Title:
Life Expectancy

Author:
Zakrzewski, Sonia, Southampton University

Abstract:
The analysis of life expectancy and longevity is one approach to analysing diversity in the population of ancient Egypt. It is, however, important to understand the difficulties in such calculations and in the data from which such calculations are derived. Adult age is difficult to determine either from documentary or biological sources, so average age-at-death is particularly hard to determine. This discussion explores the issues surrounding demography, the potential sources for such data, and suggests ways that life expectancy in Egypt might be assessed and integrated with broader archaeological and Egyptological information.

LIFE EXPECTANCY
متوسط العمر

Sonia Zakrzewski

EDITORS

WILLEKE WENDRICH
Editor-in-Chief
University of California, Los Angeles

JACCO DIELEMAN
Editor
University of California, Los Angeles

ELIZABETH FROOD
Editor
Area Editor Individual and Society
University of Oxford

JOHN BAINES
Senior Editorial Consultant
University of Oxford

LIFE EXPECTANCY
متوسط العمر

Sonia Zakrzewski

Lebenserwartung
Espérance de vie

The analysis of life expectancy and longevity is one approach to analyzing diversity in the population of ancient Egypt. It is, however, important to understand the difficulties in such calculations and in the data from which such calculations are derived. Adult age is difficult to determine either from documentary or biological sources, so average age-at-death is particularly hard to determine. This discussion explores the issues surrounding demography, the potential sources for such data, and suggests ways that life expectancy in Egypt might be assessed and integrated with broader archaeological and Egyptological information.

ان تحليل متوسط وطول العمر المتوقع هو أحد المداخل لتحليل التنوع في عدد سكان مصر القديمة. غير أنه من الضرورى أن نفهم الصعوبات في مثل تلك الحسابات وفى تلك البيانات التي تستمد منها تلك الحسابات. من الصعب تحديد سن البلوغ سواء من الوثائق أو المصادر البيولوجية ، لذلك فأن متوسط العمر عند الوفاة بشكل خاص يصعب تحديده. ومن خلال هذه المناقشة نستكشف القضايا المحيطة بالديموغرافيا (علم السكان)، والمصادر المحتملة لمثل تلك البيانات، وتقترح الطرق التى يمكن من خلالها تقييم متوسط العمر المتوقع في مصر ودمجه مع المعلومات الأثرية والمعلومات المتعلقة بالاثار المصرية.

H ow long did the average ancient Egyptian live? What was the life expectancy at birth? How did life expectancy change as a person aged? Did this vary across time periods or between areas in Egypt? While some individuals lived to reach a very old age, the average age-at-death was probably not nearly so great.

Demography: Assessing Life Span and Longevity

Demography is the study and description of the characteristics of a population (Konigsberg and Frankenberg 2013). These characteristics include life span, population size and its change over time, structure/composition in terms of sex, mortality rates, fertility rates, and geographical distribution. The distributions of ages at death of a cross section of the population are the baseline information needed to best examine the issues of longevity and average life span. This means that accurate profiles of the relative proportions of deaths occurring in each of the various subsections within a society are ideally required. If we are to construct these categories on the basis of age, then the relative proportions of individuals dying as infants, children, adolescents, young adults, and older adults are required. Demography considers populations and seeks to explain the variations seen in population size, structure, and dynamics, but it also considers groups bound together by some notion of belonging, kinship, or social ranking (Chamberlain 2006).

In an idealized scenario, all individuals go through the same basic life history stages: birth, growth and development, reproductive maturity, old age, and death. In addition to these life history events, migration events have an effect on the composition of the population or group. Even within each group, however, there are differences between people in terms of their fertility, their participation in migration, their prospects of death at particular life stages, and their survival to specific stages of life or ages. The demographic study of a group therefore involves coalescing these characteristics for all its members. In order to arrive at the demography of a group, in addition to its population size, the structure, dynamics and density, the fertility, mortality, and migration profile of the group are needed (Chamberlain 2006). But these characteristics vary across age and sex categories and between temporal periods.

