in the Sudan, northward to Egypt and the mouth of the Mediterranean Sea. The Nile Valley not only covers areas in and around the proximity of the Nile River, but also parts of the Eastern Desert from the Nile to the Red Sea and the border of Eritrea to the Western Desert as well as the Faiyum, Kharga, and Dakhla Oases. The Western Desert of Egypt and northwest Sudan are part of the Eastern Sahara, which along with neighboring segments of Chad and Libya, make up the largest hyper-arid warn desert in the world covering over 2,000,000 km^2 with little to no yearly rainfall (Kuper and Kröpelin 2006; Kröpelin et al. 2008).

The increasing aridity of North Africa and the climatic shifts that eventually shaped the Sahara date to the Eocene epoch (~40 million years ago) when the India Plate collided into the Eurasian Plate, ultimately forming the Himalayas. As the Himalayan range steadily ascended, less moisture from ocean currents and streams reached the Middle East, Arabian Peninsula, and North Africa, causing a steady decline in wet and humid conditions. After these major shifts in climate, the Sahara progressively received less and less cyclical monsoonal precipitation dating back by the Miocene (Larrasoaña et al. 2013), slowly exposing the region to increased aridity eventually causing the xeric environment of the present day. Today the Sahara appears as an extreme environment for humans, plants, and animals, though early ideas about more habitable landscape thousands of years before were apparent, yet too farfetched and fanciful at first, like that of the descriptions from Herodotus and Strabon (Herodotus, *Historia*, 440 BCE; Strabon, *Geographica* [book 1, chapter 3], 23 CE). With more survey of the Eastern Sahara by explorers and adventurers, images on cave walls attested to wetter conditions millennia prior. For example, German explorer Heinrich Barth (1857) discovered

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Figure 6. Petroglyphs from Wādī Telí-ssarhē in Libya (from Barth 1857).
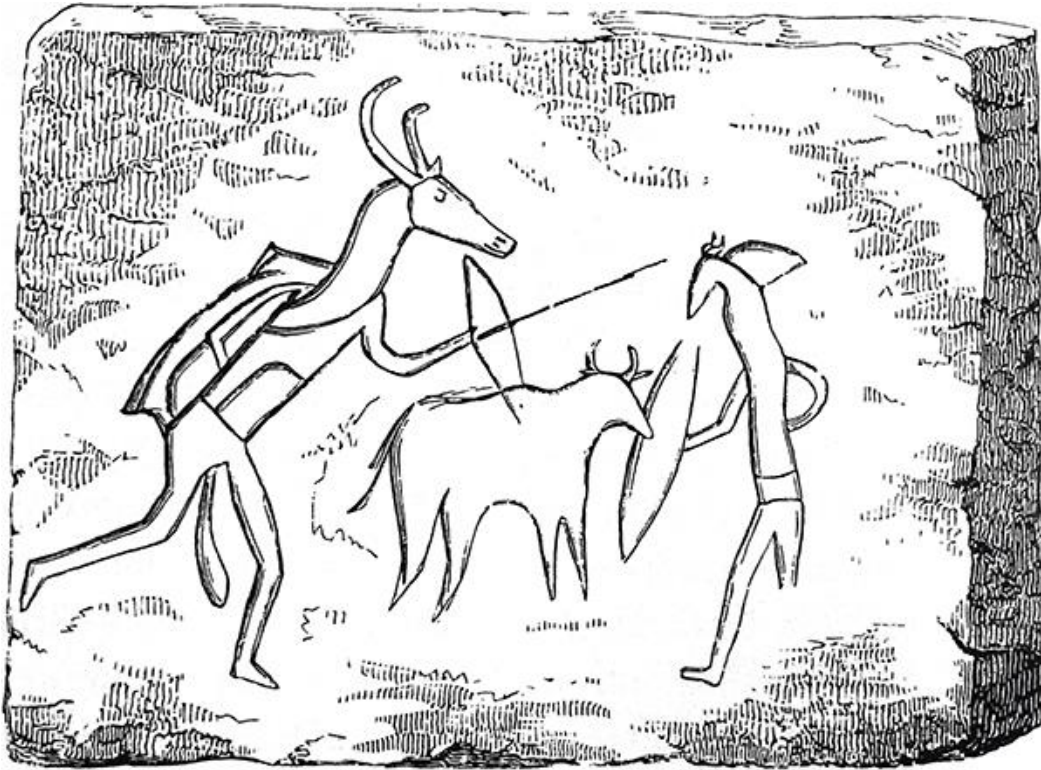
petroglyphs during his travels through North and Central Africa between 1849 and 1855 at Wādī Telí-ssarhē in the Murzuk Desert of southwestern Libya that depicted oases animals in a locality now blanketed by massive sand dunes (Figure 6). Other scientists at the time were quite skeptical that this area of North Africa was once more humid and vegetated, even when Hungarian adventurer László Álmásy (1934) boldly uttered the term *Green Sahara* after the publication of his rock art from the Eastern Sahara at Gabal El ʿUwaināt and Gilf al-Kebir. Archaeology was now thrust in the discussion of the dynamics of the Sahara in direct respects to climate change and human adaptation.

Current scholarship now supports the idea of a wetter, more humid Sahara in the past (Jolly et al. 1998; Prentice et al. 2000; Kuper and Kröpelin 2006; Kröpelin et al. 2008; Lézine et al. 2011a,b). The dynamics of the Sahara show oscillations in the monsoonal system expression of tropical Africa, and with enhanced monsoonal rainfall, the savanna accumulates oases and wetland patches, or so-called Green Saharas (Larrasoaña et al. 2013). The most recent Green Sahara is known as the African Humid Period (AHP), whereby at the Bølling/Allerød around 15,000 BP and into the early and mid-Holocene, subtropical North Africa was much less arid and more humid than the present (Nicholson and Flohn 1980; Ritchie et al. 1985; deMenocal et al. 2000; Kuper and Kröpelin 2006; Kröpelin et al. 2008; Shanahan et al. 2015). Most pollen-based paleoenvironmental models indicate high water accessibility in the region (Bartlein et al. 2011; Francus et al. 2013) from numerous perennial lakes, some containing fringe gallery forests (Kutzbach and Street-Perrott 1985; Yu and Harrison 1996; Hoelzmann et al. 1998; Coe and Harrison 2002; Hoelzmann et al. 2010; Hély et al. 2014). To say that the Sahara was greener in the past than the present is a correct statement based on current scholarship (Jolly et al. 1998; Prentice et al. 2000; Kuper and Kröpelin 2006; Kröpelin et al. 2008; Lézine et al. 2011a,b), though the term *Green Sahara* that conjures images of a lush, fertile savanna utopia is somewhat misinformed (see Claussen et al. 2017; Tierney et al. 2017a,b). Lavish oases speckled the Saharan landscapes at times, yet these refuges were scattered and often separated by great distances, making transport and population movement between them extremely challenging. The cessation of the AHP around 8,000 years ago and the steady desiccation of the Sahara caused many of the lush oases to perish, making the riverine deposits along the Nile Valley the only habitable zone to

occupy. The southern shift of the desert periphery at the terminus of the AHP is cited as a major impetus for the development of artificial irrigation systems to exploit agricultural resources in an otherwise harsh environment with little rainfall. As Neolithic communities became more increasingly tethered to the flooding cycles of the Nile River, agricultural economies began to emerge and flourish along with progressively more sedentary regimes and sociopolitical complexity. No longer were oases like the Fayum refuge habitable, and groups were forced to use and manipulate the flooding successions of the Nile River, which only occurred one-third of the year where the remainder of the year was drought (Butzer 1976). This led to the implementation of food redistribution networks directed by influential leaders and the birth of Nile pharaonic civilization (Butzer 1976; Kuper and Kröpelin 2006; Kröpelin et al. 2008; Gatto and Zerboni 2015; Wright 2017).

The Birth of Egyptology

As a discipline, Egyptology is defined as the study of ancient Egypt. Egyptology encapsulates all aspects of that culture including art, architecture, language, history, and religion, making it both a diverse and overarching enterprise of study. An important question is if the ancient Egyptians were Egyptologists themselves? They had scribes that documented their language as well as priests and priestesses that maintained the cults of various deities numbering into the 300s. They also recorded historical events on tombs and stelae and even made renovations to buildings and structures in traditional and nuanced styles. They also had their fair share of treasure hunters and tomb robbers,

lucrative enough to be maintained as a vocation, and even at times, sponsored by the state (Reeves and Wilkinson 1996; Reeves 2000).

The conquest of Alexander the Great (*c*. 330 BCE) and Hellenistic rule of Egypt brought Greek historians and epigrammatists to the Nile. It was Antipater of Sidon, who around 140 BCE, spoke of the "lofty pyramids" in a compendium of impressive "sights" of the known ancient world (see Clayton and Price 1988:8–12, 158–168). These sights are often known as the Seven Wonders of the Ancient World – with the Great Pyramids of Giza as the only one of such wonders that still stands today. The Great Pyramids of Giza were first referenced early in the fifth century BCE by Herodotus in his *Histories*. The Ptolemaic priest Manetho of Sebennytus (284–246 BCE) is credited with the tripartite chronology of ancient Egyptian history – that is, the Old, Middle, and New Kingdoms interspersed by Intermediate periods (i.e., First, Second, and Third) that were characterized by governmental destabilizations familiar to Egyptologists and archaeologists of the present-day. This system is still in use among modern scholars with slight modifications (see Table 1).

After successive conquests by the Persians and Romans, the Arabs conquered Egypt around 641 CE (20 H[1]). Arab rule brought a full millennium of medieval Arab antiquarians and scholars who discussed first-hand the antiquities strewn upon the ancient Egyptian landscape (see El Daly 2005 for a full review). Rulers and caliphs observed the tremendous wealth, both historical and financial, left by the ancients such as ꜥAbd Al-

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[1] The abbreviation 'H' for Hijri year (also abbreviated 'AH' for Anno Hegirae) is used throughout this section here in respects to Arab medieval scholars during the Common Era or 'CE.' The Hijri year follows the lunar cycle and when not provided in sources was converted from CE to H, and vice versa, using the formula $H = (CE - 622) \times 33 \div 32$ and $CE = H + 622 - (H \div 32)$, respectively. Hijra marks the migration of the prophet Muhammad with his devotees from Mecca and settlement at Yathrib (later renamed Madīnat an-Nabī) in 622 CE or 0 H.

Malik Ibn Marwan in 709 CE (90 H), who also conducted a closer investigation of the Giza Pyramids. Purportedly during a stopover by Al-Ma´moun in 832 CE (217 H), Khufu's pyramid was breached in a search for erudition as well as treasure at the alleged main entrance (Al-Qaddumi 1996:119, 128). Appropriately the pathway is named the "Robbers' Tunnel," and is the foremost entryway into the pyramid today. Arab scholars also focused upon the enigmatic pictograms, known as hieroglyphics, much like the Graeco-Romans before them (Budge 1929; Iversen 1993; Parkinson 1999; Pope 1999; Solé and Valbelle 2001). Most notable is Ibn Waḥshiyah whose analysis of some hieroglyphic texts in *c*. 985 CE (375 H) was influential to European scholars Athanasius Kircher and Joseph von Hammer in the 17th and 18th centuries (*Kitab Shauq*, MS Arabe 6805 Bibliothèque Nationale, Paris; Hammer 1806). Several other Arab scholars also recorded Egyptian hieroglyphics, with some alleged decipherment, including astute comparisons to younger Coptic text prior to and after Ibn Waḥshiyah (see El Daly 2005:65–73). Others began creating compendia of their observations, such as ᶜAbd Al-Laṭif Al- Baghdadi (1162–1231 CE / 557–628 H) in his *Account of Egypt* in two volumes during the 12th century CE (de Sacy 1810).

Amid consistent voyaging by Arab and European explorers from the 13th century CE onward, little attention was given to the Nile Valley's artifacts until the renewed interest in antiquities during the Italian Renaissance. Destabilization because of provincial struggles under Ottoman rule sparked yet another invasion of Egypt in the late 18th century by the French under the leadership of General Napoléon Bonaparte. Bonaparte sought an alternate trade route to India in order to circumvent British regulation of wealth accumulation throughout the Near East as well as quell the British

Table 1. Basic Timeline of Ancient Egypt (from Baines and Malék 2000).

Time Period	Dynasties	Dates
Pre-Dynastic	–	5000–2920 BCE
Early Dynastic	I–III	2920–2575 BCE
Old Kingdom	IV–VIII	2575–2134 BCE
First Intermediate Period	IX–XI	2134–2040 BCE
Middle Kingdom	XI–XIV	2040–1640 BCE
Second Intermediate Period	XV–XVII	1640–1532 BCE
New Kingdom	XVIII–XX	1550–1070 BCE
Third Intermediate Period	XXI–XXV	1070–712 BCE
Late Period	XXV–XXXI	712–332 BCE
Graeco-Roman	–	332 BCE–395 CE

involvement in the French Revolutionary Wars. Napoléon's armada landed in Alexandria on the first of July 1798. After invading and capturing Alexandria, Napoléon and his army of 4,000 sailors and soldiers headed south to Cairo where they encountered the local Egyptian military order known as the Mamluks and their cavalry. The Mamluks, led by Murad and Ibrahim Bey, were no match for the French forces and were easily defeated on July 21, 1798, in the alleged "Battle of the Pyramids," though the actual battle took place nearly 10 miles away at Embabeh. After successive defeats at the hands of the British and Bonaparte's failure to consolidate control over Egypt, the French were eventually driven out of the country by 1801. Though the French military campaign was ultimately a failure, a scientific hegemony of the area was not. Napoléon had brought with him nearly 160 savants – engineers, scholars, and canvassers – to document the landscape and present their findings. The Napoleonic campaign eventually led to important discoveries like the Rosetta Stone, north of el-Rashid, and the observations of the savants that later formed the extensive anthology *Description de l'Égypte*. It was not

until Jean-François Champollion announced the deciphering of the Rosetta Stone and Egyptian hieroglyphs in 1822 that scholars around the world could systematically decode ancient Egyptian inscriptions from tombs, stelae, and papyri.

A History of Nile Valley Archaeology and Bioarchaeology

From Renaissance to Rosetta Stone

The popular appeal of ancient civilizations and their vestiges experienced a resurgence in Europe near the end of the Italian Renaissance and into the European Age of Enlightenment during the 16th–18th centuries, and particularly, a profound interest in the art and archaeology of the Nile Valley. Plucky explorers and adventure seekers such as John Greaves (1626) journeyed beyond the spectacles of Alexandria and Cairo to marvel at the monuments first-hand at Saqqara such as the Pyramid of Djoser and of course the Great Pyramids of the Giza plateau, but also further south in the upper valley. Some of the trinkets that trickled to Europe from looting and pothunting during these jaunts were not only of significant historical value, but scientific value as well. These included mummies. The fascination with the ancient Egyptian practice of artificial mummification, however, was steered mostly by the curiosity of well-to-do socialites attending mummy unwrapping events than by actual scientific study. There are notable exceptions such as the makeshift dissections and tissue rehydrations performed by Gryphius (1662) and Hertzog (1716), and those more professionally trained in the natural

sciences (Hadley 1764; Blumenbach 1794), yet descriptions relating to pathology were still meager or nonexistent.

The weakening of Mamluk militias, oscillations in Ottoman control of the region, and removal of French forces after 1801 left Egypt without a central authority. In 1806, an Albanian condottiere of the Ottoman army, Kavalalı Mehmet Ali Paşa (1769–1849), declared himself khedive or viceroy of Egypt. After several years of civil unrest and strife, any threat of Mamluk governance ended by 1811. Mehmet Ali placated his citizenry and eased tensions among a populous that had endured hundreds of years of conquest, upheaval, and rebellion. The self-professed khedive sought to gain sovereignty from the Ottoman Empire. In doing so he revitalized and modernized Egypt. Some of his modernization efforts drew from Western ideas, and he effectively offered residence to foreign luminaries and dignitaries in exchange for their knowledge.

Meanwhile in Europe, interest in Egyptian antiquities continued. The most substantial specimens appropriated by the Napoleonic expeditioners, including the Rosetta Stone, were surrendered to King George III and annexed to the British Museum where they still reside to this day. The initial volumes of *Description de l'Égypte* were published and disseminated in 1809, impassioning both scholar and plunderer. Now with open invitations from Mehmet Ali to foreign governments to appoint general counsels and diplomats to Egypt, a cottage industry surfaced to extract relics from the Nile Valley and bring them back to Europe on part of the wealthy often to display in one's home with social gatherings (e.g., the alabaster sarcophagus of Sethos I on display in the home of Sir John Soane; see Reeves 2000:12–13). Thus, archaeological inquiry in the Nile Valley until the end of the 19th century lacked professional standards and rigor (Reeves and

Wilkinson 1996; Reeves 2000). After the plundering of early antiquarians and dilettantes such as Giovanni Battista Belzoni (1778–1823) and Henry Salt (1780–1827), archaeology and mummy studies became more intensely academic endeavors and more aligned with contemporary scientific approaches to the understanding of the past. Medically trained professionals conducted mummy examinations with more highly detailed pathological and anatomical descriptions and made advancements in the microscopic and histological examination of mummified tissues (Granville 1825; Pettigrew 1834; Czermak 1852; Mummery 1870; Moodie 1921:xiv; Aufderheide and Rodríguez-Martín 1998:4; Aufderheide 2003:10). Many professorships were awarded exclusively for Egyptology in European, and later, American universities. Non-profit organizations were created for scholarly activities in Egypt and the Sudan such as the Egypt Exploration Society (EES) founded in 1882. Another important milestone was the formation of the Egyptian Antiquities Service (now the Ministry of Antiquities) in 1858 while under Ottoman eyalet rule by Khedive İsmail Paşa (1863–1879) to regulate the preservation of Egypt's cultural heritage, with initial appointments to French Egyptologists like François Auguste Ferdinand Mariette (e.g., 1857, 1875, 1880) and Sir Gaston Camille Charles Maspero (Fouquet 1886; Maspero 1889; see also Dawson and Uphill 1972; David 1986).

Engineering Marvels and Archaeological Salvage

The field of archaeology in all areas of the world is consistently tied to land development. The Nile's natural cycle of periodic flooding and drought was not

conducive to growing modern populations tethered to it as a reservoir and irrigator, as torrential flooding could submerge living spaces along the floodplain as well as increase waterborne disease transmission (Prüss-Üstün et al. 2008), and severe drought could deplete water and food supplies (Butzer 1976, 1984). Therefore, dams along the Nile River were built to control and amplify floodwater accumulation. Between 1899 and 1902, the Aswan Dam (now known as the Aswan Old Dam or Low Dam) was constructed about 700 km south of Cairo and was subsequently raised to meet the increased demands for floodwater storage in 1907 and 1912, and again from 1929 to 1934, as well as the construction of another structure, the Aswan High Dam, beginning in the 1960s. The result of implementing the Aswan Dam and successive heightening was that much of the cultural heritage along the Egyptian-Sudanese border and surrounding areas would be threatened by inundation and potential destruction to significant archaeological sites. In response, salvage excavations that recovered thousands of skeletons and mummies were conducted by archaeologists in both Egypt and Nubia (Derry 1909; Reisner 1908; Reisner 1910; Firth 1912, 1915; Moodie 1923; Reisner 1923; Firth 1927; Emery 1965; Adams 1977; Davies and Walker 1993). Early analysis of the human remains and mummy tissues found were conducted almost exclusively by physicians and anatomists (e.g., Randall-McIver 1901; Elliot Smith 1910; Elliot Smith and Wood-Jones 1910; Ruffer 1913, 1919, 1920, 1921a,b; Collett 1933; Batrawi 1935; and see summation in Waldron 2000 vis-à-vis Grafton Elliot Smith).

During the same period, other teams of archaeologists, including Sir William Matthew Flinders Petrie (1899, 1901), excavated cemeteries in Upper Egypt and created some of the first seriation techniques in archaeology to date ancient Egyptian pottery.

Ancient Egyptian grave materials and associated deposits provided an excellent means to engender chronologies prior to the invention of absolute dating methods such as radiocarbon. Meanwhile, a massive survey from 1905–1907 headed by James Henry Breasted at the University of Chicago documented countless settlements, monuments, and inscriptions in Nubia. Many of these archaeological sites would yield large skeletal samples over the next century (e.g., Wādī Ḥalfā, Semna, Tombos). Primarily descriptive aspects of the skeletal material recovered from the early 20th century investigations including age, sex, and stature were published, and the literature of the time was dominated by dental and skeletal pathology and racial typologies (Fouquet 1896; Petrie 1901; Randall-McIver 1901; Elliot Smith 1910; Ruffer 1913; Derry 1915; Ruffer 1919). The narrow interest in topics such as paleopathology and biological affinity meant that often the only materials collected from burials were skulls and bones showing pathological anomalies (for examples see Collett 1933; Batrawi 1935). A methodological breakthrough in the field of mummy studies did in fact take place in 1908 with the inception of the Manchester Museum mummy project. Two mummies, brothers Nekht-Ankh and Khnumu-Nekht, from a Middle Kingdom tomb (*c*. 2040–1786 BCE) were subject to an "autopsy," during which a diverse number of experts in anatomy, Egyptology, chemistry, and textiles unveiled and thoroughly examined the specimens, gleaning much information (Murray 1910; David 1979, 1986). This procedure laid the groundwork for how mummy autopsies would be conducted in the future with interdisciplinary teams (Aufderheide and Rodríguez-Martín 1998; Aufderheide 2003; Lynnerup 2009).

From the 1920s to the late 1950s several developments emerged in the field of skeletal studies: aging techniques from the pubic symphysis were developed (Todd 1921); some of the first compendia dedicated exclusively to the analysis of human skeletal remains were published (e.g., Krogman 1955; Comas 1957); and, extensive research on the estimation of living stature from long bone measurements took place (Trotter and Gleser 1952, 1958). Sir Marc Armond Ruffer (1921a,b) also invented a revolutionary tissue rehydration process for histopathological analysis, which greatly improved the number of disease diagnoses in mummified tissue and refined into the present to further maintain tissue integrity (see Aufderheide and Rodríguez-Martín 1998:5–6; Aufderheide 2003:12–13; Lynnerup 2009: 361–362). Despite these advances, studies of ancient Egyptian and Nubian remains still focused on case studies in paleopathology (Gardner and Urquhart 1930; Salama and Hilmy 1950) and typological studies of cranial morphology (Collett 1933; Petrie 1934; Batrawi 1935, 1945, 1946, 1947; Derry 1956; Dzierżykray-Rogalski 1958). One notable exception is a study by Cave (1939), who took an epidemiological approach compiling cases of tuberculosis from the literature and demonstrating that the disease was prevalent throughout Dynastic times.

Processual Influence and Industrialization

From the 1950s to 1970s, physical anthropology and archaeology underwent tremendous changes (Washburn 1951, 1953; Willey and Phillips 1958; White 1959; Binford 1962, 1965; Clarke 1968). At the same time as this progressive shift in physical

anthropology and archaeology, numerous anthologies in human osteology and paleopathology were published (Wells 1964; Jarcho 1966; Brothwell and Sandison 1967; Ascádi and Nemeskéri 1970). The most significant event in the history of Nile Valley bioarchaeology during this time was the construction of a new dam to meet the needs of industrialization, the aforementioned Aswan High Dam, from about 1960 to 1970. Archaeologists rushed to the Nile. Dozens of multinational teams, many sponsored by United Nations Educational, Scientific and Cultural Organization (UNESCO), embarked on expeditions to the Egyptian-Sudanese border excavating archaeological sites and exhuming thousands of skeletons. Notable expeditions generating skeletal material included (1) the Oriental Institute at the University of Chicago, which aided at Abu Simbel, Bet El-Wali, and numerous cemeteries in Nubia like Qustul and Semna South (Ricke 1967; Ricke et al. 1967; Žabkar 1972, 1975; Žabkar and Žabkar 1982; Williams 1983, 1986, 1989; Williams 1990, 1991; Williams and Millet 1991; Williams 1992, 1993), (2) the University of Colorado Nubian Expedition to Wādī Ḥalfā (e.g., Greene et al. 1967; Armelagos 1968,1969; Greene and Armelagos 1972), (3) the Joint University of Colorado-University of Kentucky Expedition to Kulubnarti (see Adams 1977), (4) the Scandinavian Joint Expedition at the Nubian border (Vagn Nielsen 1970, 1973; Säve Söderbergh 1987, 1989; Säve Söderbergh and Troy 1991), (5) the Southern Methodist University expedition to Nubia (Wendorf 1968), and, (6) the Polish expedition to Faras (Michałowski 1959, 1962, 1965; Promińska 1966). These team-led expeditions uncovered a rich, deep Nile Valley past that extended tens of thousands of years prior to Dynastic times (see Figure 7).

Discoveries from the UNESCO expeditions included large formal cemeteries at

Figure 7. Chronology of Egypt and Nubia from Epipaleolithic to Dynastic Times.

Years BP	Egypt		Nubia	
	Lower	Upper	Lower	Upper
20,000 – 19,000 – 18,000 – 17,000 – 16,000 – 15,000	Late Kormusan/Halfan (Epipaleolithic)			
14,000 – 13,000 – 12,000 – 11,000	Qadan/Sebilian			
10,000 – 9,000 – 8,000	Fayum A	Neolithic		
7,000 –	Merimde El-Omari	Badari		
6,000 –	Maadi	Naqada	A-Group	Pre-Kerma
5,000 – 4,000 – 3,000	Dynastic		C-Group	Kerma
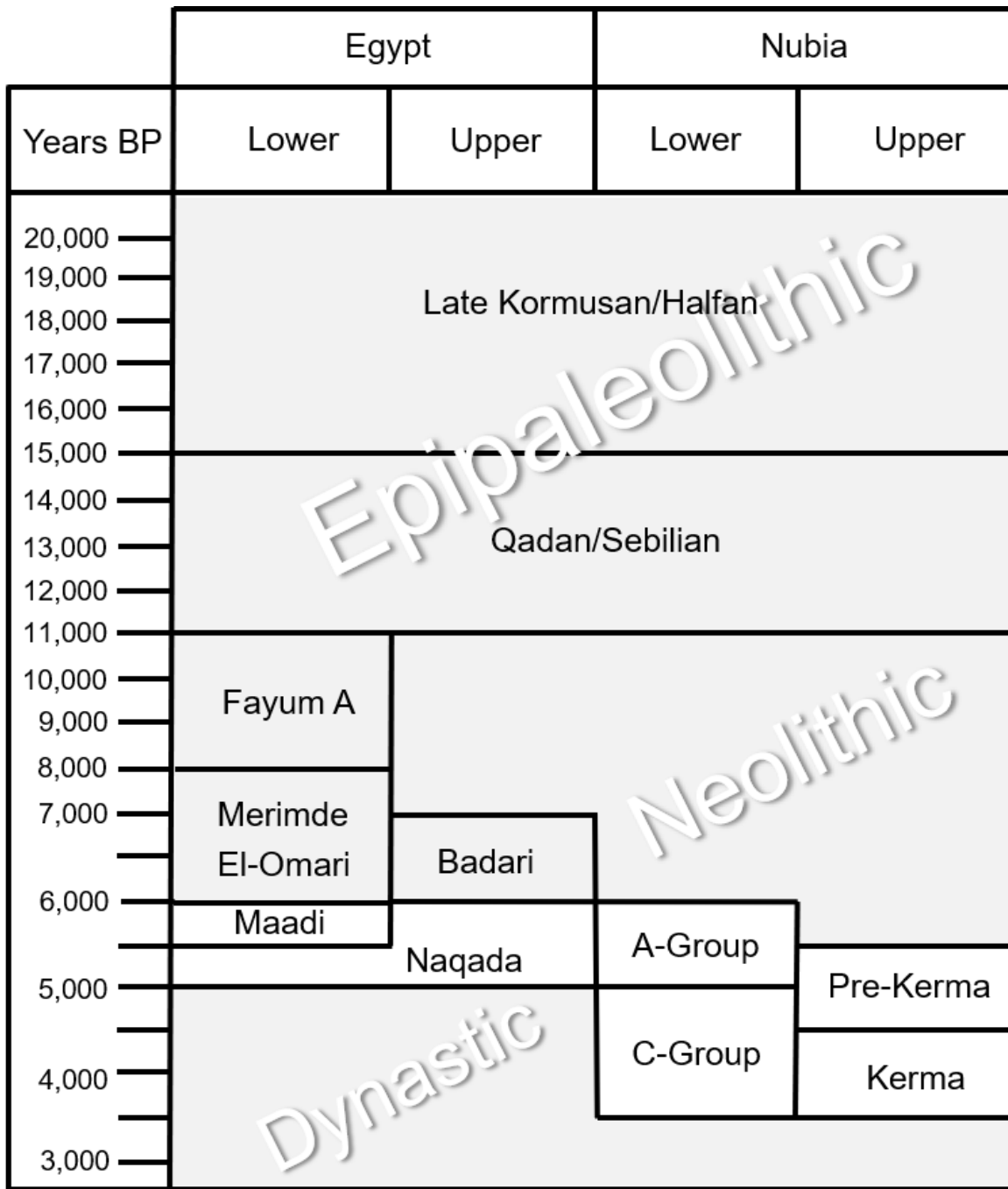
Jebel Sahaba and Wādī Ḥalfā dated to the terminal Epipaleolithic/Mesolithic (14,000–12,000 BP). The oldest evidence for interpersonal violence was discovered at Jebel Sahaba with skeletal signs of traumatic injury such as parry fractures, cut marks, and projectile points in proximity to the spinal column and thorax, as well as two points embedded in crania (Wendorf 1968; though see recent evidence at Nataruk west of Lake Turkana, Mirazón Lahr et al. 2016; Stojanowski et al. 2016; Mirazón Lahr et al. 2016). The site of Wādī Ḥalfā was rich temporally, yielding skeletal material dating from the Mesolithic to Christian periods (BCE12,000–1300 CE / 699 H), and thus, Wādī Ḥalfā became one of the first "natural laboratories" in Nile Valley bioarchaeology to embrace the new paradigm and biocultural approach, featuring prominently in bioarchaeological research since its inception (Armelagos 1964; Greene et al. 1967; Armelagos 1968, 1969; Dewey et al. 1969; Saxe 1971; Greene 1972; Greene and Armelagos 1972; Carlson 1974, 1976; Carlson and Van Gerven 1977; Van Gerven et al. 1977; Carlson and Van Gerven 1979; Bassett et al. 1980; Armelagos et al. 1981; Small 1981; Van Gerven 1982; Armelagos et al. 1984; Goodman et al. 1986; Baker 1992; Rose et al. 1993; White and Armelagos 1997; Hibbs et al. 2011; and see new work by Armelagos and Van Gerven 2017). Bioarchaeologists examined several aspects of skeletal variation through time and space with teeth (Greene et al. 1967; Greene 1972; Hillson 1979) and skull morphology (Carlson 1974, 1976; Carlson and Van Gerven 1977; Van Gerven et al. 1977; Carlson and Van Gerven 1979). Most researchers concluded that the Mesolithic hunter-gatherer crania and masticatory complexes were stouter and more robust than their temporally recent counterparts who practiced floodplain agriculture causing the reduction of dentition and craniofacial architecture (Greene 1972; Carlson 1974, 1976; Carlson and

Van Gerven 1977; Van Gerven et al. 1977; Carlson and Van Gerven 1979). Another important highlight of 1970s Nile Valley skeletal research is the volume "Population Biology of the Ancient Egyptians," the result of a multinational conference focused solely on ancient Egyptian bioarchaeology (Brothwell and Chiarelli 1973). The 1970s also saw significant advances in mummy studies due in part to the publication of Zimmerman's (1972) comparison of modern, synthetically mummified tissue with Egyptian mummies as well as the continued interdisciplinary approach of mummy autopsies (Cockburn et al. 1975; Cockburn 1978).

Late 20th Century to the Present

The end of the 20th century saw major developments in terms of analytical methods and syntheses in the field of bioarchaeology. Several techniques for aging and sexing skeletons came to the forefront (e.g., Buikstra and Mielke 1985; Lovejoy et al. 1985; Meindl and Lovejoy 1985; Suchey and Brooks 1990). Vast multi-authored volumes surfaced dedicated to the comprehensive analysis of human remains, or even an aspect of them like pathology (e.g., Krogman and İşcan 1986; İşcan and Kennedy 1989; Aufderheide et al. 1998; Saunders and Katzenberg 1992). During this time, the oldest human skeletal material in the Nile Valley was unearthed in Upper Egypt at Nazlet Khater (35,000–30,000 BP), representing the only complete human skeleton from the Early Upper Paleolithic (see Thoma 1984; Vermeersch et al. 1984a,b; Pinhasi and Semal 2000; Crevecoeur and Trinkaus 2004; Bouchneb and Crevecoeu 2009; Hublin and Klein

2011; Leplongeon and Pleurdeau 2011), and a single burial was also excavated at Wādī

Kubbaniya (20,000–12,000 BP; Wendorf et al. 1986).

The influence of the biocultural approach is prevalent in many scholarly works

during the 1980s and 1990s. An important scholarly work that influenced the discipline

was the edited volume "Paleopathology at the Origins of Agriculture" (Cohen and

Armelagos 1984), which tasked researchers to examine signs of skeletal pathology

spanning the transition from forager to food producer in human societies from several

regions of the world. The chapter by Martin et al. (1984) discussed this very transition in

Sudanese Nubia. As the skeletal preservation in the Nile Valley is quite good, skeletal

analysts could investigate such concepts as adult body shape and limb proportions and

did so of the pharaohs and Predynastic peoples (Robins and Shute 1983, 1986).

Researchers also experimented with cross-sectional geometry and histology of human

bone as well as trace elements analysis including bone mineral and collagen content and

stable isotopes (Bassett et al. 1980; Martin et al. 1981; Baker 1992; Iacumin et al. 1996;

White and Armelagos 1997; Iacumin et al. 1998). The landmark collaboration of skeletal

researchers at the Field Museum of Natural History in Chicago that resulted in the

publication of "Standards for Data Collection from Human Skeletal Remains" (Buikstra

and Ubelaker 1994) spurred a wave of interest in bioarchaeology. With a spiralbound set

of "Standards" and additional material dedicated wholly to identification of bones (White

and Folkens 1991) and teeth (Hillson 1996), the tools necessary to document and analyze

human skeletal remains were more accessible to students and scholars alike. Other

important syntheses emerged with publications by Strouhal (1981) and Baker (1997)

containing assessments and reflections of the field of biological anthropology and

bioarchaeology in ancient Egypt and the Sudan. In 1993, the volume "Biological Anthropology and the Study of Ancient Egypt" was released, the product of an international colloquium dedicated to topics of the region, with a notable chapter by Buikstra et al. (1993) examining tuberculosis over the course of ancient Egyptian history. Near the end of the 20th century, bioarchaeologists even had a bibliographic reference specifically for ancient Egypt and Nubia (Rose et al. 1996).

In the 21st century, substantial contributions to the discipline have advanced analytical and technological methods (e.g., ancient DNA, isotopic and trace element analysis, juvenile osteology [see Scheuer and Black 2004; Baker et al. 2005], bacterial histopathology [see Aufderheide 2003; Grove et al. 2015], etc.), but perhaps the most readily visible and influential changes are the development and proliferation of archaeological and social theory in bioarchaeology (e.g., Díaz-Andreu et al. 2005; Knudson and Stojanowksi 2008; Gowland and Knüsel 2009; Knudson and Stojanowksi 2009). In specific reference to the Nile Valley, several significant volumes on burial and mortuary variation emerged (e.g., Grajetzki 2003; Richards 2005; Laneri 2007), and compilations focused on the entire archaeological histories of the region (Wengrow 2006). Bioarchaeologists such as Jerry Rose enhanced collaboration with archaeologists and other diverse disciplines at recent excavations in Egypt as exemplified at Hierakonpolis, an important site for the formation of the Dynastic state (Matovich 2002; Zabecki et al. 2004; Denton 2006; Greene 2006; Irish 2006; Larsen 2009; Kumar 2009; Zabecki 2009; Batey 2012). Researchers included existing collections from previous expeditions to Egypt and Nubia, for example, integrating new excavations at Tombos from the Sudanese dam project discussing topics such as stable isotopes, biodistance, and

health (Thompson et al. 2005; Zakrzewski 2003; Buzon 2006; Zakrzewski 2007). In 2006, editors Jane Buikstra and Lane Beck released "Bioarchaeology: The Contextual Analysis of Human Remains," a comprehensive volume devoted to several aspects of the field including histories of scholarship and specific topics of bioarchaeological inquiry (e.g., biodistance and paleodemography). The inaugural publication of the annual journal "Bioarchaeology of the Near East" was released in 2007 by the University of Warsaw, opening a new outlet for current and burgeoning scholars to converge on topics covering Nile Valley bioarchaeology and the greater Near East. The fusion of social theory and bioarchaeology led to the propagation and diversification of "bioarchaeologies" – theoretically intensive, holistic treatments of skeletal analysis and synthesis including identity (Knudson and Stojanowski 2008, 2009), childhood (Lewis 2009), violence (Martin et al. 2013; Martin and Harrod 2015), care (Tilley 2015; Tilley and Oxenham 2011; Tilley and Schrenk 2017), and impairment and disability (Byrnes and Muller 2017). Long gone are the vignettes and tabularizations that characterized the field in its infancy. Greater attentiveness is now given to the interpretation of human skeletal remains within the lens of social and theoretical concepts and this is observed in countless publications into today that focus on the Nile Valley (e.g., Dabbs and Schaffer 2008; Stock et al. 2011; Buzon and Simonetti 2013; Wheeler et al. 2013; Schrader 2015; Smith-Guzmán 2015; Buzon et al. 2016).

Summary

This chapter summarizes the available literature pertaining to the geography and physiography of the Nile Valley region as well as more inclusive history of Egyptology and then a narration of the archaeology and bioarchaeology of Egypt and the Sudan. Chapter 3 focused on important contributions to bioarchaeology both in terms of knowledge acquisition but also advances in the field in terms of technology, methodology, and the increasing integration of sociocultural theory. As Chapter 3 concentrated on broader themes and influences in the Nile Valley as a whole, the next chapter transitions to a history and archaeology of the city of Amarna, including previous bioarchaeological studies of the Amarna South Tombs cemetery – the skeletal sample at the focal point of this dissertation.

Chapter 4:

A HISTORY AND ARCHAEOLOGY OF AMARNA

Building from a general discussion of the history of archaeology and
bioarchaeology of the Nile Valley as well as fundamental concepts such as biodistance
and paleodemography in bioarchaeological inquiry, this chapter will discuss the history
and archaeology of the Amarna Period, the ancient city of Akhetaten (modern: Tell el-
Amarna, el-Amarna, or simply Amarna), and the Amarna South Tombs cemetery (STC).
It begins with an overview of the New Kingdom at the beginning of the 18th Dynasty and
then briefly discusses the formation of the city of Amarna in antiquity, as well as
introducing the theoretical concept of disembedded capitals. The earliest documentation
and excavations of the Amarna archaeological site are detailed thereafter, including
modern excavations that have taken place since 1977, and the current bioarchaeological
research undertaken at the Amarna STC.

The New Kingdom and Amarna

The New Kingdom of Egypt (1549–1069 BCE) is a time frame associated with
grandiose wealth, expansion, and power of the state. The inception of the New Kingdom
is characterized by the removal of the Hyksos and the powerful reign of the pharaoh
Ahmose I (1549–1524 BCE). The first of the 18th Dynasty kings (1549–1292 BCE)
established Egypt as the dominant polity in the Near East by annexing territories in the

Levant, Nubia, and Syria-Palestine (Bryan 2004:218–219). Other 18th Dynasty pharaohs such as Hatshepsut (1479–1458 BCE), Thutmose III (1479–1425 BCE), and Amenhotep III (1388–1350 BCE) solidified Egypt's standing in the Near East and the rest of the known world by expanding commercial trade, exuding military force, and fortifying the territories initially acquired by Ahmose I or later reacquired (Bryan 2004:242, 245–248; Van Dijk 2004:272).

The 18th Dynasty pharaoh Amenhotep IV (1355–1338 BCE) made drastic changes to the empire, its belief system, and the office of the king that were unprecedented in the history of ancient Egypt (Van Dijk 2004). The pharaoh had changed his birth name to Akhenaten, relocated the capital of the empire to Middle Egypt, and transformed the religion of the state to a primitive form of monotheism (or quasi-monotheism), likely either henotheism or monolatrism. Henotheism and monolatry are similar concepts that depict the worship of one main deity, but also the belief (or lack of denial) in the existence of other gods or goddesses. The god Amun was an important Upper Egyptian deity that became more influential after the expulsion of the Hyksos and the rule of Ahmose I exemplified by the fusion of Amun with the sun god Ra (i.e., Amun-Ra) at the onset of the New Kingdom. The cult of Amun continually attained greater prominence through the reigns of pharaohs bearing the name Amenhotep (e.g., I–IV; meaning "Amun is pleased"). Amenhotep IV not only followed his father's traditions but brought the cult to new heights via a royal decree mandating the worship of only one god or aspect of Amun-Ra, the Aten or the sun disk (Murnane 1995:145, 171). The pharoah was also interested in creating a capital city where no other gods or goddesses had tarnished the soil – a city for which he pioneered the construction and named Akhet-Aten

(modern: Tell el-Amarna, el-Amarna, or simply Amarna), meaning the 'Horizon of the Aten' (Hornung 1999; Van Dijk 2004; Kemp 2006, 2012). Along with a new religion and city, the king also formally changed his name to Akhen-Aten – a name which embodied his primary god as the "living spirit of" or "effective for" Aten. The city of Amarna was constructed around 1352 BCE in Middle Egypt, nearly equidistant from the empire's two major centers, Memphis (Cairo) and Thebes (Luxor; Figure 8). Memphis in the north was the administrative center and Thebes in the south served as the focal point for religious functions. By constructing a new city between these two centers, the pharaoh Akhenaten was able to integrate both the administrative and religious components of the state into one locale, or capital, to promote his new belief system and political agenda.