A population profile is a curve that describes the internal structure of the population. This is usually done by aggregating people into age intervals, usually in terms of years, such as five-year or ten-year age classes. In some situations, three simplified intervals may be used: juvenile, prime adult, and old adult. These three broader age classes reflect important periods in the life history of the individual. The population profile also includes the sex distribution, usually calculated as the number of males divided by the number of females.

The mortality or death rate (denoted by q) is defined for a specific time interval as the proportion of the population that is alive at the start of that interval but dies before the end of the time interval. The probability of dying, however, is not constant with age. The following section provides a series of definitions of terms required for demographic study. For all these technical terms, an age category is referred to as x, so age-specific mortality (q_x) is the mortality rate of individuals in age category x. Age-specific mortality (q_x) is high in juveniles, falls to a low during adolescence and early adulthood, and then rises steadily with increasing age (Chamberlain 2006: 25). Mortality rates are also affected by factors such as sex and social status. Most groups normally exhibit an attritional mortality profile, where the mortality pattern follows that described above. However, there are also situations where high mortality (or crisis/catastrophic mortality) conditions exist, such as during natural disasters, e.g., flooding or famine, epidemic disease, or period of conflict, and this affects the profile.

Life tables are a way of representing the mortality of populations, and model life tables summarize this for typical populations and are useful when reconstructing the life table of a population for which reliable data is only available for some of the age categories (as in most archaeological assemblages). The model life table most commonly used when modeling historical or prehistoric populations, with their high levels of mortality, is the Coale and Demeny "West" model (1983), such as for Roman Egypt (Bagnall and Frier 1994). An example Roman Egyptian female life table, as calculated by Bagnall and Frier (1994: 77), is given in Table 1 below. Using this life table, one may plot the mortality and survivorship curves for Roman females (fig. 1).
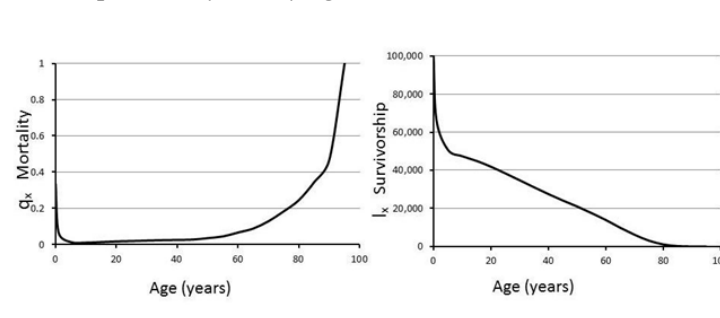

Figure 1.   Mortality profile (A) and survivorship curve assuming a cohort of 100,000 (B) for Roman women (derived from Bagnall and Frier 1994).

Table 1.   Model life table for Roman Egyptian females, calculated from census returns using Coale and
Demeny "West" model, after Bagnall and Frier (1994)

Age x	q_x	l_x	100,000 l_x	L_x	T_x	e_x
0	0.33399	1	100,000	78,290	2,250,000	22.500
1	0.23760	0.66601	66,601	224,642	2,171,710	32.608
5	0.06657	0.50776	50,776	244,586	1,947,068	38.346
10	0.05205	0.47396	47,396	231,061	1,702,481	35.920
15	0.06744	0.44930	44,930	217,375	1,471,420	32.750
20	0.08385	0.41899	41,899	201,066	1,254,045	29.930
25	0.09369	0.38386	38,386	183,300	1,052,979	27.431
30	0.10558	0.34790	34,790	165,133	869,680	24.998
35	0.11511	0.31117	31,117	146,987	704,546	22.642
40	0.12227	0.27535	27,535	129,594	557,559	20.249
45	0.12967	0.24168	24,168	113,319	427,965	17.708
50	0.16518	0.21034	21,034	96,832	314,646	14.959
55	0.20571	0.17560	17,560	79,129	217,814	12.404
60	0.29144	0.13947	13,947	59,982	138,684	9.943
65	0.37118	0.09883	9,883	40,609	78,703	7.964
70	0.49858	0.06214	6,214	23,636	38,093	6.130
75	0.63720	0.03116	3,116	10,616	14,458	4.640
80	0.75601	0.01130	1,130	3,172	3,841	3.398
85	0.87919	0.00276	276	613	670	2.429
90	0.95785	0.00033	33	55	57	1.709
95	1.00000	0.00001	1	2	2	1.187