The Disembedded Capital and Population Dynamics

Amarna is classified as a disembedded capital since it was founded on a neutral location away from the existing power bases of the Egyptian empire (Blanton 1976; Willey 1979; Joffe 1998). Creation of a disembedded capital can be an important strategy to fortify local polities through a regional-scale center using neutrality as the primary tactic. To develop a more regional-scale polity via neutrality, the capital must be removed or disembedded geographically from the local regimes so as to compartmentalize them. Many modern examples of disembedded capitals are readily available. For example, Washington, D.C. was founded at a neutral location along the Potomac River to balance the economies of the northern and southern states (Walton 1966; Bowling 1991). Ottawa in Canada was created as the nation's capital to quell the feuding between English and

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Figure 8. Map of Egypt Depicting the Location of Tell el-Amarna (Courtesy of the Amarna Project).
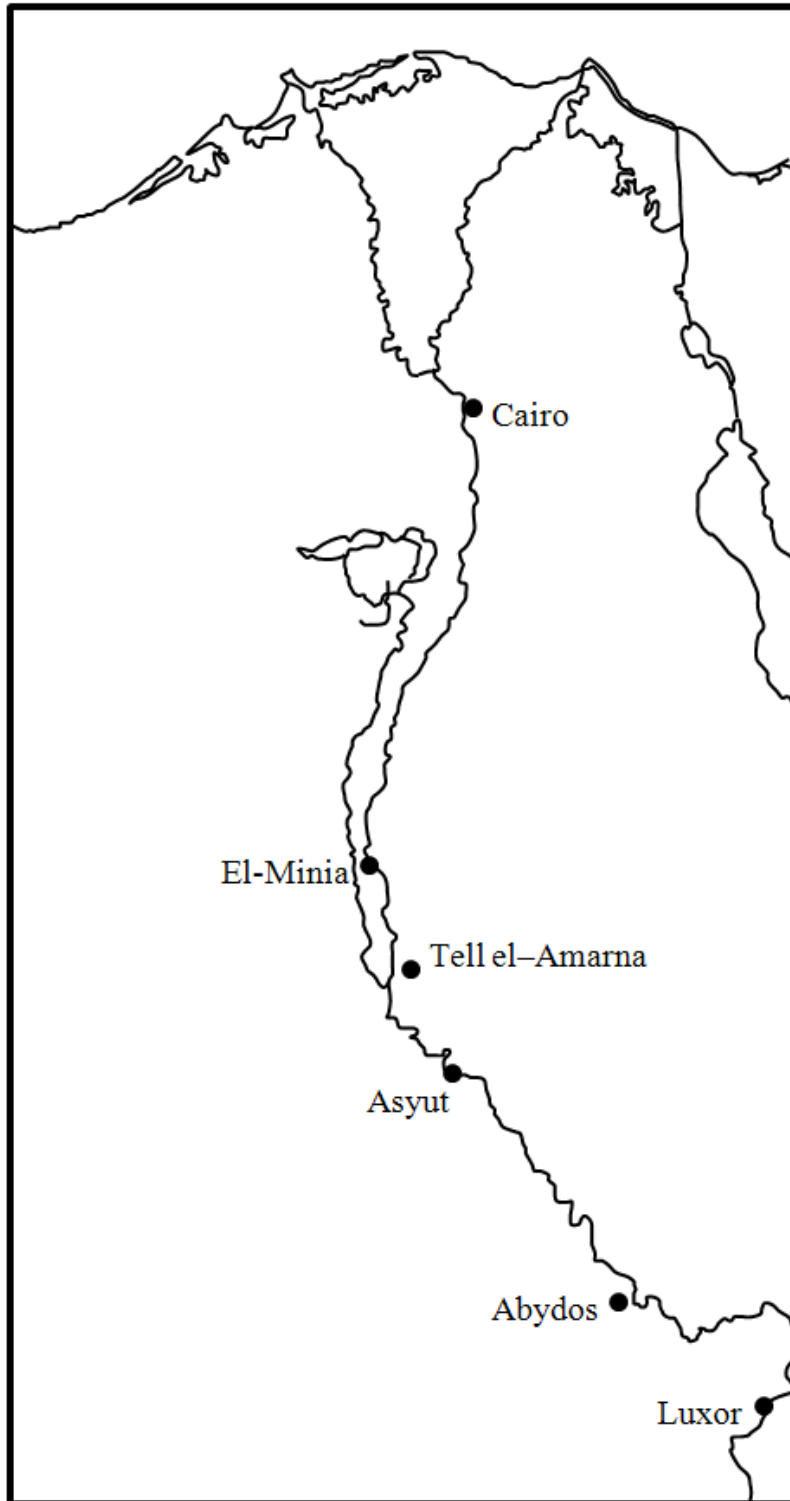
French provinces (Knight 1977, 1991). Other similar instances are observed in Australia, India, and Brasil. Canberra was chosen as the location for a capital to settle the quarreling within the Australian federation between provincial capitals Melbourne and Sydney; New Delhi was strategically formed near India's Hindu/Muslim margin to remove power from its other dominant and prevailing cities Mumbai and Kolkata (Fischer 1984); and, Brasília was similarly built, without concern for local resources, as it was constructed in a dense tropical forest, though its purpose was to integrate a country weakened by the competing power centers of Rio de Janeiro and São Paulo (Epstein 1973:28–30). For Amarna, the pharaoh Akhenaten's motive was to construct his royal city in a similar fashion, seeking to equalize and suborn the empire's main power centers at Memphis and Thebes.

A small, but informative anthropological literature exists on the theoretical concept of disembbeded capitals and their importance in state formation and maintenance (Blanton 1976; Willey 1979; Joffe 1998). However, the identification of disembedded capitals in antiquity is challenging due to the nature of archaeological data. A capital city or principal settlement from the past may be identified as a disembedded capital simply because of its remoteness geographically, yet it can be difficult to argue against the formation of a capital due simply to organic growth. Debate about "disembeddedness" has surrounded the settlement of Monte Albán in Mexico since it is situated in the highlands within the Valley of Oaxaca (Blanton 1976; Willey 1979; Blanton et al. 1999:65–66). Other purported disembedded capitals such as the Assyrian capitals and some Chinese capitals may have been founded in a similar way on neutral grounds (Joffe 1998). Perhaps a somewhat analogous, but more recent historic example to the city of

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Amarna is the city and fortress of Sīhāgiri (or Sigiriya) in Sri Lanka constructed by the

King Kassapa I (477–495 CE) during his ascension to the throne. Kassapa I thus

attempted to shift power away from the previous capital Anuradhapura and the reign of

his father King Dhatusena (Bandaranayake et al. 1990; Bandaranayake and Saṃskṛtika

Aramudala 2005; Ponnamperuma 2013). The settlement of Sigiriya was grandiose and

expensive to assemble, situated on top of a massive foundation of granite almost 200

meters high (known as the Lion Rock), and adorned with elaborate palaces, entryways,

frescos, and gardens. It was also short-lived, abandoned soon after the death of King

Kassapa I when the capital of the kingdom returned to Anuradhapura (Bandaranayake et

al. 1990; Bandaranayake and Saṃskṛtika Aramudala 2005; Ponnamperuma 2013).

Important distinctions when identifying disembedded capitals in antiquity,

particularly difficult to ascertain without the written record, are *de novo* construction and

the existence of contemporaneous powers bases. First, demonstrating that a settlement

was constructed on new ground with a specific intention to remove it from existing power

bases is problematic given the nature of archaeological materials and in the absence of

historic records. Secondly, rich archaeological and historical records are necessary to

validate the co-existence of other major power bases. Amarna has been cited as the

quintessential example of a disembedded capital (Willey 1979; Joffe 1998) since two

major power bases co-existed during this time period in the history of ancient Egypt

(Memphis and Thebes) and that the pharaoh Akhenaten also built his city on neutral

ground where no other god or goddess had previously occupied (Murnane 1995:145,

171). Moreover, disembbedded capitals are quite costly to erect and are usually short-

lived (see previous example of Sigiriya; Bandaranayake et al. 1990; Bandaranayake and

Saṃskṛtika Aramudala 2005; Ponnamperuma 2013). The city of Amarna was likely very expensive to construct, and its temporal span was no more than 20 years (*c*. 1352–1336 BCE). This makes the ancient city of Amarna an appropriate vehicle for the study of both ancient cities and disembedded capitals.

Unfortunately, little is known about the geographic origins of populations migrating to ancient cities or even disembedded capitals. A common assumption for the peopling of cities in antiquity is a rural-to-urban migration process (Smith 2014) and that early cities were populated through coerced or forced migration (Morris 1972; Hugo 2006). Since the pharaoh integrated both the administrative and religious functions of the empire into one capital city, functions previously divided between the cities of Memphis and Thebes, a plausible migration scenario is that many people were coerced or forced to migrate to Amarna from these large centers.

Thus, the history and archaeology of Amarna can help inform our expectations for the identity of its inhabitants. Where did the people of Amarna come from? Did they relocate from the other major centers such as Memphis and Thebes or did the new city draw people from across the Nile Valley and the ancient world? The pharaoh Akhenaten spent his childhood at Thebes near Malkata, and evidence suggests that his earliest years on the throne were headquartered there as well, a pattern similar to other pharaohs of the 18th Dynasty (Kemp and O'Connor 1974; Kemp 1977a). Likely a number of officials and their families were required to relocate with the king, and they too may have grown up with the pharaoh and his family and even held office at Thebes. The rock tomb of Parennefer, the king's cup-bearer and steward to the king since his youth (Murnane 1995:178), was constructed at Thebes during the beginning of Akhenaten's rise to the

throne (Theban Tomb, no. 188 at El-Khokha; Manniche 1987), and later one was fashioned for him at Amarna (South Tombs, no. 7; Davies 1908). This evidence demonstrates that administrators relocated alongside the pharaoh (Kemp 2012:41). Also, the workers' village at Thebes, Deir el-Medina, which housed the laborers responsible for constructing the rock tombs of the Valleys of the Kings and Queens, appears analogous to the Amarna Workmen's Village (Peet and Woolley 1923:101; Bierbrier 1989; Lesko and Lesko 1994; Kemp 2012:191). These laborers may have moved *en masse* from Thebes to Amarna to build the North, South, and Royal Tombs. For instance, one of the tenants of the Workmen's Village had the same title ('Servant of the Place [of Truth]') as an occupant at Deir el-Medina (Peet and Woolley 1923:101; Kemp 2012:191).

However, Akhenaten's integration of both administrative and spiritual functions of the empire within one central location (i.e., Amarna) likely required administrators and officials not only from as far north as Memphis, but also from provincial towns beyond the royal family's primary sphere of influence in the south (Kemp 2012:41). For example, the fan-bearer, May, and the high priest at Amarna, Panehsy, describe how the king helped expand their families and supporters, but also how their promotion by the king facilitated greater influence in their home towns (Murnane 1995:145, 171). Presumably their origins were not only at Thebes, but also elsewhere along the Nile (Kemp 2012:44). The king likely required support from provincial towns, such as *nome* capitals, outside the royal family's primary influence in the south and the highest tiers of administration at Memphis (O'Connor 1972; Hassan 1993; O'Connor 1993; Murnane 1995:145, 171; Kemp 2012:41). Only one of Akhenaten's functionaries has a rock tomb at both Thebes and Amarna (i.e., Parennefer; Theban Tomb, no. 188 at El-Khokha;

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Manniche 1987, and Amarna South Tombs, no. 7; Davies 1908), which might suggest

that the rest of the king's closest officials are not derived from elite pedigree and *novi*

homines – leaders of smaller provincial towns without direct ties to existing royalty and

with geographic origins that do not include Memphis or Thebes (Hari 1976; Redford

1984:149–153; Aldred 1988:172–173; Gardiner 1961:222–224; Murnane 1995:145, 171;

Joffe 1998; Kemp 2012:44). Another factor could be population movement to Amarna

from areas occupied by Egypt, such as Nubia or even Syria-Palestine. Amarna may have

housed foreign officials or scribes, or even drawn people from the Nubian frontier

(Erichsen 1933; Kemp 2012: 214–216, 227, 269–271). Several artifacts found at Amarna

originate from these far-off places that extend even into the island of Cyprus, such as

Mycenaean pottery (Kemp 2012:214–216, 227). These goods may have been acquired

through trade but even brought by foreign mercenaries who made Amarna their home

(see the Harris Papyrus; Erichsen 1933). Another important question pertinent to this

research is: how was the new city populated? For instance, did relocation reflect a select

subset of the parent community, perhaps a kin group or a cluster of young adults, and

then gradually more diverse age groups were drawn to the new capital? By contrast, did

whole communities relocate *de novo* to begin carrying out functions necessary to fuel the

newfound settlement? Migrant studies usually recognize the 20–30 age group as the

largest constituent of initial migrants to frontier communities and to metropolitan areas

(Lefferts 1977; Simkins and Wernstedt 1971; Swierenga 1982; Blanchet 1989; Anthony

1990; Fuguitt and Heaton 1995; Burmeister 2000; Cabana and Clark 2011; Crawford and

Campbell 2012; Baker and Tsuda 2015). As this age group settles in the new community,

they soon bring families and friends, and thus population increase and diversity is

accretional. Is the same pattern of frontier settlement documented during historic times and in modern cities visible demographically at Amarna; or, were entire families including children and elders transplanted to Amarna to fuel the new city, similar to the family labor system seen in mill villages that were constructed for the textile industry during industrialization? The frontier or accretion scenario would have correlates for demography in that the age structure would be narrow, comprised of many young adults oftentimes with a male bias, and fertility would be lower than expected under stable population conditions (Lefferts 1977; Simkins and Wernstedt 1971; Swierenga 1982). However, the main demographic analogy used in this research is the American northern frontier, which was heavily skewed toward subadults 0–9 years of age (~35%); suggesting that low fertility is not always the case (Davis 1977). In contrast, a scenario at Amarna akin to the formation of mill villages that were prevalent in the American South, Northeastern United States, and United Kingdom would have seen houses for families constructed *de novo* for their arrival and labor enforced immediately (Lander Jr. 1969; McHugh 1988; Glass 1992; Kulik et al. 1992; Mrozowski et al. 1996; Mrozowski 2006). The demographic signature of mill families shows a broader adult age structure, with a female bias, but with a much larger composition of subadults (5–19 years of age) indicative of fertile families and a child labor force with an average family size of four to five (see McHugh 1988:9, 55, 78).

The city of Amarna formed in a linear fashion aligned north-south parallel to the Nile, and it likely began with the construction of palaces for the king, his family, and servants as well as temples dedicated to the worship of the Aten (Kemp 2012:161). As the city subsequently expanded, this linear alignment was abandoned in favor of

following the natural curvature of the Nile's bank and the desert's topography, with the North Riverside Palace following a northwesterly pattern. By contrast, in the south, a more organic spread of neighborhoods eventually became a city that housed up to 50,000 people (Kemp 1977a, 1981, 2012:161, 272). To build the palaces and temples, an immediate labor force was necessary, as well as the presence of the king, his family, attendants and officials to begin conducting the business of the empire. Kemp (2012:44) mentions that the collective experience in ancient Egyptian society was one that involved the reliance of officials on their crowd of dependents (and vice versa) who were not only integrated through familial ties, but also through their obligations to the state. This type of social structure suggests that the city of Amarna did not conform to accretionary expectations but was instead populated by relocated communities likely from Thebes, Memphis, and other major towns along the Nile (Murnane 1995:145, 171; Kemp 2012:44).

Early Documentation and Excavations of the City

The name 'Tell el-Amarna' is traced back to an ethnic group known as the Beni Amrân during the 18th century. The Danish explorer Frédéric-Louis Norden (1737–8) recalls that the area was referred to both as Beni Amrân and Amarna ("Beneamraen ou Omarne"). Norden discusses the term as referring to a district of four villages set apart from each other ("On comprend sous ce nom une étendue de terre où sont situés quatre villages voisins les uns des autres"), corresponding to the modern-day village place names: el-Till (or el-Til), el-Hawata, el-Hagg Qandil, and el-Amiriya. Archibald Sayce,

Professor of Assyriology at the University of Oxford, commented on Norden's voyage that the word 'Amarna' was "either Bedouin or schoolmaster's Arabic" (Frothingham 1893:570). Nonetheless, the settlers formed four villages in a district boundary stretching south to Gebel Abu Feda. The addition of the word 'Til' may have been introduced by British Egyptologist John Gardner Wilkinson (1824), who popularized ancient Egyptian lifeways to Victorian Britain in his six-volume set *Manners and Customs of the Ancient Egyptians*. Wilkinson's *Extract from Hieroglyphical Subjects* (1828) references "the town near the modern village of Til el Amarna," which suggests that the etymology of the site is a combination of the village of 'el-Till' (or 'Til') with that of the tribal name 'Beni Amrân.' The appellation 'Tell el-Amarna' then sounds like a corruption of 'Til' to 'Tell,' maybe to specifically refer to an archaeological site located within the district of four villages (i.e., Amarna or el-Amarna). In Arabic, a 'tell,' or 'tel' as it is also written, specifically refers to a mound formed by human activity and subsequent desertion. They can vary in shape and form, but the typical 'tell' is a truncated cone-shaped feature, so that a relatively level ridge evolves, much like a plateau with sloping sides, similar in dimensions to a trapezoidal prism. The moniker is popular in the Middle East and North Africa (and even in the Anatolian Plateau, e.g., Çatalhöyük) to describe archaeological sites. Though the ancient city is located on level ground near the floodplain, it was not continually inhabited. The city does not take the classic form of a 'tell,' and the highest elevations on-site are from dilapidated mudbrick walls and foundations as well as spoil heaps from previous excavations (e.g., Flinders Petrie).

The earliest documentation of Amarna on a map was by French traveler Paul Lucas (1731), who made voyages in and around Egypt in 1704 and 1714. Lucas

(1731:126–128) mentions that his map included all sites visited during his stay, yet without any descriptions of the Amarna city ruins, some scholars doubt as to whether Lucas himself set foot on the site (Monterrat 2000:59). A French Jesuit missionary named Père Claude Sicard appears to be the first European to not only document a visit to the site, but to also record one of the boundary stelae, known as stela A, at Tuna el-Gebel in November of 1714 (Fleuriau d'Armenonville 1717; see Figure 9). The first plan of the ancient city of Amarna appears in a map constructed by Edmé Jomard, one of the savants of the Napleonic expedition in 1798/1799 (Paris 1817). The main road running through the city and the Small Aten Temple is visible with an obviously more linear city plan than what exists from more recent mapping efforts (Kemp and Garfi 1993). Jomard was impressed with the architecture and construction of the Small Aten Temple and rivaled it in comparison to other structures of grandeur like the palace of Luxor. In 1819, the British Counsel-General to Egypt, Henry Salt, returned from an expedition to Egypt with a yellow limestone statue (now in the Louvre, Paris [N831]) that many antiquarians identified as the king Akhenaten (Freed et al. 1999:230; Reeves 2000:24). Though the provenance of the statue is still unknown, this artifact may very well have been recovered from Amarna.

Later, Wilkinson constructed his own maps after his visits to Amarna in 1824 and again in 1826, showing a plan map of the main part of the Central City – a zone of the city containing the Aten temples, the principal state palace, and various administrative buildings. He also recorded the tombs of Meryra in the north group, explored an alabaster quarry, presumably Hatnub, and made casts and drawings of artifacts (1836). Wilkinson, along with antiquarians James Burton and Robert Hay, sought to record and document

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Figure 9. Illustration of Boundary Stela A and Statues of the Royal Family (from Davies 1908; Courtesy of the Amarna Project).

archaeological materials, as opposed to earlier expeditions that simply removed artifacts

for sale in the museum and antiquities trade markets. Even Rosetta Stone decipherer

Jean-François Champollion made a brief visit to Amarna in November 1828, as part of

the Franco-Tuscan expedition directed by Champollion himself and Tuscan academic

Ippolito Rosellini. With only a one-day stop, Champollion briefly observed and recorded

one of the boundary stelae, purportedly the same stela (stela A) that Sicard documented at

Tuna el-Gebel (see Hornung 1999). By 1833, approximately 70 sheets of Robert Hay's

drawings were published by the British Museum. Hay's sketches contained some of the

first images of the South Tombs available to the general public, including a claim that he

opened the tomb of Ay. Shortly thereafter, French Egyptologist and artist Nestor

Nippolyte Antoine L'Hôte, made his own sketches of some of the tombs and stelae along

the bordering desert on two voyages to Amarna between 1838 and 1842. In the 1840s, a

Prussian expedition funded by King Friedrich Wilhem IV and led by German

Egyptologist Karl Richard Lepsius, mapped the Central City, parts of the southern

residential area, and even the North Tombs with the aid of German illustrators, the

brothers Weidenbach (Ernt and Max). This was part of an epic twelve volume

compendium known as the *Denkmäler aus Aegypten und Aethiopien* affixed with five

volumes of text (Lepsius 1849–1856).

In the 1880s, a short two-day French mission was conducted at Amarna. At

roughly the same time local villagers discovered a sculptor's plaque and a large tomb in

the eastern desert cliffs of Gebel Abu Hasa. The plaque was subsequently purchased by

an American journalist who frequented Egypt, Charles Edwin Wilbour, in 1881 (now

commonly known as the Wilbour Plaque, see Capart 1936:95–96; Freed et al. 1999:245).

The Wilbour Plaque contained one of the first glimpses of the unique Amarna art style readily visible among all forms of ancient Egyptian art, as it depicted both the king and queen side-by-side (Brooklyn Museum, 16.48). It was a preview of the sculpture that was to be unearthed in the coming decades and the most significant find since the days of Lepsius and the Prussian expedition. The tomb found in the eastern desert cliffs was rumored to be the final resting place for the king himself and his family (now referred to as the Royal Tomb). Today museums in Edinburgh and Liverpool house material purportedly robbed from the Royal Tomb circa 1882, including gold jewelry such as the ring bearing the queen's second name-form 'Nefernefruaten-Nefertiti.' Rumors circulated that a mummy was also found in the Royal Tomb, which is speculated to belong to the king (though see controversies surrounding WV25 and KV55 in Hawass et al. 2010 and responses by Lorenzen et al. 2010). The Egyptian Antiquities Service, under the leadership of Alessandro Barsanti, allegedly cleared the Royal Tomb as early as 1891, focusing exclusively on the king's burial chamber (Martin 1974, 1989; Reeves and Wilkinson 1996:118). Apparently, the work of Barsanti and his team was careless, and the archaeological data gathered during their stay was lost and never found. Less careless was the intuition of a local woman who recovered a large collection of clay tablets in 1887; other locals who subsequently identified the markings on them as cuneiform (as *kitba mismârî* or 'nail-writing'; Reeves 2000:72–74). Approximately 300 of these clay tablets were salvaged at the time, but now total about 382 due to more recent finds (e.g., Flinders Petrie). Popularly known as the Amarna Letters, they are one of greatest discoveries of ancient Egypt due to their contribution to its political and administrative history.

Formal archaeological excavations at Amarna were initiated by Flinders Petrie (1894) in November of 1891. Petrie began to document the painted floors and frescos of the state palace. Months later Petrie was joined by Howard Carter, who endeavored to first publish preliminary sketches of the mourning scene in the Royal Tomb (*The Daily Graphic*, 23 March 1892). Carter started excavations at the Great Aten Temple and Petrie effectively took the rest of the city including the palaces, the other temples, and the residential housing. Neither Carter nor Petrie recorded in detail where their artifact finds were located but knowing the rudimentary division of their excavations of the city, some general provenience data can be estimated. Shortly thereafter in the early 20th century, the North and South Tombs were documented with photographs and line drawings by Norman de Garis Davies (1903–1908). Then, Ludwig Borchardt headed excavations at Amarna under the Deutsche Orient-Gesellschaft beginning with test pits at several parts of the city including the residential area in 1907. For four seasons between 1911 and 1914, Borchardt and his expedition uncovered parts of the official housing in the eastern part of the city and in the southern area of the Central City (Hinrichs 1910–1913). His work recovered mostly statuettes and figurines from the workshops of sculptors; the most notable belonged to Thutmose where the fabled bust of Nefertiti was discovered. More intensive archaeological investigations took place again in 1921 with the excavations of Peet and Wooley (1923) sponsored by the Egypt Exploration Society (EES). These sponsored excavations were conducted until 1936 (Frankfort and Pendlebury 1933; Pendlebury 1951), and cleared most of the North Suburb, Central City, housing of officials, and also part of the Workmen's Village, and formed the basis of most of the site's artifact typologies.

Modern Excavations at Amarna (1977–Present)

After the initial excavations sponsored by the EES, no formal excavations were undertaken until the arrival of Barry Kemp (Professor of Egyptology at Cambridge University) in 1977. Kemp understood that the city of Amarna was an important place because it was the only archaeological site that could inform about urbanism, urban planning, and urban life during the New Kingdom of ancient Egypt (Kemp 1977a,b; Jeffreys and Giddy 1992; Shaw 1998). Archaeologists also combated a long-held belief engendered by social scientists like Wilson (1960:124), who dismissed the notion of urban complexity in the Nile Valley's past and described ancient Egypt in the New Kingdom as the "civilization without cities." Much of this confusion among social scientists was a result of directly comparing the large city-states that developed earlier in Mesopotamia to the type of state that ancient Egypt formed, which was a territorial one (Trigger 2003). Trigger (2003:120) has gone even further stating that "there is no evidence of a 'civilization *without* cities'" [emphasis added]. Kemp began his tenure at Amarna with a number of early publications examining the basic structure of the site, including a plan of the city and other important attributes, such as population size and density. He noticed that the formal aspects of the city, such as the temples, palaces, and residences of the officials in the Central City formed around a main road in a linear fashion. To the south, however, residential housing followed a more organic pattern of growth that broke the linearity of the road and mimicked the natural curvature of the Nile (Figure 10). Following the early surveys and expeditions led by Kemp (1978–1983), he

estimated that the city was around 440 hectares based on the site's expanse on the east

bank of the Nile (Kemp 1977a, 1981), and based upon the number of houses surveyed

and excavated, he estimated a total population range of between 20,000 and 50,000

people.

After remapping the archaeological site of Amarna along with a better

understanding of its spatial limits (Kemp and Garfi 1993), a diverse research program

developed on-site from surveys and excavations ranging from topics covering pottery

(among other artifacts) and kilns, faunal and botanical remains, as well as fabric,

basketry, and pigments (Nicholson et al. 1997; Shaw 1998; Kemp and Vogelsang-

Eastwood 2001; Thompson 2006; Nicholson 2007; Kemp and Stevens 2010a,b;

Thompson 2010; Hill 2012; Kemp 2012:177–180, 283–296; Thompson 2012a,b). A

number of animal pens, wells, and residential houses were also formally excavated, more

recently the House of Ranefer in the Main City, but also satellite villages east of the Main

City, known as the Stone Village and Workmen's Village, that housed the workers and

tomb builders (Kemp 1987, 2005, 2006, 2007; Kemp and Stevens 2010a,b).

The Amarna South Tombs Cemetery

The city of Amarna was one of the largest settlements in the history of ancient

Egypt, both in terms of its estimated settlement size and population size, and was

equivalent in size to Memphis and Thebes during the New Kingdom (Sjoberg 1960;

Kemp 1977a,b, 1981; Uphill 1988:66; Hassan 1993; O'Connor 1993; Fletcher 1995;

Kemp 2012:161, 272). However, until the last ten years, knowledge of daily life inferred

Figure 10. Plan Map of the Archaeological Site at Tell el-Amarna (Courtesy of the Amarna Project).
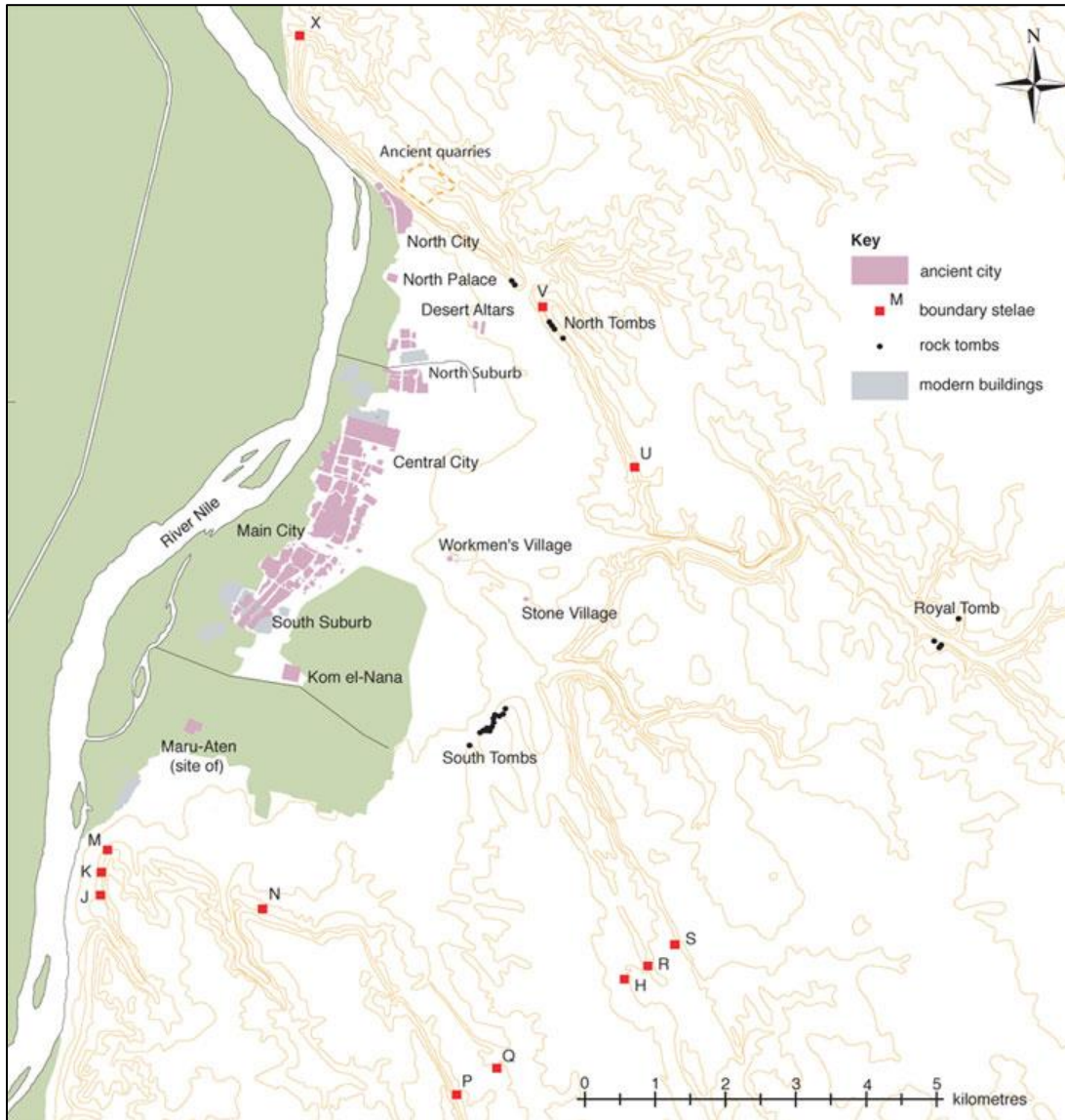
through bioarchaeological analysis was absent. The Royal Tombs and additional tombs of officials both in the northern and southern limits of the site (North and South Tombs) were documented for more than 100 hundred years (Davies 1903–1908). It was not until

the adjacent areas between the Central City and the North, South, and Royal Tombs were surveyed that three to five large cemeteries were discovered around the North and South Tombs revealing thousands of well-preserved graves belonging to the non-elite Amarna residents (Fenwick 2005). Bioarchaeological analysis began at the South Tombs in 2005 with a surface collection of the wadi to examine skeletal preservation (Rose 2006). Initial osteological investigation and archaeological survey demonstrated the presence of many complete individuals, which was followed by formal cemetery excavations. From 2006–2013, three main areas of the wadi were sampled (i.e., the lower, middle, and upper sites; see Figure 11). Subsequent osteological analysis occurred, principally through a seasonal field school sponsored by the Department of Anthropology and King Fahd Center for Middle East Studies at the University of Arkansas with teams of undergraduate and graduate students from universities worldwide under the direction of Dr. Jerome C. Rose and his colleagues.

The Amarna South Tombs Cemetery (STC) is located along the eastern desert plateau nestled between the tombs of officials carved into the cliff face (Figure 11). It is the resting place of an estimated 5,000 non-elite Amarna residents who may have had some allegiance to the officials buried in the South Tombs. Like many cemeteries in antiquity, the Amarna STC was subject to looting. Many of the graves appear to be disturbed with the intent to recover relics, leaving some of the remains disarticulated. Most graves were disturbed by grave robbing, though many individuals were associated with their grave pits. Remnants were intact, with excellent preservation including organic material such as fabric and matting, as well as human soft tissues including skin, brain matter, and keratin-rich tissues such as fingernails, toenails, and hair. Most graves are

Figure 11. Plan Map of the Amarna STC Showing the Main Areas Sampled during Excavations (i.e., wadi mouth, lower, middle, upper, and wadi end sites; courtesy of Anna Stevens and the Amarna Project).
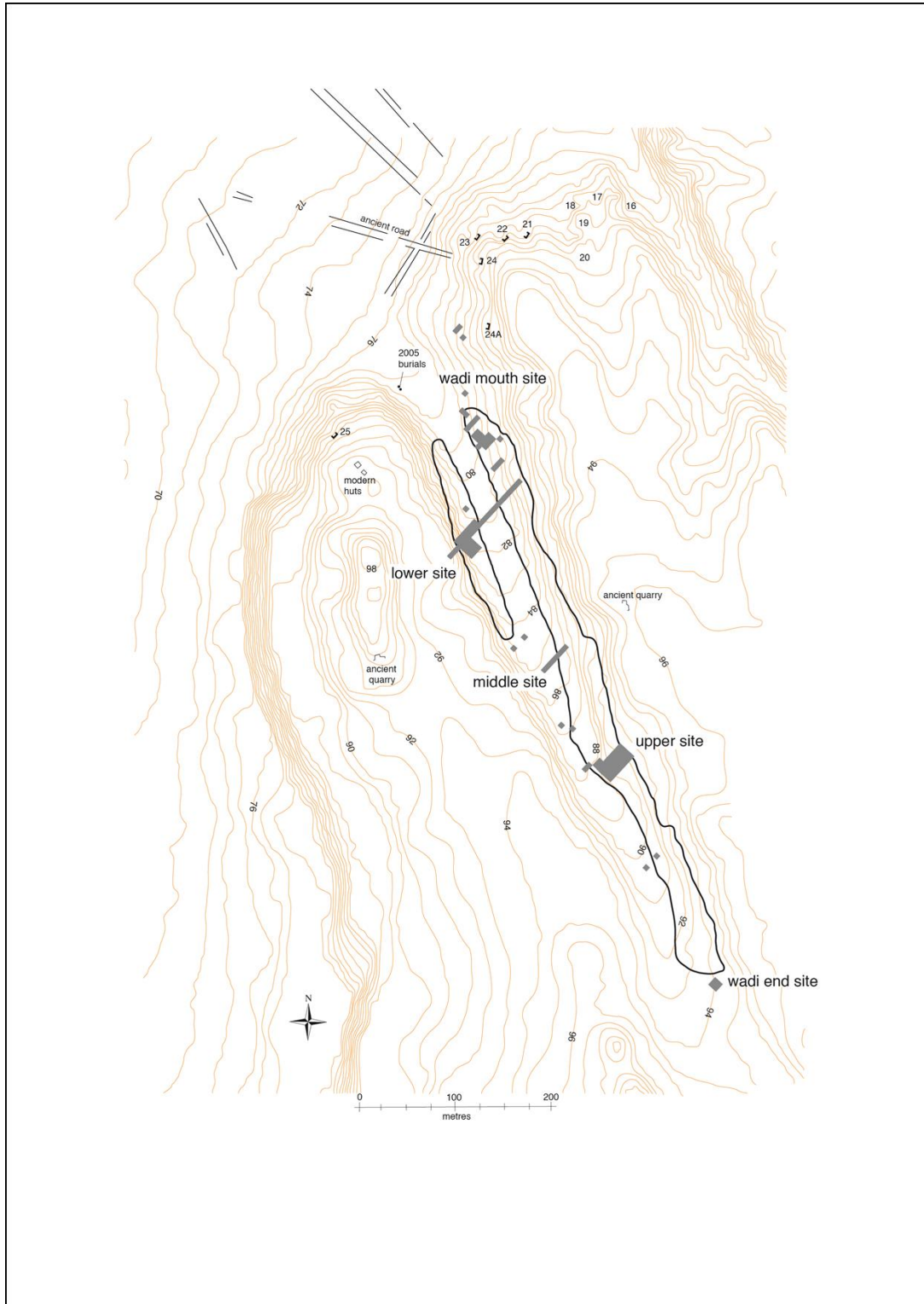
inferred to have originally contained one body, as the pits for interment were not much larger than the space required for a single corpse. However, the few multiple burials appear to consist mostly of adult females with children. There is, however, considerable variation in the treatment of the dead. Organic material such as fabric is prevalent in many graves, but it was not sufficiently preserved to determine whether it represents burial shrouds or clothing. The most consistently observed burial treatment included various types of organic matting, the most common being sticks of palm midrib (*gereed*) and tamarisk fastened together by cordage. Other forms of organic matting involved were fibers woven around vegetal material or bundled with material such as palm-leaf or *halfa* grass, but also reeds and sedges. In some cases, thicker cordage was fastened seemingly with a handle on the outside of the matting. Other forms of burial treatment consisted of mud or wooden coffins, which adorned at least 20 individuals. Some wooden coffins were left undecorated, but others were embellished with colorful tones that included motifs and legible hieroglyphics. Less frequent burial treatments included at least four carved grave markers made of stone and a tomb made of mud-brick. Personal effects included grave goods, commonly made of faience but also of precious metals. Amulets, bracelets, earrings, necklaces, rings, and pottery also were recovered (Kemp et al. 2013).

The accumulated funerary evidence suggests that a wide spectrum of social roles and statuses existed among the Amarna city residents buried in the South Tombs cemetery. These people contrasted with the officials interred in the rock-cut tombs. This begs the question: how was the Amarna STC organized? Was it structured by biological relatedness or in some other manner? Alternatively, the STC might be organized by new affiliations made within the city via occupation (e.g., craft guilds, industries), or might

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even mimic the clustering of families around officials, or neighborhoods, as seen in the residential part of the city itself (Kemp 1977a, 1989:261–317; Kemp and Stevens 2010a:473–516,b; Kemp et al. 2013). Thus, it perhaps was a further extension of the co-dependence among servants and statesmen that existed in ancient Egyptian life (Kemp 2012:44) but persisting into deathways and the afterlife. An intracemetery model is necessary to test the validity of these ideas with the Amarna STC sample, and this type of small-scale biodistance analysis is a major part of this dissertation.

Results from the extensive bioarchaeological investigations at the STC suggest that life was quite stressful environmentally and physiologically for the Amarna residents. A majority of adults were affected by degenerative joint disease (DJD) in the upper limbs (66%), but also in the lower limbs (48%), and even the spine (57%). Evidence of traumatic injury is low in both the upper (22%) and lower limbs (11%), but high rates were recorded in the trunk (56%; Kemp et al. 2013). Zabecki (2009) examined musculoskeletal stress markers (MSMs; also referred to as enthesopathies) in the STC and demonstrated that the Amarna residents show more developed muscle attachments than any other ancient Egyptian skeletal sample from multiple time periods. It is unclear if the DJD or MSM evidence is due to the natural progression of degeneration common through the aging process or from intense workloads since DJD and MSM prevalence was not seriated by age class (i.e., young adult, middle adult, and older adult). Yet, high levels of activity in the form of advanced DJD and MSM might be expected of the Amarna residents who helped built a city from the ground up over a few years. The city of Amarna was constructed mostly of mud-brick, but the temples and parts of the palaces were made with limestone building blocks or *talatat* (in modern Egyptian Arabic) blocks

– a relatively new form of construction that was introduced during the Amarna Period (Laboury 2010). Many *talatat* blocks are of standard size (52.5 × 25cm; 20.7 × 9.8in) and weighed more than 70kg or 154lbs. An appealing explanation for the high levels of DJD and MSMs in the STC sample is that it resulted from the expedited construction of a royal city, coupled with the introduction of the *talatat* block as a building material.

Another interesting aspect from the bioarchaeological analysis of the STC is the high level of nutritional stress in the sample – a seemingly sharp contrast to the murals in the nearby tombs of the royals and officials that depict bountiful harvests (Davies 1903–1908). Nearly half the individuals with preserved orbits present with cribra orbitalia (43%), which manifests in the skeleton due to episodic deficiencies of one or more essential nutrients (Walker et al. 2009). The prevalence of cribra orbitalia in contemporaneous New Kingdom skeletal samples ranges from 11%–25% (Buzon 2006). These differences across samples might suggest that the city of Amarna was not one characterized by the modern concept of post-industrial cities where greater access to resources in terms of food supply, medical care, and income exists in comparison to rural areas (Lawton and Lee 1989; Corsini and Viazzo 1997). Rather, Amarna may have been similar to industrial cities during 19th century Europe and the United States, due to factors associated with rapid population growth such as overcrowding, lack of clean water, poor sanitation, and close proximity to animals (Williamson 1981; Wohl 1984; Woods and Woodward 1984; Kearns 1988; Floud et al. 1990; Kearns 1991; Preston and Haines 1991; Neven 1997; Woods and Shelton 1997; Szreter and Mooney 1998; Vögele 1998; Hubbard 2000; Woods 2000; Haines 2001; Reher 2001; Haines et al. 2003; Komlos 1994; Steckel and Floud 1997; Komlos and Baten 1998; Komlos and Coll

1998; Baten and Murray 2000; Haines and Steckel 2000; Floud et al. 2011). During the

Amarna Period, lift irrigation technology developed (i.e., *shaduf*), bringing more

freshwater from the Nile for drinking and sowing more crops, particularly in times of

drought (Giles 1970; Kemp 2012:51). The innovation of lift irrigation likely brought

more freshwater to the city and helped support its large population with an increased

agricultural yield. However, the innovation of the *shaduf* probably caused greater

exposure to several water-related diseases (e.g., schistosomiasis, helminthiasis, lymphatic

filariasis), as well as waterborne diseases from the ingestion of or contact with water

containing bacteria or viruses contaminated by human and animal feces or urine (Prüss-

Üstün et al. 2008). Waterborne diseases from poor sanitation and inadequate personal

hygiene or contact with contaminated water also would have posed a greater health risk

in both urban contexts and after the invention of lift irrigation (Prüss-Üstün et al. 2008).