Where the 100,000 l_x column describes the l_x probability as the number of females from a theoretical
initial population of 100,000 newborn females.

In order to understand mortality profiles and life tables, certain concepts need to be understood. Survivorship (l_x) is a useful concept that expresses the probability that an individual will survive to a particular age category x (Chamberlain 2006: 28-31). The probability of survivorship is, by definition, between zero and one, and decreases with increasing age. If one imagines a population of 1,000 individuals born at the same time in the same place, over time, all of those individuals will die. But the age at which they die varies. Some will die in the first year; others will die during the next year. There are therefore fewer and fewer individuals present each year. Survivorship curves permit the visualization of how the number of living individuals from the same cohort (i.e., born in the same year) decreases with time.

As noted earlier, life tables are a way of representing the mortality of populations and for exploring the effects of survivorship on age-specific probabilities of death (Chamberlain 2006: 27-32). "A cohort of individuals of a given age will experience a predictable number of deaths during a finite interval of time, with the proportion dying depending on the length of time interval and on the population's age-specific probability of death. The number of survivors at the end of the time interval will equal the original cohort minus the individuals who have died. Thus survivorship decreases at each successive age interval, from a maximum value at birth to zero at the age at which the last survivor dies" (Chamberlain 2006: 28). The proportion of all the deaths that occur within age interval x (d_x) is the product of the survivorship (l_x) and the age-specific probability of death (q_x). The age-specific probability of death (q_x), i.e., the mortality, is the likelihood that persons aged exactly x will die before they are old enough to enter the next older age category. Age-specific

mortality is therefore a conditional probability, and might be phrased as "given that someone has lived to enter age bracket x, what is the chance that they will die before reaching the next older age bracket?" Life tables may also include the number of years the average person will live within each age interval (L_x). If all values of L_x are summed, the total person years of life remaining to the cohort entering each age category (T_x) is obtained. The age-specific average life expectancy (e_x) is this final value (T_x) divided by survivorship (l_x). Age-specific average life expectancy (e_x) can also be thought of as a conditional expectation, so the life expectancy at that age is the expected additional years of life remaining given that a person has already lived to a certain age.

Longevity is a general term referring to the length of life, whereas life span designates the maximum age to which an individual may live. Life expectancy is normally considered as short for life expectancy at birth, which is equal to the mean age-at-death within a population (Chamberlain 2006: 30, 52-54). Life expectancy therefore is the middle of a range of variation in age-at-death, whereas the life span value is the upper extreme of that range. Life expectancy can be calculated from a life table. As noted above, the most commonly quoted life expectancy is the average life expectancy at birth (*e₀*). This value can be superficially misleading as life expectancy at birth does not inform as to the average age-at-death because mortality in humans peaks in the youngest and oldest age groupings (Chamberlain 2006: 25). This means that if an individual survives their earliest years, to about five years of age, their overall life expectancy dramatically increases.

For example, if average life expectancy at birth is 45 years, the most common age-at-death might be 55 years, as the reduction by 10 years results from the individuals who died at much younger ages. Figure 2 demonstrates this pattern. At birth, life expectancy is age *e₀*. If, however, the individual survives the early years of life, then their actual life span is usually longer, leading to an older age with the most common age-at-death for the over 1s. Figure 2 demonstrates clearly how a person who survives to five years of age has a massive

increase in life expectancy from life expectancy at birth. Once the person survives the periods of high childhood mortality, their life expectancy does not continue to increase as rapidly. There are fewer additional years of life expected from life expectancy at five (e_5) to life expectancy at 20 (e_{20}) than between life expectancy at birth (e_0) and at age five (e_5). It is important to distinguish between life expectancy at birth and life expectancy at later ages because they impact upon understanding how long each ancient Egyptian person actually lived. In addition, ideally an understanding of the risks that may affect the quality of life, death and birth rates, and the causes of death need to be known. The archaeological populations or samples that are available for study are also problematic because skeletons of juveniles are rarely as well preserved as those of adults (Walker et al. 1988). This means that this massive number of deaths in the early years of life is rarely recognizable archaeologically, although the Kellis 2 cemetery at Dakhla oasis is an exception (Wheeler et al. 2011). Paleodemography is the term used for such studies of ancient or past populations.
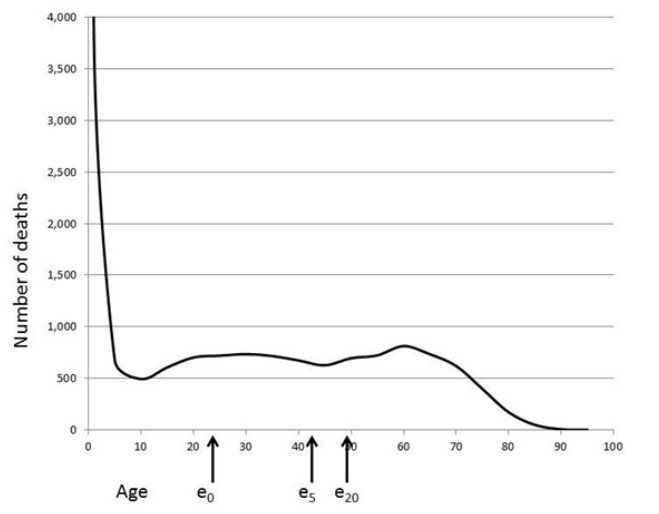

Figure 2. Distribution of Roman female deaths by age, calculated from life table using a theoretical population of 100,000 females from Bagnall and Frier (1994). e_0 = life expectancy at birth; e_5 = life expectancy at age 5; e_{20} = life expectancy at 20.

Methods for demographic analyses of mummies and skeletal samples has recently changed as it has been understood that the methods used to assign ages and sexes to skeletons are conditional upon the samples from which the methods are derived. As a result, aging and sexing are now undertaken in association with demographic studies. Indeed Konigsberg and Frankenberg (2013: 294) argue that "individual age or sex estimates cannot be produced until after the demographic analyses have been performed." Life table study, although still common, has started to be superseded by analysis of hazard models of mortality and estimations of the age-at-death structure of a population. Hazard models are a type of statistical model that specifies the time until an event (death) occurs, and so hazard functions express the risk of death as a function of time (Chamberlain 2006: 32-34). This means that these models can represent a continuous age-at-death distribution using a relatively small string of parameters, such as frequencies of juvenile mortality, and old-age mortality, but enable the maximum amount of information to be used in the analysis of deaths in a population (Chamberlain 2006: 32-34; Konigsberg and Frankenberg 2013). Hazard models develop probability density functions ($f(x)$) which are the rate of change of the probability that an individual survives to at least age x ($S(x)$). These values are thus similar to the life table values of d_x and l_x respectively. Use of such methods requires both mathematical and computational analysis and so are, at this stage, only starting to be implemented within bioarchaeology.

Documentary Demographic Data

In Roman Egypt there are a variety of different documentary sources of demographic data, including tax and census returns. From this period, over 840 census declarations still exist (Scheidel 2012), with the earliest dating from 12 CE and the latest to about 259 CE (Bagnall and Frier 1994). From these census returns, nearly 1100 registered persons can be made out, with sex known for more than 1000 people, and age for more than 700. Census data have their own issues, such as the unit of filing

(i.e., at the household or person level) or who was required to file a declaration, but Bagnall and Frier (1994) believe that the entire population of Egypt, whatever the social status, was registered. About three quarters of the Roman Egyptian census returns are from the Arsinoite and Oxyryhnchite nomes, and so are neither fully representative nor random. It is also impossible to quantify how thorough Egyptian administrators were in collating such census returns, or how diligent and accurate residents were in completing their returns (for critique, see Scheidel 2001).