Yet another disease due to standing water that would have caused greater morbidity and

mortality for the Amarna residents is malaria, which is caused by mosquitoes bearing

Plasmodium sp. parasites (*P. falciparum*, *P. malariae*, *P. ovale*, and *P. vivax*). Recent

diagnostic criteria has been developed to infer malarial parasitic infection in human

skeletal remains, and the diagnostic lesions to suggest infection with malaria has been

identified in the Amarna STC (Smith-Guzmán 2015a,b; Smith-Guzmán et al. 2016a,b),

yet all skeletal lesions used to diagnose malaria in the skeleton remain as indicators of

non-specific infections.

Other patterns of variation of interest to bioarchaeologists is the death profile (d_x)

or age-at-death distribution of the Amarna STC. When examining the age-at-death

distribution (Table 2), the highest proportions of deaths are in the 15–24.9 age category

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Table 2. Age-at-death Data from the Amarna STC (from Kemp et al. 2013).

Age Class	N	%
[0–2]	63	17.6
[3–6]	33	9.2
[7–14]	61	17.1
[15–24]	69	19.3
[25–35]	59	16.5
[36–50]	64	17.9
51+	8	2.2
Total	357	100.0

(19.3%), followed by individuals aged 7–14.9 years (17.1%; see Kemp et al. 2013). The observation of such high proportions of individuals in late childhood and adolescence might suggest high mortality during these years of life at Amarna. Dabbs et al. (2015) argue that this age-at-death pattern, along with the distribution of the 25–35 year age class (16.5%), presents as a catastrophic mortuary assemblage comparable to the demography of documented epidemic diseases during medieval times and in the early 20th century (Margerison and Knüsel 2002; Signoli et al. 2002). On the other hand, paleodemographic modeling has consistently demonstrated that fertility rate has a greater effect on mean age-at-death than mortality rates (Sattenspiel and Harpending 1983; McCaa 2002). The paleodemographic model in this study will provide results relevant as to whether the individuals excavated from the STC experienced a period of mortality crisis.

Summary

This chapter underscores the historical and archaeological richness of the Amarna archaeological site and appends a cross-cultural perspective of the concept of the disembedded capital and associated biocultural dynamics. Chapter 4 sought to display the previous and recurring intensity of bioarchaeological inquiry at the Amarna South cemetery, conducted by Jerry Rose at the University of Arkansas and his academic advisees. As the historical and archaeological background of the archaeological site of Amarna is concluded and the problem orientation of the research questions delineated in Chapter 1 bolstered by the theorization of the disembedded capital, biocultural dynamics, and expectations for analysis, Chapter 5 shifts to the methods as well as comparative materials employed in this dissertation to answer those research questions.

Chapter 5:

MATERIALS AND METHODS

This chapter details the specific biodistance and paleodemographic analytical procedures, replete with mathematical derivations, that are utilized to address the previously defined research questions. Each research question is segmented into models. The first model, Model 1, is designed as a large-scale biodistance analysis using the sample from the Amarna STC and comparative New Kingdom samples with tight temporal continuity to investigate if the Amarna STC shares biological affinity with another contemporaneous site inferring the geographic origin of its migrants. Model 2 engages a small-scale biodistance analysis asking if the South Tombs cemetery is organized via biological relatedness. The third and final model, Model 3, is a sophisticated paleodemographic analysis used to ascertain if the city of Amarna was peopled via an accretional process or a transplanted community. The following text contains several mathematical formulae transcribed from previous studies. All errors in transcription and derivation are my own.

Model 1: Large-scale Biodistance

Buccolingual and mesiodistal dental cervical measurements were recorded for the mandibular and maxillary arcades of individuals excavated from available Egyptian and Nubian sites to investigate New Kingdom population structure. Samples included the

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Table 3. Contextual Data for New Kingdom Skeletal Samples for Use in Large-scale Biodistance Analysis.

Sample	N	Location	Dynasty	Dates	Curated	Source(s)
Tombos	18	UN	18th	1539–1292 BCE	Purdue University	Buzon 2004, 2006
Qurneh/Thebes	66	UE	19th–22nd	1295–1186 BCE	Duckworth, Cambridge	Irish 2006; Schillaci et al. 2009
Memphis/Sakkara	27	LE	18th	1539–1292 BCE	Duckworth, Cambridge	Buzon 2006
Amarna STC	103	ME	18th	1350–1330 BCE	El-Till/El-Hagg Qandil, Egypt (on site)	Kemp et al. 2013

KEY: LE = Lower Egypt; ME = Middle Egypt; UE = Upper Egypt; UN = Upper Nubia

Table 4. New Kingdom Skeletal Samples Sorted by Biological Sex for Use in Large-scale Biodistance Analysis.

Sample	N	Males / Females / Indeterminate
Memphis/Sakkara	27	20 / 7 / 0
Qurneh/Thebes	66	40 / 25 / 1
Amarna STC	103	36 / 47 / 20
Tombos	18	8 / 9 / 1

Figure 12. Map of Present-day Countries of Egypt and the Sudan with Locations of Ancient Egyptian and Nubian Sites Sampled (modified from Schrader et al. 2014:269).
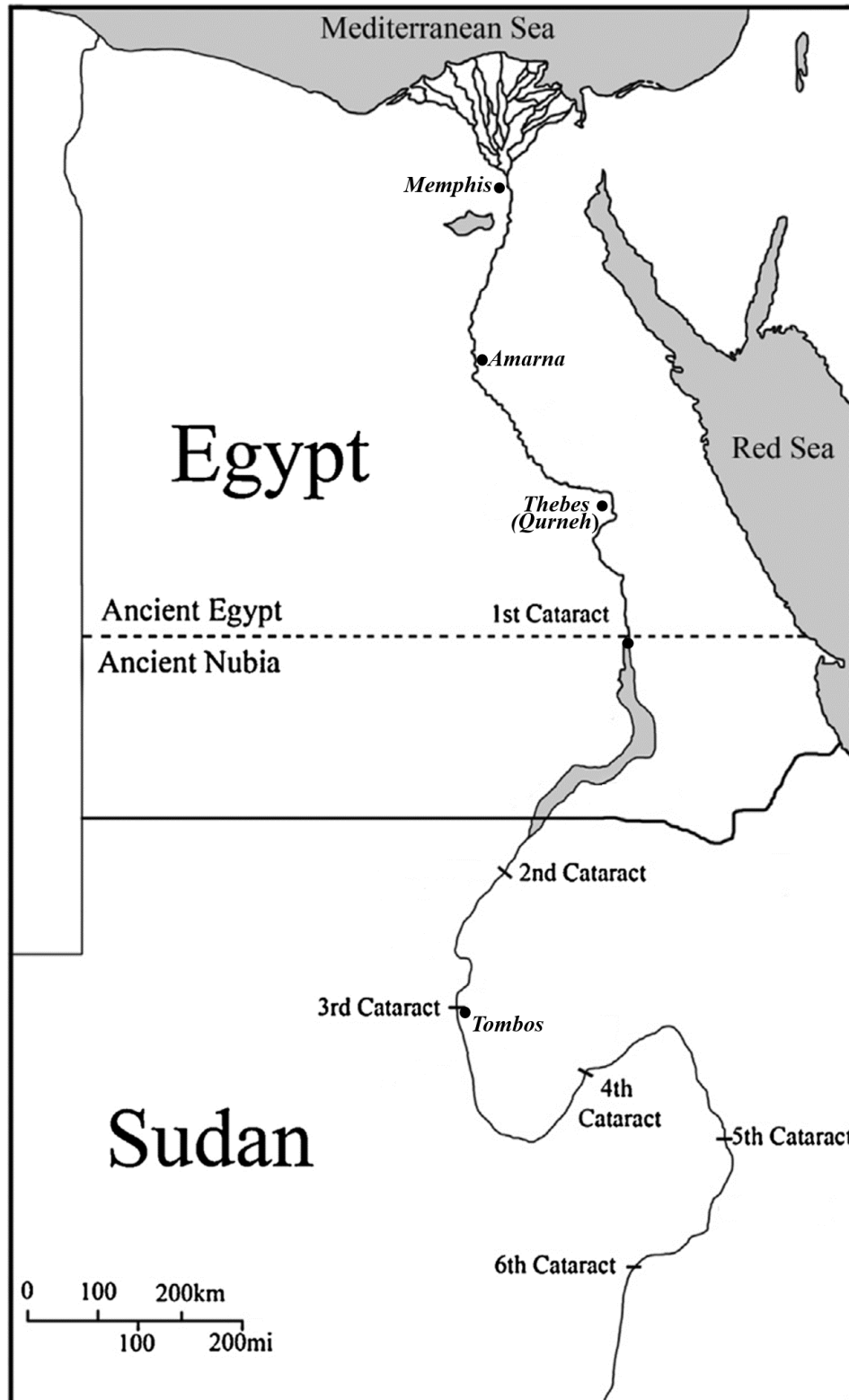
Amarna STC, Memphis/Sakkara (from this point forward referred to as Memphis) and

Qurneh/Thebes (from this point forward referred to as Thebes), both curated at the

Duckworth Laboratory within the Leverhulme Center for Human Evolutionary Studies

(LCHES) at the University of Cambridge in the United Kingdom, as well as Tombos

from Upper Nubia housed at Purdue University in West Lafayette, Indiana (see Tables 3

and 4; Figure 12). Each measurement was recorded to the nearest 0.01 mm using Hillson-

FitzGerald calipers (Hillson et al. 2005). One tooth per mandibular and maxillary tooth

class (i.e., incisors, canines, premolars, and molars) was selected for further analysis to

reduce the effect of intertrait correlation within tooth classes and avoid phenotypic (and

thereby, genetic) redundancy (Stähle 1959; Filipsson and Goldson 1963; Garn et al.

1965a,b; Moorrees and Reed 1964). When left and right tooth sides were present, the

arithmetic mean of both sides was employed. The influence of fluctuating asymmetry and

environmental variance is reduced by using one tooth class per mandibular and maxillary

arcade and the mean of both tooth sides (Bateson 1894; Butler 1939; Dahlberg 1945).

Dental cervical measurements were also examined prior to analysis for age and sex trends

using one-way ANOVAs and Tukey's HSD post hoc tests.

The most representative tooth with smallest percentage of missing values in each

mandibular and maxillary tooth class was selected, including an equal number of

buccolingual and mesiodistal measurements. This was conducted to ensure the largest

population sample sizes and to maximize variance by evaluating missing values per tooth

measurement per individual. A total of 16 measurements, with eight buccolingual (BL)

and mesiodistal (MD) measurements each, were selected for large-scale biodistance

analysis: LI2-BL, LI2-MD, LC-BL, LC-MD, LP2-BL, LP2-MD, LM2-BL, LM2-MD,

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UI2-BL, UI2-MD, UC-BL, UC-MD, UP2-BL, UP2-MD, UM2-BL, and UM2-MD (L = lower or mandibular; U = upper or maxillary; I = incisor; C = canine; P = premolar; M = molar; BL = buccolingual; MD = mesiodistal). Individuals with missing values were imputed using the Expectation-Maximization (or EM) algorithm (Dempster et al. 1977). In total, the overall matrix contained 11.5% of imputed data, with the Tombos matrix having the greatest percentage of imputation at 23.6%, followed by Memphis (17.4%), Thebes (12.4%), and then Amarna, with the lowest percentage of imputed values at 7.3%. Both the total imputed matrix of all samples and individual samples are less than the threshold of 25% data imputation limit set by previous studies (e.g., Stojanowski 2003b). A Q-mode transformation was conducted on the cervical tooth dimensions by first calculating the geometric mean of all 16 measurements and then solving for each individual variable divided by the geometric mean. Q-mode transformation allows for the conversion of a shape variable without dimension and it effectively eliminates size due to human isometry. A principal component analysis (PCA) was performed on the 16 Q-mode transformed dental cervical measurements to control for correlation. The PCA loadings whose eigenvalues were ≥ 1, a total of seven, were selected for statistical analysis. Pre-analysis data treatments were conducted in Microsoft Excel, *R* (R Core Team 2018), and SYSTAT (2009) for Windows. The seven PCA loading scores and additional string data was converted to ASCII format for use with RMET 5.0 (Relethford and Blangero 1990; Relethford et al. 1997).

The RMET (R matrix for METric traits) 5.0 program executes many analyses, including **R** matrix for metric or quantitative traits, fixation indices (or F_{ST}), Relethford-Blangero analysis (based on the Harpending and Ward [1982] model), and generalized

Mahalanobis D^2 distances. Relethford and Blangero (1990) used an extension of the Harpending-Ward model that postulates that the expected heterozygosity of a population i [$E(H_i)$] can be calculated by examining the total heterozygosity of a region (H_t) with the distance between population i and a regional centroid represented as r_{ii}. An equation that examines the expected linear regression line of heterozygosity and the distance from the regional centroid can be expressed as:

$$E(H_i) = H_t(1 - r_{ii}).$$

Relethford and Blangero (1990) created derivatives of both univariate and multivariate extensions for quantitative traits where the Harpending-Ward model is conveyed as an **R** matrix. Where Δ is the matrix of deviations from the population centroid formulated as:

$$\Delta = (I - \mathbf{1}W')X,$$

with I as a $g \times g$ identity matrix, $\mathbf{1}$ as a vector of g ones, **W** as the relative census size (in vector form), and X as a $g \times m$ matrix encompassing the means of the subdivisions. These deviations are now defined as a C matrix with

$$C = \Delta G_w^{-1}\Delta'.$$

G_w^{-1} is defined as the inverse of the pooled within-subdivision additive genetic covariance matrix. The **R** matrix is expressed now as a function of C with

$$R = C(1 - r_0)/2m.$$

Therefore, the genetic distance from the ith subdivision is estimated by

$$r_{ii} = c_{ii}/(2m + \sum w_i c_{ii})$$

with the average genetic distance expressed as

$$r_0 = (\sum w_i c_{ii}/(2m + \sum w_i c_{ii}).$$

The **R** matrix examines the observed phenotypic variance in subdivisions (e.g., subdivision i $[\sigma_{P_i}^2]$) using the sample variance with

$$r_{ij} = c_{ij}(1 - r_0)/2h^2 \sigma_{P_w}^2.$$

Populations with positive r_{ij} values are more closely related than average relationships (Relethford et al. 1997). The expected $[E(H_i)]$ and observed heterozygosity (H_i) is also compared. The pattern of greater than expected within-group phenotypic variance $[H_i > E(H_i)]$ equates to greater than average external gene flow and the converse suggests less than average external gene flow $[E(H_i) < H_i]$. The weighted average diagonal of the **R** matrix (e.g., r_{ii}) provides a more contemporary method to estimate the fixation index or F_{ST} from metric data. It is expressed as

$$F_{ST} = \sum_{i=1}^{g} w_i r_{ii}$$

where g is number of population samples and w_i is the estimated population size or sample size.

There are many distance measures available in the "family of distances" (Burghouts et al. 2007). The Mahalanobis D^2 distance is prominent in biological anthropology in general, but also in bioarchaeology and forensic anthropology due in part to its computation factoring for variation in the form of the covariance matrix (see for example Jantz and Owsley 2001; Cunningham and Jantz 2003; D'Amore et al. 2009). Otherwise, without the variation of the covariance matrix, the Mahalanobis D^2 distance is roughly Euclidean with

$$D^2 = \left(X - \bar{X}_j\right)' \Sigma^{-1} (X - \bar{X}_j)$$

where X is the vector of measurements from transformed dental measurements, Xj is the mean vector for population j, and Σ is the pooled within-sample covariance matrix. The RMET 5.0 program also computes Mahalanobis D^2 distances.

Model 2: Small-scale Biodistance

Buccolingual and mesiodistal dental cervical measurements that were collected

for the mandibular and maxillary arcades of individuals excavated from the Amarna STC

also were used to conduct an intra-cemetery analysis to investigate if biological

relatedness structured the Amarna STC (see Table 5). Methodologies for measurement

recordation and pre-analysis data treatments are identical to the large-scale biodistance

analysis (Model 1). A total of 15 measurements were used in this analysis: LI2-BL, LC-

BL, LC-MD, LP2-BL, LP2-MD, LM1-BL, LM1-MD, UI2-BL, UI2-MD, UC-BL, UC-

MD, UP2-BL, UP2-MD, UM2-BL, and UM2-MD (L = lower or mandibular; U = upper

or maxillary; I = incisor; C = canine; P = premolar; M = molar; BL = buccolingual; MD =

mesiodistal). Less than 6% of the data matrix was imputed for 95 individuals from an

original sample size of 60. Inter-individual Mahalanobis D^2 distances (Defrise-

Gussenhoven 1967) were calculated from the first six PCA loadings whose eigenvalues

were $\geq$ 1. All statistical analyses were conducted using R (R Core Team 2018) and

SYSTAT (2009).

Mahalanobis D^2 between pairs of individuals i and j are obtained in the same way

as previously derived, where:

$$D_{ij}^2 = \left(X_i - X_j\right)'\Sigma^{-1}(X_i - X_j)$$

and X_i and X_j are characterized by their respective measurement vectors with p normally

distributed characters, $X_i = (i_1\dots i_p)$ and $X_j = (j_1\dots j_p)$ (Jantz and Owsley 2001;

Cunningham and Jantz 2003; D'Amore et al. 2009). Defrise (1955) demonstrated that

generalized distances have properties in common with the classical quantities of

Table 5. Adults and Subadults from the Amarna STC Sample Organized by Biological Sex and Cemetery Site (i.e., lower, middle, etc.; see Figure 11).

	Total		Males		Females		Subadults	
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*
Amarna STC	95	100	34	35	41	42	22	23
Wadi Mouth	18	19	5	28	7	39	6	33
Lower	23	24	13	54	6	25	5	21
Middle	12	13	3	23	7	54	3	23
Upper	41	44	13	31	21	50	8	19

Mahalanobis. And Defrise (1968) also showed that for a given X_i and X_j that D_{ij}^2 is distributed as a non-central χ^2 with p degrees of freedom (number of variables). The program R computes Mahalanobis distances (in matrix form) among individuals (as vectors) using the function mahalanobis.dist available in the R package {StatMatch} version 1.2.4 (D'Orazio 2015, 2016). Intrasite D^2 distances in the Amarna STC are compared with the Euclidean grave shaft distances using Mantel tests (Mantel 1967).

In order to investigate whether biological relatedness structured the Amarna STC, spatial analysis must demonstrate that there is a correlation of geographic distance with biological distance. A positive spatial correlation with geographic distances and phenotypic distances suggests that the Amarna STC was organized along lines of biological affinity. An effective way to explore spatial autocorrelation with these types of data is a Mantel test (Mantel 1967) which uses matrices of geographic distances (i.e., Euclidean) between grave shafts (**A**) and inter-individual Mahalanobis D^2 distances (**B**), evaluating the degree to which these two data sets (or matrices **A** and **B**) are correlated (Mantel 1967).

In a symmetrical matrix with n cells (i.e., the distance from item i to item j is

equivalent to the distance from item j to item i) the matrix represents

$$\frac{n(n-1)}{2}$$

distances. Symmetrical matrices are square and equal to its transpose, so only diagonals

of the matrices are tested. A Z statistic is computed to show the values of two matrices

and their distance measurements between value pairs as

$$Z = \sum_{i=1}^{n} \sum_{j=1}^{n} A_{ij} B_{ij}$$

where the **A** matrix represents Euclidean grave shaft distances and the **B** matrix as inter-

individual Mahalanobis D^2 distances. An r statistic is then computed incorporating a

normalization procedure whereby the mean of each matrix is subtracted from each object

and then each object is divided by the standard deviation so that

$$r = \frac{\sum \sum stdA_{ij}\, stdB_{ij}}{n-1}.$$

Mantel's (1967) original procedure included an asymptotic test, but many modern

programs use permutations of dissimilarity matrices by randomly rearranging N rows and

columns to calculate a distribution for the test statistic that is generated through the

various iterations of this process. Mantel tests (Mantel 1967) were performed on the

Amarna STC globally for all males, females, and subadults (10–14 and 15–19 years of

age-at-death) together, as well as individually and within sampled sections of the site

(i.e., wadi mouth, lower, middle, and upper sites). The *R* package {vegan} contains a

function which generates the *r* statistic and the default number of permutations was set at

1,000 (Legendre and Legendre 2012). With small sample sizes, and therefore small

matrices, the number of dissimilarity matrices and permutations can be greatly restricted,

thus causing difficulty when attempting to detect significant spatial patterning. A

significant result ($p < 0.05$) suggests spatial autocorrelation.

Model 3: Paleodemography

To ascertain whether the ancient city of Amarna was populated via gradual

accretion or community transplantation, the method developed by Bonneuil (2005) was

utilized. Since the Amarna STC was only active for 15–20 years, the method designed by

Bonneuil (2005) is an excellent way to assess the population dynamics surrounding the

peopling of the city of Amarna because it relaxes the stable population assumption by

implementing an approach employing varying mortality and fertility schedules, which is

similar to a Monte Carlo iteration but popularly known as simulated annealing

optimization (Kirkpatrick et al. 1983; Press et al. 1992). The distribution of deaths from

the Amarna STC can be envisioned as a target in expansive *n* dimensional space. The

route nearest to population stability that manifests the target over the depositional period

is computed.