Bagnall and Frier (1994) recorded ages for 337 women from Egyptian census returns. Using the Coale-Demeny "West" model, the life expectancy at birth (e_0) for Egyptian women was 22.5 years, but on their 20th birthday (e_{20}) it was another 29.9 years (i.e., 49.9 years of age). Overall, they reconstruct Roman Egyptian female life expectancy at birth as 20 to 25 years, and life expectancy at age 10 of 34.5 to 37.5 additional years. Furthermore, from the census returns, they calculated an annual female birth rate of 42-54 per thousand and an annual female death rate of 42-49 per thousand. They also recorded ages for 350 males from census returns, and obtained an overall sex ratio of 1.104 (males to females, i.e., more than 110 males for every 100 females). Separating the villages from the metropoleis provided a different pattern, with the sex ratio in villages being just 0.861, whereas it was 1.447 in metropolitan areas. This demonstrates the problems with calculating sex ratios from raw data in census returns. Bagnall and Frier (1994) also argue for a male life expectancy at birth of at least 25 years, of between 35 and 40 further years at age 10, and of slightly more than 30 additional years at age 20. In addition, they suggest an annual birth rate of about 45 per thousand and an annual death rate of just over 40 per thousand across the whole population.

Bagnall and Frier (1994) noted 211 instances where the census returns preserve both the age of the mother and of her child. From these they calculated that the median age of Egyptian maternity was about 26 years. They also noted 155 cases in which both the age of the father and his child were known, with paternity

recorded as rare before age 20 and peaking in the early thirties. The median age of paternity was approximately 37 to 38 years. Slaves also presented census problems, as documentarily, at least, they did not have legal fathers and rarely had a named mother unless the mother was also a slave resident within the household. Less well studied for demographic purposes, but common in earlier periods in Egypt, are commemorative inscriptions. From the Middle Kingdom onwards, funerary stelae and tombs contain biographical information, but almost always lack ages at death or dates of birth or death. Autobiographical elements, albeit primarily related to the tomb-owner's work and position in society, are most common in tomb decoration during the New Kingdom (Dodson and Ikram 2008). An example of a private citizen detailing their life with ages occurs in the 21st Dynasty (Moftah 1983). Examples from the 18th Dynasty include an autobiographical stela from Memphis in which the name of Thutmose may be invoked as an omen for protection (Moftah 1983). Other artifacts, however, do provide some evidence. From the reign of Ramesses II, the high priest of Amun at Karnak, Bakenkhons, provides career information on one of his limestone block statues (Jansen-Winkeln 1993; Frood 2007: 39-46; Janssen and Janssen 2007: 61, 195, 218-219). Altogether, summing together his years of education and periods as various forms of priest, a time span of 85 years is recorded, suggesting that he must have been at least 90 when he died. Such commemorative inscriptions, while useful, are often biased in terms of ages or gender, and usually vastly underrepresent children and infants. Scheidel (1998) has demonstrated that, during the Roman Period at least, where dates are given on tombstones and mummy labels, these refer to the completion of mummification rather than the actual date of death.

In addition to the taxation records noted earlier, longevity and other demographic data may also be obtained from other written sources, such as ostraca, papyri, etc. These may be in the form of letters, receipts, lists of workers, or other similar documents.