Only individuals with dental ages from 5–19 years were included in the paleodemographic model as three age classes: 5–9 ($N = 30$), 10–14 ($N = 21$), and 15–19 ($N = 19$). Ages 0–4 were omitted since this age range is under-represented in ancient cemeteries (Moore et al. 1975; Buikstra et al. 1986). Individuals aged ≥ 20 were also omitted because they bear greater standard deviations in terms of age range confidence intervals (e.g., 15-year age ranges: 21–34 and 35–49 years) leading to issues for use in mathematical modeling. The raw data for all aged skeletons from the Amarna STC was previously presented in Table 2. Aging from dental development was conducted using the reference sample of Al Qahtani et al. (2010). The model ultimately reduces the samples sizes for the 5–9, 10–14, and 15–19 age classes by only including individuals aged from dental development and avoiding skeletons that were aged using long bone lengths and/or epiphyseal union. Subadult sample reduction was conducted in this manner to reduce error in aging since dental development is demonstrated to be more resistant to environmental effects than skeletal growth (Garn et al. 1959; Lewis and Garn 1960; Widdowson and McCance 1960; Garn et al. 1965a,b; Niswander and Sujaku 1965; Eveleth and Tanner 1976; Murchison et al. 1988; Smith 1991; Bowman et al. 1992; Saunders et al. 2000; Cardoso 2007; Šešelj 2013). Reducing the subadult sample size for the inclusive age classes to only those with dental ages is still representative of the larger sample that includes individuals aged using dental development, long bone lengths, and epiphyseal union ($\chi^2 = 0.73$; $df = 2$; $p = 0.69$).

As mentioned previously, this variation of simulated annealing optimization for application to paleodemography was designed by Bonneuil (2005). All methods and equations contained herein are attributed to his publication. Any errors in formulaic

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expression are my own. The first procedure is to set up the system of equations for the minimal route to stable population parameters for the Amarna STC. This requires a fit to the distribution of deaths by age $\left(D_{[x,x+h]}\right)_{x\in\{x_1,\ldots,x_n\}}$ cumulated over the period of deposition ($T = 15/16$), as closely as possible, using the principals of mathematical demography and population dynamics. $D_{[x,x+h]}$ is the distribution of deaths between age x and $x + h$, and $\{x_1, \ldots, x_n\}$ represents the series of age classes. The estimated median total number of people $p(t, x)$ for the city of Amarna is equal to 35,000 (Kemp 1977a, 1981, 2012:161, 272), and the force of mortality at time t and age x is $\mu(t, x)$ so that the fit can be fulfilled by

$$D_{[x,x+h]} = \int_T^0 \int_h^0 \mu(t + u, x + u)p(t + u, x + u)dudt.$$

With M'Kendrick's (1925) partial differential equation of population dynamics and Lotka's (1907) renewal equation with a scheduled time and age dependent birth rate, we can arrive at the initial age distribution:

$$\frac{\partial p(t,x)}{\partial t} + \frac{\partial p(t,x)}{\partial x} = -\mu(t,x)p(t,x),$$

$$p(t,0) = \int_\infty^0 p(t,x)f(t,x)dx,$$

$$p(0,x) = p_0(x).$$

The fit to the distribution of deaths $D_{[x,x+h]}$ now becomes a target to locate the minimal distance to a stable population where mortality, fertility, and the population growth rate are constant over time. Estimating life expectancy e from a life table $l(.)$ in human skeletal remains requires the population growth rate ρ. The simplified equation to solve the problem of a distribution of deaths by age for a stable population after removal of the constant terms is

$$\frac{D_{[x,x+h]}}{D_{[x+h,x+2h]}} = e^{\rho h}\frac{{}_hq_x}{{}_hq_x(1-\,{}_hq_x)} = e_{\text{stable}}$$

where ${}_hq_x$ is the probability of dying between ages x and $x + h$.

The minimal distance to the target and to a stable population path requires permissible values of life expectancy at birth $e(t) \in (e_{\min},e_{\max})$, fertility $f(t) \in (f_{\min},f_{\max})$, $t = 0, \ldots, T-1$, and the initial age distribution $p_0(x)$, $x = 0, \ldots, \omega$ to be parameterized by variables including population growth, population size, and life expectancy at birth of a stable age distribution with age-specific fertility rates for non-industrial populations (Weiss 1973:32–35). To find this optimal path, a large system of equations must be minimized or assigned as a series of weights $(w_1,\ldots,w_n)$.

The first weight (w_1) is to fit the distribution of deaths by age with the percentage of deaths by age in reference to the target:

$$\frac{1}{n}\sum_{x\in\{x_1,\ldots,x_n\}}\left(\frac{D_{[x,x+h]} - \widehat{D}_{[x,x+h]}}{\widehat{D}_{[x+h,x+2h]}}\right)^2 .$$

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The second weight (w_2) requires fitting the distribution of deaths by age to the total number of deaths:

$$\left(\frac{\sum_{x \in \{x_1,\dots,x_n\}} \left(D_{[x,x+h]} - \widehat{D}_{[x,x+h]} \right)}{\sum_{x \in \{x_1,\dots,x_n\}} \widehat{D}_{[x,x+h]}} \right)^2 .$$

With regard to the stable path, we locate the $e(t)$ around the possible e_{stable}, which is the best fit to the distribution of deaths cumulated over the deposition period by a stable population (w_3):

$$\frac{1}{T} \sum_{0}^{T-1} (e(t) - e_{\text{stable}})^2 .$$

The path to stability is characterized by constancy in mortality and fertility, and thus, the stable path would have the fewest relative variations in respect to life expectancy at birth and fertility (w_4):

$$\frac{1}{T-1} \sum_{1}^{T-1} \left(\frac{e(t) - e(t-1)}{e(t-1)} \right)^2 + \left(\frac{f(t) - f(t-1)}{f(t-1)} \right)^2 .$$

A stable population also requires a constant growth rate. Accordingly, the stable path is defined by the minimal standard deviation in population growth (σ_ρ), and this term is included as the fifth weight (w_5). Also, the initial age structure $C(t,x)$ should conform to the demographic forces of mortality and fertility over the period of deposition as closely

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as possible or to the stable age structure $\bar{C}(x)$ associated with mean fertility and mortality over the period of deposition; consequently, this necessitates a sixth weight (w_6):

$$\frac{1}{(\omega+1)T}\sum_{t=0}^{T-1}\sum_{x=0}^{\omega}\left(C(t,x)-\bar{C}(x)\right)^2.$$

The whole program then consists of:

$$\min_{(e(t),f(t)),t=0,\ldots,T-1,\rho(0),P(0),e_0}$$

$$\frac{w_1}{n}\sum_{x\in\{x_1,\ldots,x_n\}}\left(\frac{D_{[x,x+h]}-\widehat{D}_{[x,x+h]}}{\widehat{D}_{[x+h,x+2h]}}\right)^2$$

$$+w_2\left(\frac{\sum_{x\in\{x_1,\ldots,x_n\}}\left(D_{[x,x+h]}-\widehat{D}_{[x,x+h]}\right)}{\sum_{x\in\{x_1,\ldots,x_n\}}\widehat{D}_{[x,x+h]}}\right)^2$$

$$+\frac{w_3}{T}\sum_{0}^{T-1}(e(t)-e_{\text{stable}})^2$$

$$+\frac{w_4}{T-1}\sum_{1}^{T-1}\left(\frac{e(t)-e(t-1)}{e(t-1)}\right)^2+\left(\frac{f(t)-f(t-1)}{f(t-1)}\right)^2$$

$$+w_5\left(|\bar{\rho}(t)|+\sigma_\rho\right)$$

$$+\frac{w_6}{(\omega+1)(T+1)}\sum_{t=0}^{T}\sum_{x=0}^{\omega}\left(C(t,x)-\bar{C}(x)\right)^2,$$

under constraints

$$\sum_{0}^{T-1} {}_h q_x(t) p(t,x) = \widehat{D}_{[x,x+h]}$$

$$p(t+1, x+1) = p(t,x)(1 - {}_h q_x(t)), t = 0, \dots, T-1$$

$$p(t,0) = \sum_{x=0}^{\omega} p(t,x) f(t,x), t = 0, \dots, T$$

$$p(0,x) = p_0(x), x = 0, \dots, \omega.$$

Initial weights and minimization dimensions and parameters were tuned by

Bonneuil via trial and error to implement the method and obtain the best model fit. The

simulated annealing algorithm and confidence intervals are also provided by Bonneil

(2005:37–38) and are available in a *C* program. The controls are the initial population

size, the initial age structure, the time series of the parameters yielding the model life

tables, and the time series of the fertility index (the age structure of fertility being the

standard pattern of the Hutterites, one of the only datasets with this type of information

available [Coale 1969]).

As the depositional period for Amarna is roughly 16 years, it was divided into

three quinquennial periods (by multiplying the target by 15/16). This generates nine

control variables with three fertility indices, three model life tables, initial population

size, and the two parameters that typify the initial age structure that approximates a stable

population pattern. Using the central limits theorem, a distribution of confidence intervals

of the distribution of deaths by age is estimated. An optimal demographic path closest to

stable population parameters for each arrangement of boundary parameters of the

distribution is generated along with confidence intervals for each quinquennial period ($t =$ 5, $t = 10$, and $t = 15$). The output generally simulates the living population.

Summary

Chapter 5 detailed and described the methodological composition of each analysis and its application to address the three stated research questions. The following chapter, Chapter 6, presents each mathematical model.

Chapter 6:

RESULTS

As the previous chapter on materials and methods featured the bases of the analytical techniques used in this dissertation including comparative samples and cross-cultural comparisons, this chapter communicates the outcomes of each computation and preludes the discussion and interpretation of these results.

Model 1: Large-scale Biodistance

The results of the large-scale biodistance model using **R** matrix are presented here. The RMET 5.0 program generates both biased and unbiased values. Only the unbiased values are reported here. The complete **R** matrix and D^2 values between and within New Kingdom sites are presented in Tables 6 and 7. The diagonals of the **R** matrix are used to calculate a value for the fixation index or F_{ST}. In this case, the unbiased $F_{ST} =$ 0.01736 with a standard error of 0.00933. The value associated with F_{ST} is close to or nearly 0 suggesting a relatively panmictic Nile Valley region, at least according to the samples tested, demonstrating little to no mating restrictions or genetic isolation between population samples. Both the **R** matrix and D^2 distances suggest similar patterns of biological affinity between groups. Memphis and Thebes appear to have the closest population affinity to each other and Amarna shows the closest biological affinity to Memphis. Tombos has the most distant biological affinity between groups. None of these

Table 6. Values Generated from **R** Matrix Analysis.

Sample	Memphis	Thebes	Amarna	Tombos
Memphis	0.00838	–	–	–
Thebes	0.00819	0.01100	–	–
Amarna	0.00313	-0.00349	0.00592	–
Tombos	-0.03822	-0.02327	-0.01042	0.04414

Table 7. Matrix of Mahalanobis D^2 Distances between Sites.

Sample	Memphis	Thebes	Amarna	Tombos
Memphis	0.00000	–	–	–
Thebes	0.00301	0.00000	–	–
Amarna	0.00803	0.02389	0.00000	–
Tombos	0.12896	0.10168	0.07089	0.00000

Figure 13. Plot of the First Two Eigenvalues from a PCA of the **R** Matrix.

```
:--------------------------------------:
:                                      :
:                                      :
:                                      :
:                                      :
:                               B      :
:                                      :
:                                      :
:                                      :
:D                                     :
:                          +         A :
:                                      :
:                                      :
:                          C           :
:                                      :
:                                      :
:                                      :
:                                      :
:                                      :
:                                      :
:                                      :
:                                      :
:--------------------------------------:
```
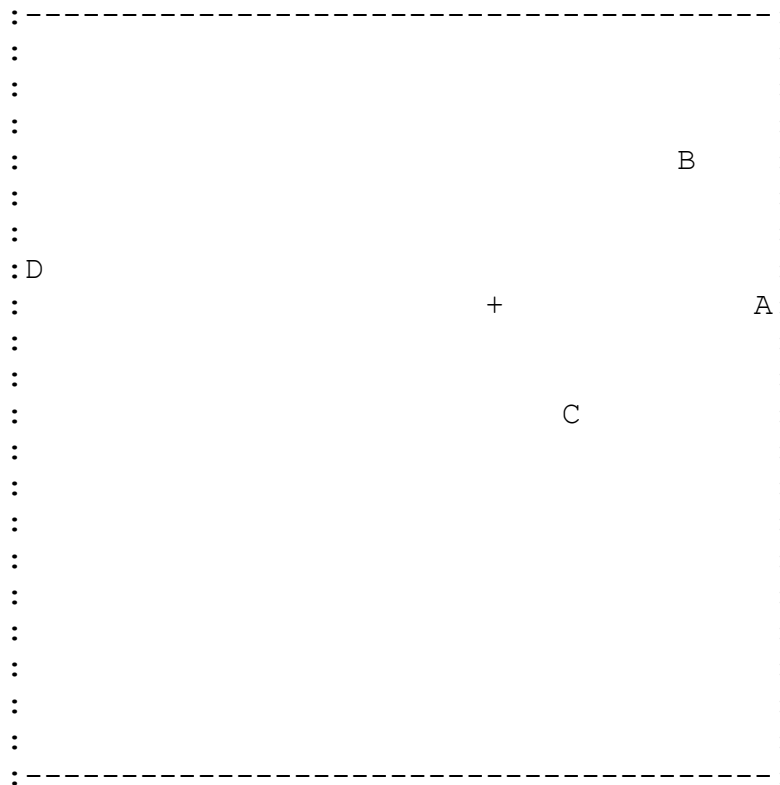
Key: + = Centroid; A = Memphis; B = Thebes; C = Amarna; D = Tombos

pairwise distances are significantly different from each other. A PCA of the **R** matrix

shows two eigenvalues accounting for 100.0% of the variation among samples, the first

eigenvalue accounting for 88.2% of the variation, and the second eigenvalue accounting

for 11.8% of the variation (see Figure 13). Amarna is noticeably the closest to the

centroid (r_{ii}), followed by Memphis, Thebes, and then Tombos. All three ancient

Egyptian sites (Amarna, Memphis, and Thebes) cluster to the exclusion of Tombos in

Nubia.

The results of the Relethford-Blangero analysis are presented in Table 8. For all

sites except Amarna, the observed mean within-group variance ($\bar{v}_i$) is greater than the

expected [$E(\bar{v}_i)$], suggesting greater than average external gene flow to Memphis,

Thebes, and Tombos. Amarna is the only site sampled where the observed mean within-

group variance ($\bar{v}_i$) is less than the expected [$E(\bar{v}_i)$], demonstrating less than average

external gene flow. A similar pattern is observed for the residuals ($\bar{v}_i - E[\bar{v}_i]$). Amarna

has negative residuals indicating strong endogamy, while Memphis, Thebes, and Tombos

have positive residuals showing slight exogamy. A simple z-score calculation ($z = \frac{x-\mu}{\sigma}$)

among sites indicates that this low level of observed mean within-group variance ($\bar{v}_i$) and

Table 8. Results of the Relethford-Blangero Analysis.

Sample	r_{ii}	$\bar{v}_i$	$E(\bar{v}_i)$	Residual
Memphis	0.008383	1.200	1.087	0.113
Thebes	0.010997	1.109	1.085	0.024
Amarna	0.005918	0.790*	1.090	-0.300*
Tombos	0.044138	1.212	1.048	0.164

Residual $= \bar{v}_i - E(\bar{v}_i)$
$\bar{v}_w = 1.078$
* $P < 0.0001$

negative residuals within the Amarna STC sample compared to the other New Kingdom sites sampled is a highly statistically significant pattern ($p < 0.0001$).

Model 2: Small-scale Biodistance

Overall, the results of this model suggest robust patterns in the structure of the Amarna STC. Correlograms of both spatial and biological distances are presented in Figures 14 and 15. Areas in red are known as "hot spots" with greater distances between objects and areas in blue represent "cold spots" or lesser distances between objects. If the Amarna STC conformed to the expectation that geographic distance was fully autocorrelated with biological distance, both correlograms would appear identical. The correlogram of Euclidean distances demonstrate clear division between parts of the cemetery sampled, with the exception of the wadi mouth and lower sites, though divisions between both the wadi mouth and lower sites with the middle and upper sites are readily apparent when examining cold spots (see Figure 14). The correlogram of biological distances (Figure 15) demonstrates very few hot spots, and many cold spots, which do not visibly conform to the variation in the correlogram of spatial distances while demonstrating that the Amarna STC sample is relatively homogenous in terms of biological affinity deduced from dental cervical measurements.

The computations of 20 Mantel tests (Mantel 1967), both globally throughout the entire cemetery sample as a whole, and by age and sex as well as within each sampled section of the cemetery (i.e., wadi mouth, lower, middle, and upper), are presented in Table 9. Most statistical tests (14 out of 20 or 70%) were able to fulfill the standard 999

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Figure 14. Correlogram of Euclidean Distances between Grave Shafts (**A** Matrix).
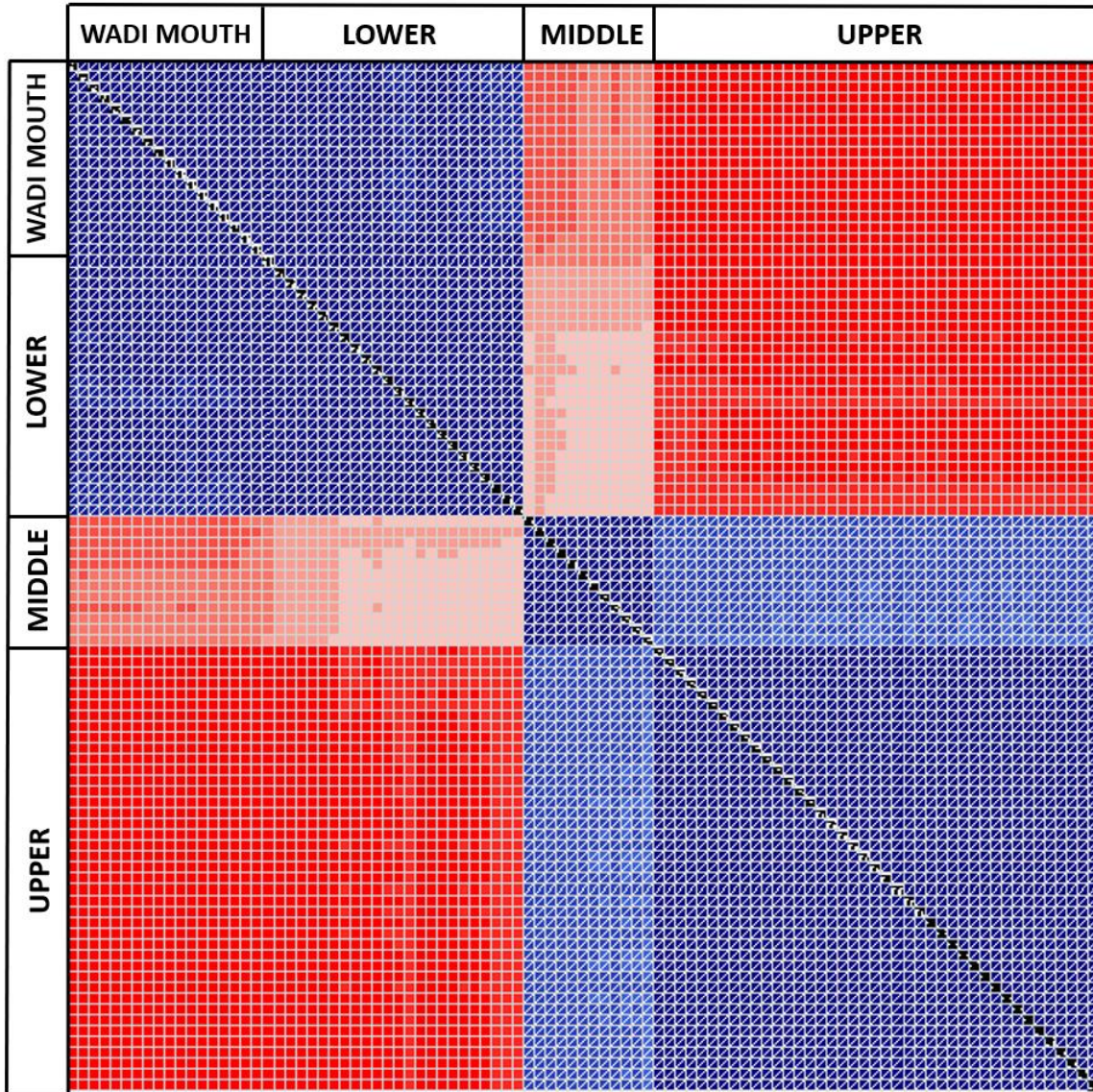
Figure 15. Correlogram of Inter-individual Mahalanobis D^2 Distances (**B** Matrix).
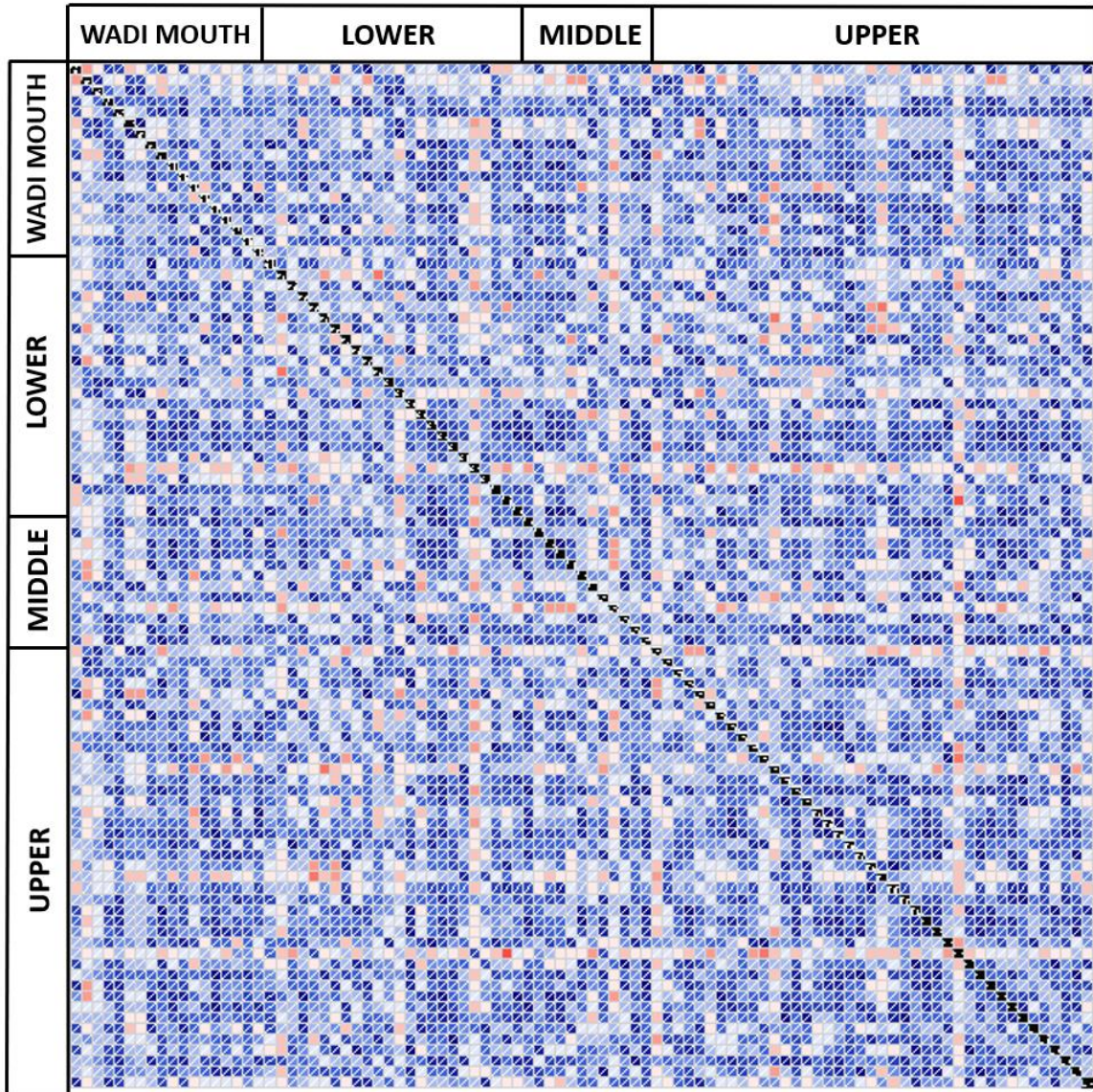
Table 9. Spatial Autocorrelation with Biological Distance in the Amarna STC.

All	N	Mantel R	*P*-value	Permutations
Total Site	95	0.005	0.418	999
Wadi Mouth	18	0.268	0.041*	999
Lower	23	0.190	0.042*	999
Middle	12	-0.139	0.824	999
Upper	41	0.048	0.246	999
Males	N	Mantel R	*P*-value	Permutations
Total Site	34	-0.079	0.951	999
Wadi Mouth	5	0.454	0.200	119
Lower	13	-0.082	0.633	999
Middle	3	0.112	0.667	5
Upper	13	0.122	0.156	999
Females	N	Mantel R	*P*-value	Permutations
Total Site	41	0.102	0.050*	999
Wadi Mouth	7	0.532	0.009**	999
Lower	6	-0.082	0.613	719
Middle	7	0.031	0.408	999
Upper	21	0.268	0.010**	999
Subadults	N	Mantel R	*P*-value	Permutations
Total Site	22	0.049	0.169	999
Wadi Mouth	6	-0.196	0.790	719
Lower	5	0.105	0.300	119
Middle	3	-0.858	1.000	5
Upper	8	-0.245	0.801	999

* $P \leq 0.05$
** $P \leq 0.01$

permutations in *R* consisting of dissimilarity matrices, however, for matrices that were

too small, the number of dissimilarity matrices were more limited. As a whole, females

have a strong correlation ($p \leq 0.05$) between spatial and biological distances within the

Amarna STC. Cemetery samples in closer proximity to the South Tombs such as the wadi

mouth and lower sites show strong spatial autocorrelation ($p \leq 0.05$) for males, females,

and subadults (10–14 and 15–19 years) combined, but this structure does not exist further away from the cliffs of the South Tombs at the middle and upper sites.

Model 3: Paleodemography

This particular model used a target that consisted of three quinquennial periods ($t = 5$, $t = 10$, $t = 15$), representing the 15-year occupation of the site of Amarna for three age classes (0–4, 5–9, 10–14). Before presenting the results of the simulated annealing model, the weights used to obtain the best model fit consisted of 1 on the sum

$$\frac{1}{T-1}\sum_{1}^{T-1}(\frac{e(t)-e(t-1)}{e(t-1)})^2 + (\frac{f(t)-f(t-1)}{f(t-1)})^2 \quad \text{where } T = 3 \text{ is the period of deposition, } e(t)$$

at quinquenial period t is the life expectancy at birth, $f(t)$ the overall Coale index; 1.5 for the fit for the structure to the three empirical numbers of skeletons

$$\frac{1}{3}\sum_{x\in\{5,10,15\}}(\frac{D_{[x,x+5]}-\hat{D}_{[x,x+5]}}{\hat{D}_{[x,x+5]}})^2 \text{, where } D_{[x,x+5]} \text{ is the total number of simulated deaths}$$

from age x to age x+5 over the period of deposition, $\hat{D}_{[x,x+5]}$ the total number of

skeletons from age x to age x+5, 1 for the fit $\dfrac{\sum_{x\in\{5,10,15\}}(D_{[x,x+5]}-\hat{D}_{[x,x+5]})}{\sum_{x\in\{5,10,15\}}\hat{D}_{[x,x+5]}}$ for the total

number of deaths, 8 for the deviation $\dfrac{1}{T}\sum_{0}^{T-1}(e(t)-e_{stable})^2$, where e_{stable} is one parameter of

the initial age structure, 6 for the fit $\dfrac{1}{T}\sum_{0}^{T-1}(f(t)-f_{stable})^2$, where e_{stable} is the other parameter

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of the initial age structure. The last two terms are replaced by the relative error between

the age structure along the temporal path and the initial age structure, and the relative

error between the growth rate along the path and the parameter like a growth rate

governing the initial age structure (Bonneuil 2005).

Initial stable population parameters were estimated with confidence intervals and

are presented in Table 10. Using the central limit theorem, Bonneuil (2005) used a

distribution of confidence intervals of the distribution of deaths by age (Table 11) and fit

an optimal demographic path closest to a stable path to each combination of boundary

values of this distribution with confidence intervals for each demographic characteristic

along the optimal path (Table 12). The population size of those interred in the Amarna

STC is estimated to be between 2000–2500 people. Fertility was estimated at 4.0 children

per woman at $t = 5$, with a slight reduction at $t = 15$ to 3.6. The consequence of a minor

drop in fertility is an estimated population decrease of 1.1% a year on average from $t = 0$

to $t = 5$, of 1.3% a year from $t = 5$ to $t = 10$, and 1.4% a year from $t = 10$ to $t = 15$. Over

the three simulated quinquennial periods, life expectancy at birth is relatively the same,

which is consistent with an overall 15-year time frame without mortality crisis. The living

population, as a result of using the estimated population size of the cemetery and the

demographic path reducing the distance to the stable path and the distribution of deaths

by age, was projected for the initial stable population through $t = 15$ (see Table 13 and

Figure 16). The age distributions presented in Figure 16 do not indicate a bias toward

individuals aged 20–30 years at $t = 0$ or more recently (i.e., $t = 5…$), which is the

expected pattern for documented frontier communities (Lefferts 1977; Simkins and

Wernstedt 1971; Swierenga 1982; Blanchet 1989; Anthony 1990; Fuguitt and Heaton

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Table 10. Parameters of the Stable Initial Population (*t*=0) for the Amarna STC. Confidence Intervals Below (estimates, [in brackets]).

Population growth rate	Life expectancy at birth	Initial population size
0.001	19.4	2496.0
[- 0.027,0.007]	[8.9,31.0]	[1652.7,6295.5]

Table 11. Percentage of Deaths for the Empirical, Simulated, and Three Quinquennial Periods (*t*=5, 10, 15). Confidence Intervals Below (estimates, [in brackets]).

	Total number of deaths				
	Over the three quinquennial periods		Simulated over one quinquennial period		
Age class	empirical	simulated	first	second	third
0–4	28.1	28.5	8.0	11.0	9.4
	[18.1,38.2]	[16.3,38.5]	[2.2,10.6]	[5.5,17.9]	[4.7,20.8]
5–9	19.7	15.3	4.7	4.6	6.0
	[11.2,28.2]	[9.2,27.9]	[1.6,6.6]	[2.4,5.7]	[2.9,21.2]
10–14	17.8	20.0	7.0	6.7	6.3
	[9.8,25.9]	[12.9,27.2]	[2.8,10.5]	[3.8,8.9]	[4.0,10.7]

Table 12. Life Expectancy and Fertility Index on the Demographic Path Minimizing the Distance to a Stable Population and to the Distribution of Deaths by Age Classes 5–9, 10–14, and 15–19 (from the most reliable age estimates from dental development).

date	Life expectancy at birth, in years, over [*t*-5,*t*]	Coale fertility index*	Total fertility rate**	Population size
t = 5	29.7	0.32	4.0	2360
	[24.5,49.8]	[0.11,0.57]	[1.4,7.1]	[1499,5457]
t =10	28.2	0.31	3.9	2215
	[22.9,38.6]	[0.14,0.52]	[1.7,6.5]	[1359,4652]
t =15	28.2	0.29	3.6	2066
	[13.4,29.9]	[0.12,0.54]	[1.5,6.7]	[1237,3966]

*: overall Coale index: $I_f(t) = \dfrac{B(t)}{\sum_a p_f(t,a)\, h(a)}$, where $p_f(t,a)$ is the total number of women

of age a at date *t* endowed with the fertility schedule $h(a)$ of the Hutterites, and *B(t)* the total number of living births (Coale 1969).

**: equal to $I_f(t)\sum_a h(a)$.

Table 13. Population Size along the Demographic Path Minimizing the Distance to a Stable Population and to the Distribution of Skeletons by Age.

	Date							
	t=0		*t*=5		*t*=10		*t*=15	
Age class	N	%	N	%	N	%	N	%
0–4	331.5	13.3	295.6	12.5	267.4	12.1	232.0	11.2
5–9	144.0	5.8	187.9	8.0	160.8	7.3	145.7	7.1
10–14	145.9	5.9	136.0	5.8	176.8	8.0	151.3	7.3
15–19	153.7	6.2	141.2	6.0	131.4	5.9	170.8	8.3
20–24	156.1	6.3	146.6	6.2	134.4	6.1	125.1	6.1
25–29	160.9	6.5	149.1	6.3	137.0	6.2	125.6	6.1
30–34	161.9	6.5	150.2	6.4	138.8	6.3	127.6	6.2
35–39	162.2	6.5	150.5	6.4	139.2	6.3	128.7	6.2
40–44	161.5	6.5	149.9	6.4	138.7	6.3	128.3	6.2
45–49	159.8	6.4	148.2	6.3	137.1	6.2	126.9	6.1
50–54	157.0	6.3	145.3	6.2	134.3	6.1	124.3	6.0
55–59	150.8	6.0	139.6	5.9	128.8	5.8	119.1	5.8
60–64	139.1	5.6	129.2	5.5	119.2	5.4	110.0	5.3
65–69	120.2	4.8	112.2	4.8	103.8	4.7	95.8	4.6
70–74	93.9	3.8	88.2	3.7	81.9	3.7	75.8	3.7
75–79	61.8	2.5	58.8	2.5	54.9	2.5	51.0	2.5
80+	33.0	1.3	31.5	1.3	29.8	1.3	27.8	1.3
Total	2493.3	100.0	2360.0	100.0	2214.3	100.0	2065.8	100.0

1995; Burmeister 2000; Cabana and Clark 2011; Crawford and Campbell 2012). Aside from the 0–4 age class, the most notable biases are among individuals in the 5–9 age class at *t* = 5, the 10–14 age class at *t* = 10, and the 15–19 age class at *t* = 15. This overall increasing bias over time for subadults 5–19 years of ages is consistent with the age structure of mill villages constructed in in the American South, Northeastern United States, and United Kingdom in the 19th century (Lander Jr. 1969; McHugh 1988; Glass 1992; Kulik et al. 1992; Mrozowski et al. 1996; Mrozowski 2006). Though the estimated fertility over the three quinquennial periods is shown to be reduced, the increase in

Figure 16. Graphical Representation of Population Size by Age and Time (data from Table 13).
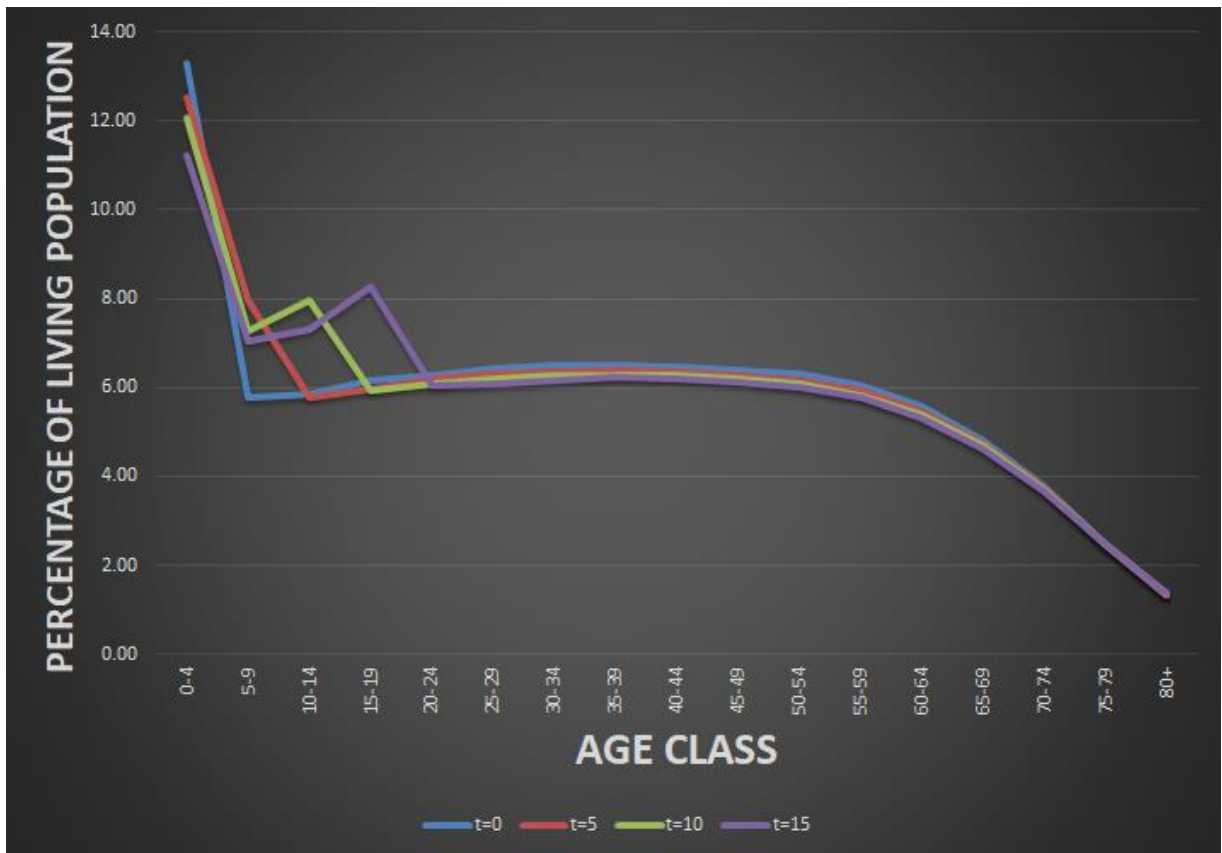
the subadult age bias (5–19 age) could be due to an increase in migration of individuals in those age classes, or of families with older children, or the outcome of more individuals living to older subadult ages within the city as a whole.

Chapter 7

DISCUSSION

Model 1: Large-scale Biodistance

The large-scale biodistance model for the New Kingdom sites produces an intriguing picture of both the dynamics of Nile Valley population history and the peopling of the city of Amarna. The fact that the values of F_{ST} between Memphis, Thebes, Amarna, and Tombos are zero or nearly zero suggests an environment of panmixia in an area approximately 1200 km (north-south) along the Nile River whereby individuals were able to interbreed with little to no restrictions as there is no evidence of significant genetic isolation among samples. Both the **R** matrix and Mahalanobis D^2 values between sites are very small and show no significant pairwise differences (see Tables 6 and 7), corroborating the fixation index. The sites from Egypt (Amarna, Memphis, and Thebes) cluster together to the exclusion of Tombos when examining a PCA of the **R** matrix (see Figure 13). Tombos is located in Nubia furthest south geographically out of the sites sampled. This fits the isolation by distance model in that the location most geographically distant is the most distant biologically from the group centroid (r_{ii}).

Does the Amarna STC reflect gene flow from a specific region? The Amarna STC shares the closest biological affinity to Memphis, but it is not significantly different from Thebes. These results do not support a dominant geographic origin for the Amarna STC

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people. Both the low values of F_{ST} and inter-group distances indicate a relatively panmictic Nile Valley region, with little mating restrictions and little isolation among samples. These results suggest that the new city of Amarna could have potentially drawn people from throughout the Nile Valley.

More intriguing are the results from the Relethford-Blangero analysis (see Table 8). Most of the Nile Valley population samples, except for the Amarna STC, have analogous findings. Memphis, Thebes, and Tombos all show greater than expected mean within-group variance ($\bar{v}_i > E[\bar{v}_i]$), suggesting greater than average external gene flow. This observation is supported by the positive residuals indicating slight exogamy, with the sample from Tombos having the strongest signal of exogamy (0.164). In contrast, the Amarna STC has significantly lesser than expected mean within-group variance ($\bar{v}_i < E[\bar{v}_i]$) and significant endogamy exemplified by negative residuals (-0.300). The comparative samples (i.e., Memphis, Thebes, and Tombos) all have greater than expected mean within-group variance ($\bar{v}_i > E[\bar{v}_i]$) and evidence of exogamy likely because the temporal span of these samples collectively varies between 100–250 years (1539–1292 BCE). During this time frame, it appears that the sites of Memphis, Thebes, and even Tombos were able to receive consistent levels of external gene flow and maintain greater than expected heterogeneity due to large effective population sizes. The lesser than expected mean within-group variance ($\bar{v}_i < E[\bar{v}_i]$) and comparatively significant endogamy within the Amarna STC sample is indicative of a strong signal of mass migration to the Amarna city and a smaller effective population size. The results support that the individuals of the Amarna STC were a small endogamous community or enclave that formed after migrating to the city. Moreover, the loss of phenotypic variation after

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the migration to Amarna is probably due to a founder effect in which a small number of individuals are drawn from a larger, parent population, or the sampling of a lineage from a short temporal span as the Amarna STC was only in use for 15–20 years, with limited time to accrue changes in phenotypes (see Cadien et al. 1974). The fact that the comparative samples from New Kingdom Egypt are significantly more diverse lends credence to this inference.

Model 2: Small-scale Biodistance

The results of the intra-cemetery model suggest robust patterns in cemetery structure. The Mantel tests (Mantel 1967) used in the analysis are versatile since they can be used for simple exploration of spatial autocorrelation as well as inference. Local Mantel tests (Mantel 1967) were sufficiently sensitive to detect spatial autocorrelation. Cemetery samples in closer proximity to the South Tombs (i.e., wadi mouth and lower sites) show strong spatial autocorrelation ($p \leq 0.05$) for males, females, and subadults (10–14 and 15–19 years) combined, yet further away from the rock cliffs of the South Tombs this pattern disappears. This may be due to social status, as individuals buried closer to the South Tombs had stronger and closer biological affinity to the non-ruling elites, but also apparently mimics the clustering of families around officials as seen in the residential parts of the city itself, thus reinforcing the relationship among administrators, close kin, and servants in the afterlife (Kemp 1977a, 1989:261–317; Kemp and Stevens 2010a,b; Kemp et al. 2013).