Cemeteries: Realities and Pitfalls

Aspects of demography can be developed from data obtained by analyzing skeletal or mummified remains. There are, however, a number of issues that arise with this data. No cemetery sample fully and accurately reflects the population structure. The remains buried and excavated from a cemetery are a sample of those who lived at a particular time. Four major extrinsic factors affect the dead assemblage, and all tend to reduce the size of the sample so that it is much smaller than the original population. They are:

i) the proportion of all those who died that were buried at the site,
ii) the proportion of those who were buried whose remains survived to discovery,
iii) the proportion discovered, and
iv) the total excavated, recovered, and curated (Waldron 1994, 2007).

The final skeletal assemblage studied is therefore only a sample of those who lived, were buried, whose burial survived, and whose body could be discovered, excavated, and studied. It is a sample very much removed from the living population (fig. 3).
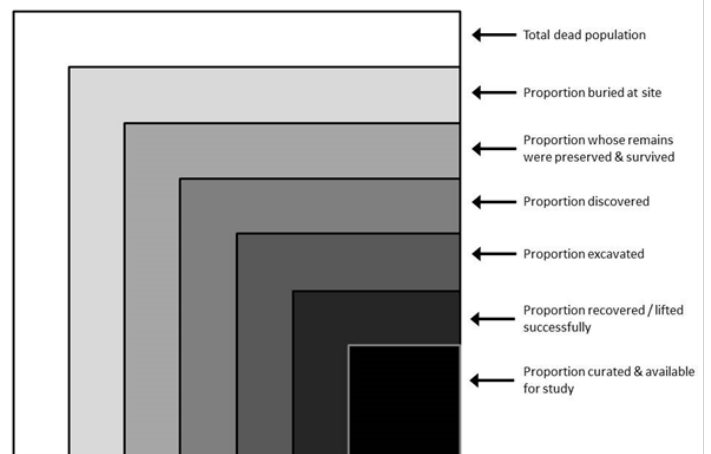

Figure 3. Diagrammatic representation of the reduction in skeletons or mummies available for study as a result of human and taphonomic processes.

The proportion of the dead that are buried at the site is itself complex. The dead individuals are not necessarily representative of the living population, as they are, by definition, dead. The buried population studied thus is related to the living population from which it originally derived, but it is not a straight and simple reflection of the composition of that living population. This is especially important when considering the interaction with disease and the aging process. Superficially, one might assume that a skeleton displaying greater number of pathological lesions was more "ill" than a skeleton not displaying any such lesions. Similarly, rationally, one might assume that if a population shows a higher proportion of skeletal lesions, or a lower age-at-death profile, the more "unhealthy" that population was relative to comparator groups. Paradoxically, this is not the case. Many diseases do not affect the skeleton. In addition, many people suffering from a disease that does leave pathological lesions on the bone may die before any pathological lesions form on the skeleton. As a result, those disease processes seen on the body do not fully represent the health or illness of the individual (Wood et al. 1992). This is the osteological paradox, whereby individuals expressing skeletal lesions of disease may be the healthier portion of the living population as they were the people who lived long enough with the disease to produce the skeletal markers of that disease. This means that they survived long enough to display the pathology. Furthermore, within any living population variation in susceptibility to disease exists (so-called "frailty"; Wood et al. 1992). Those individuals who are actually the most "sickly" or "ill" in a population may leave a skeleton bearing no evidence of disease, whereas those whose health was more robust in life may leave a skeleton exhibiting severe skeletal pathology due to their long survival with one or more infections. Furthermore, infection can reduce immunity to other infections, thereby also affecting mortality patterning, with the most "frail" being most susceptible to other disease processes.

Following this osteological paradox, the people recovered from a funerary context may have been more or less susceptible to disease or other biological stressors than the surrounding wider population (Wood et al. 1992). In addition, social customs for a particular period or place may restrict those who get a burial in such a way that the cemetery would never reflect the true distribution of deaths in the population. It is well-known that Egyptian graves and cemeteries were prone to disturbance as a result of grave robbing or agricultural or urban encroachment.