In the entire cemetery, females have a significant correlation ($p \leq 0.05$) between spatial and biological distances, with males being more variable. At face, this pattern might infer an uxorilocal or matrilocal post-marital residence rule (Stojanowski and Shillaci 2006). Yet inscriptions on ostraca and papyri recovered from the New Kingdom site of Deir el-Medina (1500–1100 BCE) in Thebes suggest that post-marital residence rules may have been quite variable. There are at least three references to specific actions for the groom in the form of providing either gifts or services to the father-in-law and his estate in exchange for marrying his daughter (Ostracon Berlin P.12406, Papyrus DM 27, and Papyrus Turin 1966). One ostracon (Ostracon Nash 6) contains a list of objects that a man brought with him after he tried twice, without success, to move in with a woman and her household. Allam (1973) has inferred that mentions of bride wealth in Papyrus DM 27 and the text from Ostracon Nash 6 infer a matrilocal residence rule. There are, however, documented cases (e.g., Stato Civile; Valbelle 1985:81–87). where newlyweds resided with the bridegroom's parents (virilocal or patrilocal) before settling in a home of their own (neolocal). An additional New Kingdom text, known as "The Instruction of Any", is well-represented on several papyri recovered at many New Kingdom sites and even on ostraca found at Deir el-Medina. This text follows the genre of wisdom literature, ubiquitous throughout the ancient Near East, structured as sage advice from elders to impart piety and integrity upon youth. In this case, the scribe Any (or Ani) instructs his son to: "[3,1] [T]ake a wife while you're young" and "[6,6] [B]uild a house or find and buy one (Lichtheim 1976:136, 139). These passages from Any suggest that the form of post-marital residence in the New Kingdom is primarily neolocal. In her extensive studies of marriage, and even divorce and remarriage at Deir el-Medina, Toivari-Viitala (2001:

87–89, 2002:617) remarks that post-marital residence rules were likely fluid, and seemingly situational, based on practical matters that included the social statuses of both the families of the bride and groom and the ability of the new couple to afford a home of their own. Thus, depending on logistical factors, newlyweds could have resided with the bride's parents or the groom's parents (ambilocal), if even temporary or permanent, or in a neolocal residence if feasible.

Other important aspects of divorce are also detailed in texts from Deir el-Medina, such as division of assets and property (e.g., Ostracon DM 764). In the dissolution of a marriage, most sources depict an outcome where the woman moved out of the nuptial domicile, but also maintained a right to one-third of the matrimonial property, provided that she was not convicted of adultery, and the ex-husband cared for the children (Lüddeckens 1960; Pestman 1961:60–61, 139; Janssen and Pestman 1968:165; Černý and Gardiner translated in Allam [1973:157, 160–161, 234–235]; Toivari-Viitala 2001:90–91, 2002:618–619). A scenario where matrilocality predominates with the potential for the marriage to dissolve and the state enforcement of a woman to abandon her own parent's home while her ex-husband inherits up to two-thirds of the in-law's estate seems unlikely at both Deir el-Medina and Amarna. Furthermore, it seems impractical from a standpoint of inheritance of estates and transfer of wealth. Even the modern ethnographic record details that human societies blending matrilocal residence with patrilineal descent is quite rare (see for example Nickerson 1993). Inheritance in ancient Egypt appears to be via bilateral descent insofar as men and women could receive assets from both parents. The eldest son is believed to inherit twice that of his siblings, likely due to his responsibility to arrange and pay for the mortuary rites of their parents, and only males are thought to

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inherit offices, professions, and titles (Janssen and Pestman 1968; Vernus 1981; Eyre 1992; though see Whale 1989:260–261).

In Shelia Whale's (1989) examination of 93 18th Dynasty (1549–1292 BCE) tombs, mostly from Thebes, sons are routinely featured as prominent figures in the funerary cults of their parents (see Whale 1989:255). They are often shown presenting offerings and performing funerary rituals. If the son was too young to assume this responsibility, or in the absence of a son due to premature death, for instance, a grandson or brother is depicted performing these duties. In some tombs, sons and grandsons carry out these duties in consort (Whale 1989:266–267, 270–271). Whale (1989:262–263) also observed that a mother is represented in the tomb of her son more often than their son's wife, and sons are commonly illustrated as fulfilling official functions and carrying out funerary rites in the company of their mothers, especially if their son held an official position or royal title. To this end, Whale (1989:262–263) concluded that the mother-son relationship was more significant than the husband-wife relationship, at least in mortuary contexts, though the strength of this bond also may have been prevalent in daily life.

Much of the research on ancient Egyptian kinship and familial organization implies that the nuclear family consisted of the neolocal conjugal couple as the focal point, with unwed children, and additional female kin such as sisters, aunts, and mothers, who were either widowed, divorced, never had a family, or lost their family (Campagno 2009:4). One can then imagine the exemplary family unit in ancient Egyptian times as comprised of the eldest son and his wife in the home they started, their unmarried children, and all the female kin from the extended family including the son's mother after her husband (his father) died. These types of family units likely explain the pattern of

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female spatial autocorrelation with biological distance in the Amarna STC, and not post-marital residence rules, where related females are dispersed spatially in predictable ways based on biological affinity because many of them that are closely related are concentrated in one home. One such grave pit, 12132, in the Amarna STC may provide clues as how females and their kin were situated within their family units for funerary rites. This grave pit contained the remains of a female aged 40–45 years (Individual 69A) and a child 1–5 years (Individual 69B). The bones of Individual 69A were likely associated with a coffin that contained a wooden face painted red (the normal color for a male's coffin for this period) and fragments of hieroglyphics that stated repeatedly her name and her title normally indicative of a married woman: 'The Lady of the House, Maiai' (Kemp 2008:4). Her grave was part of a crowded cluster of grave pits, which may have been her nuclear family. Based on the previously outlined historical and funerary record of kinship and familial ties in ancient Egypt, 'Maiai' may have been a mother whose funerary rites were arranged by her eldest son and clustered around her are likely her children, aunts and uncles, and kin from her son's household. These types of clusters may very well exist in other parts of the Amarna STC.

Model 3: Paleodemography

The results of the paleodemographic model show a few informative patterns. First, the values of life expectancy at birth presented in Table 12 are approximately the same from $t = 5$ to $t = 15$ (28.2–29.7 years of age at death), which is consistent with a period of demographic stability, and at a level slightly greater than but consistent with

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values found in studies on mortality of populations using simulated annealing

optimization (Bonneuil 1990; Rathbun and Steckel 2002; Saunders et al. 2002; Bonneuil

2005). Fertility is also consistent over time, but rather low (4.0 children per woman) by

comparison (Bonneuil 2005). When simulating the living population from the Amarna

STC data from $t = 0$ to $t = 15$ (see Figure 16), there is no indication of a bias of

individuals 20–30 years of age, which is the typical demographic pattern containing

highly mobile young adults in documented frontier settlements (Lefferts 1977; Simkins

and Wernstedt 1971; Swierenga 1982; Blanchet 1989; Anthony 1990; Fuguitt and Heaton

1995; Burmeister 2000; Cabana and Clark 2011; Crawford and Campbell 2012). The data

do demonstrate a greater bias of subadult individuals aged 5–19 years, and a steady

increase in the number of subadult individuals of older ages. This pattern is reminiscent

of the age structure of 19th century mill villages in the Southern and Northeastern United

States as well as United Kingdom (Lander Jr. 1969; McHugh 1988; Glass 1992; Kulik et

al. 1992; Mrozowski et al. 1996; Mrozowski 2006). The increase in subadults living to

older age ranges could be the result of more families with older children and adolescents

migrating to Amarna over the three quinquennial periods, or more subadult individuals

within the city attaining older age. One could assume that the large bias of individuals in

the 15–19 age class at $t = 15$ would be highly selected for resettlement. The attainable

evidence from the paleodemographic model using the Amarna STC and comparing it to

known documented cases of settlement formation suggests the city of Amarna was

populated via a transplanted community or communities.

Chapter 8:

CONCLUSION

This dissertation focused on the skeletal sample from the Amarna South Tombs cemetery (STC) to better understand the nature of the sample and the community of people as part of a disembedded capital that was populated in Middle Egypt during New Kingdom times (1352–1336 BCE). This bioarchaeological study was specifically theorized in terms of a disembedded capital and the migratory and settlement patterns that fueled ancient cities, of which little is known (Morris 1972; Blanton 1976; Willey 1979; Joffe 1998; Hugo 2006; Smith 2014). Previous bioarchaeological research of the Amarna STC has focused primarily on aspects of age-at-death distributions (Rose 2006; Kemp et al. 2013; Dabbs et al. 2015), gross skeletal pathology (Rose 2006; Kemp et al. 2013; Dabbs et al. 2015; Smith-Guzmán 2015a,b; Smith-Guzmán et al. 2016a,b), cross-sectional geometry (Schaffer 2009), and musculoskeletal stress markers (or MSMs; Zabecki 2009). Overall, the results from this dissertation have added to our knowledge of dental phenotypic variation of Nile Valley settlements in the New Kingdom (1539–1186 BCE) during the 18th–22nd Dynasties of ancient Egypt and Nubia including a sample of the variation contained within the city of Amarna. This study has helped clarify how the Amarna city was peopled and settled, who the Amarna residents were, and how they organized themselves in cemeteries in preparation for the afterworld. This chapter reflects on the results and inferences contained in the dissertation and informs on how it has

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advanced the discipline of bioarchaeology and bioarchaeological research in the Nile

Valley as well as recommendations for future research.

Implications for Bioarchaeology and Bioarchaeological Research in the Nile Valley

The results included in this dissertation continue to bolster the robustness of large-

scale biodistance analysis in bioarchaeology, demonstrated by the ability to detect a

strong signal of migration to the Amarna city from a founder effect causing low dental

phenotypic diversity. Examining the phenotypic variability of the Amarna STC against

contemporaneous sites of New Kingdom Egypt and Nubia also illustrates the veracity of

Caiden et al.'s (1974) critique of population analysis in skeletal studies. Caiden et al.

(1974) have argued that a skeletal sample that spans hundreds or even thousands of years

is not a "population" in specific reference to the modern definition of the biological unit

known as a population: a group of interbreeding individuals (Mayr 1963). Rather,

bioarchaeologists are frequently sampling an aggregate of populations living at

temporally distinct time frames, even within a single skeletal sample, with potentially

some, little, or no range overlap. Bioarchaeologists, then, may be sampling population

lineages. The dental phenotypic variation of the comparative samples in the large-scale

biodistance analysis, Memphis, Thebes, and Tombos, show very high levels of

phenotypic variation by comparison, perhaps because they are samples of population

lineages with 100 to 250 years of accumulated evolutionary change. By contrast, the

Amarna STC has very low phenotypic variation, is a sample of a lineage only comprising

of a few generations, and "would reasonably approximate a static statistical population

insofar as the directional processes of evolution would presumably have had little opportunity to alter gene frequencies and phenotypes, from the initial to the terminal generation of the lineage" (Caiden et al. 1974:199).

Though this dissertation was unable to definitively indicate that the Amarna migrants originated disproportionately from either Memphis or Thebes, the fact that the New Kingdom samples collectively have an appreciably low fixation index or F_{ST} suggests that the city of Amarna may have been peopled by individuals and families drawn from throughout the Nile Valley. The nearly zero value of F_{ST} and the homogeneity observed among samples reveals a highly mobile and geographically unrestricted Nile Valley of the New Kingdom in terms of population movement and gene flow. **R** matrix metric trait analysis was applied here for the first time in Nile Valley bioarchaeology. Other large-scale biodistance studies have not utilized **R** matrix and use samples from various time periods of ancient Egypt and Nubia (Brace et al. 1993; Prowse and Lovell 1996; Irish 2006; Zakrzewski 2007; Godde 2009; Schillaci et al. 2009; Godde 2010; Irish and Friedman 2010; Godde 2018), even including samples of modern origin or the more recent past (see Brace et al. 1993; Godde 2010). The main research question asked of some these studies is: where did the population of Dynastic Egypt originate? This question is not too dissimilar to the obsession with the origin of the "Dynastic Race" consumed by researchers in the early 20th century (e.g., Derry 1956).

The examination of phenotypic variation in Nile Valley bioarchaeological samples synchronically in this study informed on gene flow and population movement into the New Kingdom exclusively. When comparing the Amarna STC to Nile Valley skeletal samples diachronically, a different picture emerges. For example, preliminary

work using craniometric data from the Amarna STC (Dabbs and Zakrzewski 2011)

demonstrates a greater coefficient of variation (CV) within the STC sample in

comparison to a pooled sample of several cemeteries dating from the Badarian through

the Middle Kingdom (*c*. 4000–1900 BCE; see Zakrzewski 2007:504), suggesting that the

Amarna STC gene pool was highly diverse. However, the comparison by Dabbs and

Zakrzewski (2011) only informs how the Amarna STC sample is more morphologically

diverse compared to previous time periods in ancient Egypt, and not how diverse the

Amarna STC is in relation to other New Kingdom populations. Here I have demonstrated

that when including contemporaneous New Kingdom populations (i.e., Memphis,

Thebes, and Tombos), the Amarna STC is the least diverse, suggesting that the Nile

Valley into the New Kingdom was more diverse than in the Middle Kingdom and the

Pre-Dynastic.

A notable exception to the body of large-scale biodistance analyses of the Nile

Valley is the work of Michele Buzon. Buzon (2006) has previously examined the

phenotypic diversity of Nile Valley populations during the New Kingdom. Using cranial

measurements, she demonstrated that sites in New Kingdom Nubia, such as Tombos and

Kerma, have greater morphological heterogeneity than contemporaneous sites in Egypt,

suggesting that people living and buried in Nubia were comprised of both Nubians and

Egyptians. The results presented in this dissertation are similar in that Tombos in Nubia

has a greater amount of dental phenotypic variation than samples from Egypt such as

Memphis, Thebes, and the Amarna STC.

The inclusion of small-scale biodistance analysis showcased the capabilities of

studying intracemetery variation and how spatial autocorrelation can recognize

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convincing patterns in data and make valuable interpretations about ancient Egyptian social organization, biological relatedness, and kinship (Stojanowski and Schillaci 2006; Johnson and Paul 2015; Ensor et al. 2017). Intracemetery variation in the Amarna STC showed much structure for both sexes and subadults (aged 10–14 and 15–19 years of age) in samples adjacent to the South Tombs (i.e., wadi mouth and lower sites), but in other parts of the cemetery further up the wadi, this organization was much weaker or non-existent. The formal structure observed in the samples closest to the South Tombs support the idea of a symbiotic relationship between officials and peasantry that existed at Amarna that is seen in the Central and Main City, where administrators resided in larger estates and smaller homes clustered or resonated around them, both reifying the co-existence among non-ruling elites and non-elites not only during life but for the afterworld as well (Kemp 1977b, 1989:261–317; Kemp and Stevens 2010a,b; Kemp et al. 2013). Another important aspect of the small-scale biodistance model conducted in this dissertation is the potential to include a greater breadth of interpretation in ancient cemeteries by moving beyond simply post-residence rules, but also including concepts such as marriage dissolution and division of assets and property, remarriage, lineal descent, kin ties, and nuclear family dynamics (e.g., Toivari-Viitala 2001, 2002; Campagno 2009). Combining traditionally interpreted matrilocal patterns in intracemetery data with known historical texts of the New Kingdom, mostly from Deir el-Medina, this dissertation has shown that bioarchaeological inquiry can expand to additional aspects of sociocultural phenomena and further enhance our knowledge of family unit dynamics in ancient societies as well as open an entirely new body of research on the topic.

In terms of its contribution to small-scale biodistance analysis in the Nile Valley region, this dissertation joins only a handful of studies on intracemetery variation with the only other research conducted at the Roman Period (300–400 CE) Kellis 2 cemetery in the Dakhleh Oasis from Kellis, Egypt (Kron 2007; Haddow 2012). Kron (2007) was able to identify pockets of the cemetery that contained rare skeletal non-metric traits and Haddow (2012) showed a slight bias in the frequency of dental non-metric traits in segments of the Kellis 2 cemetery. Phenotypic variation and expression of dental non-metric traits between females and males was not significantly different, inferring a relatively homogenous sample at Kellis 2 resulting from endogamous marriages (Haddow 2012). The historical record suggests that Egypt during the Roman Period practiced predominately patrilocal residency (Bagnall and Frier 1994). Though nuptials between cousins, nieces and uncles, and even half-siblings were seemingly acceptable throughout during much of ancient Egyptian history (Forgeau 1986:144), marriage between full sisters and brothers was regularly reserved only for the royal elite until the Graeco-Roman Period where it was more common (Černý 1954; Bagnall and Frier 1994:127; Scheidel 1996a,b, 1997; Clarysse and Thompson 2006:193; Remijsen and Clarysse 2008; Rowlandson and Takahashi 2009). This change in marriage norms may explain the differences observed in the cemetery structures and variation of both the Amarna STC and Kellis 2.

This dissertation also has made important contributions to the field of paleodemography, particularly in the Nile Valley, with the use of sophisticated mathematical demography employing Monte Carlo simulation methods, which looks to be the first application in Nile Valley bioarchaeology (though see Batey [2012] with the

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use of hazard models). Early studies of Nile Valley paleodemography like that of Masali

and Chiarelli (1972) compared Pre-Dynastic remains from Gebelein to the Dynastic

remains from Gebelein and Asyut both in Upper Egypt from the Museo Egizio collection

in Turin, Italy. Variables such as life expectancy and survival rates were used to examine

differences between the sexes, as well as between Pre-Dynastic and Dynastic contexts.

Others such as Green et al. (1974) and Armelagos et al. (1981) in the Wādī Ḥalfā area

calculated life table data and compared them within and between Meriotic, X-Group, and

Christian Periods. These studies did not consider a number of assumptions in

paleodemography, but the common theme beyond describing age-at-death distributions

was calculating life table data assuming a stationary population (stable birth and death

rates with zero growth rates). Most other studies of Nile Valley paleodemography

examine only age-at-death distributions (Podzorski 1990; Sterling 1999; Tocheri et al.

2005; Buzon 2006; Kemp 2013; Kemp et al. 2013), with the exception Batey's (2012)

work using hazard models for Pre-Dynastic cemeteries at Hierakonpolis, Naga-ed-Dêr,

and Naqada.

Paleodemographic study requires that many assumptions be addressed (e.g.,

uniformitarian, whopper, others from stable population theory like growth rates and

population size, etc.). These assumptions must be considered, and methods implemented

to limit biases inherent in transforming demography into paleodemography. The Amarna

STC sample presents many challenges for paleodemographic analysis. As a newly

populated migrant settlement *c*.1352 BCE, the peopling event of Amarna likely violated

many of the assumptions of stable population theory (Lotka 1922, 1956; McFarland

1969; Keyfitz 1977). The use of a technique that relaxes these assumptions and utilizes a

Monte Carlo method known as simulated annealing optimization (Kirkpatrick et al. 1983; Press et al. 1992; Bonneuil 2005) to find the path closest to stable population parameters based on the age-at-death distribution of the Amarna STC is unique. Also, inherent bias was reduced by using only the portion of the age-at-death distribution of the Amarna STC that is most accurate using dental aging techniques (5–9, 10–14, and 15–19 years age classes; see Al Qahtani et al. 2010) and less affected by subadult under-enumeration (0–1 and 1–5 age classes). A projection of the living population for the Amarna STC did not demonstrate a pattern similar to documented frontier settlements that have a bias in the 20–30 year age categories (Lefferts 1977; Simkins and Wernstedt 1971; Swierenga 1982; Blanchet 1989; Anthony 1990; Fuguitt and Heaton 1995; Burmeister 2000; Cabana and Clark 2011; Crawford and Campbell 2012). Instead the prominent levels of individuals 5–19 years of age indicates that the people of the Amarna STC were a transplanted community or communities, as this is the identical pattern of the age distribution of mill villages of the 19th century United States and United Kingdom (Lander Jr. 1969; McHugh 1988; Glass 1992; Kulik et al. 1992; Mrozowski et al. 1996; Mrozowski 2006).

Future Research Directions

The unique restrictive time span of the Amarna site (15–20 years) presents challenges when comparing it to other archaeological sites that extend over hundreds of years. However, this narrow temporal duration allows for new questions in archaeology and bioarchaeology to develop, like migratory patterns, population movement, and family unit dynamics. Thus, the Amarna STC has proved very valuable as a "natural laboratory"

to engage using problem-oriented and theoretically driven skeletal analysis. Additionally, demonstrating statistically strong spatial autocorrelation ($p \leq 0.05$) with spatial analysis, which was evident in the Amarna STC, is often a preliminarily exploratory technique, and with this condition met, more advanced interpolation models can be generated for the Amarna STC such as prediction, kriging, splining, and inverse distance weighting, as well as trend surface analysis and more sophisticated cluster analysis (see for example Johnston et al. 2001).

Moreover, this dissertation only highlighted the South Tombs cemetery, one of likely five cemeteries (see Fenwick 2005) that housed the ancient city of Amarna's residents – a city that may have housed 50,000 people or more at one point in time. More recent excavations are conducted at the North Tombs cemetery (NTC; see Stevens 2018). The same type of intensive analysis could be performed including the NTC and STC for the Amarna site as a whole, but also as subsets. How the inclusion of multiple cemeteries from this important and exceptional site will affect the current results and interpretation is just one of many future directions of this research.

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