Taphonomic factors affect the relative preservation of burials in differing conditions, with small bones, such as those of juveniles, more rarely being preserved. Furthermore, samples available for study are commonly biased by their discovery and excavation methods. In Egypt, this is further complicated by the varying methods used by past excavators and their contractors. The skeletal and mummy samples curated in western museums are a product of this selection process, and so are biased in their composition. Most were selected for their "interest," be that their association with beautiful grave goods or for their palaeopathological lesions or for the completeness of their crania (see Hoffman 1979; Duhig 2000; or Zakrzewski 2001 for a discussion relevant to ancient Egypt). Examples include the Pearson 'E' series of skulls from Giza, selected by Petrie on the basis of their completeness and hence their suitability for the development of statistical techniques by Karl Pearson. The last variable affecting sample composition is the degree of curation and associated documentation, which impacts on the number of individuals available and suitable for study. Washing, processing, packing, and other such activities can all further reduce the number of individuals who comprise the sample for study. Current research has focused on recently excavated material, such as from Amarna (Kemp et al. 2013), Amara West (Binder et al. 2011; Binder 2014), Dakhla oasis (Rashed 2010; Wheeler et al. 2011; Haddow 2012), Tombos (Buzon 2006, 2008), and Gabati (Judd 2012), and thus does not suffer from the same issues with curation selection as skeletal collections developed in the nineteenth and twentieth centuries, such as Naga el-Deir (Podzorski 1990).

Age and Sex Estimation

In order to undertake demographic analyses, reliable and precise estimates of age and sex are required. Biological ages (as opposed to chronological or social ages) are estimated from markers of maturation and growth or markers of degeneration of the bones and teeth. Similarly, while it may seem odd to refer to the "estimation" of sex, the sex of skeletons (as opposed to mummies) can be treated as "known" only under certain circumstances, such as if sexing through genetic methods or the visual inspection of preserved external genitalia. Assigning sex and age categories to skeletal material involves errors and probabilities, and so this process should be considered as estimation or assessment rather than the determination of age and sex.

Although sex is of less importance than aging when considering the ancient Egyptian life span, it does have an impact on demographic studies. In an ideal situation, some individuals would form a reference sample of persons of "known" sex against which other individuals might be sexed. Ideally this would be done through genetic studies, but more commonly and practically involves using the Phenice (1969) pubic bone characteristics. Research is currently ongoing to develop metric methods for estimating sex for ancient Egyptians based on modern forensic methods (see Marlow 2013 for summary).

Biological age can more accurately be assessed for juveniles than for mature aged individuals. Long bone length, dental development, and timing of formation of ossification centers (zones in which bones form in juveniles as part of the growth process) and epiphyseal union (joining together of such separate bones as part of the growth and development process) can all be used to estimate age-at-death for subadult remains (Scheuer and Black 2000). Dental development is considered the most accurate means of estimating age-at-death in subadults because it is thought to be under the greatest genetic control (Scheuer and Black 2000). By adulthood, no further dental or bone growth occurs, and hence age estimation of adults relies on degenerative methods. The most

common methods include assessment of the pubic symphysis (anterior area of the pelvis; Brooks and Suchey 1990), auricular surface (where each of the two pelvic bones joins the sacrum at the base of the spine; Lovejoy et al. 1985; Buckberry and Chamberlain 2002), rib ends (İşcan et al. 1984), cranial sutures (Meindl and Lovejoy 1985), and dental wear (Brothwell 1981). Some of these, such as dental wear, are problematic for Egyptian samples as many ancient Egyptian teeth exhibit high grades of dental wear as a result of the foods consumed and the storage and processing methods used for those foods. Transition analysis and multifactorial methods (e.g., Boldsen et al. 2002; Uhl et al. 2011), based upon Bayesian analysis, appear hopeful in improving the accuracy and precision of Egyptian age estimates. These latter methods use "known" reference samples and survivorship models to estimate at what age those known aged individuals transition from one skeletal phase to another. In the absence of Bayesian methods, most bioarchae-ologists working in Egypt rely on multiple indicators to obtain the best estimates of age.

Skeletal and Mummified Assemblages

As noted earlier, there are issues with the overall representatives of assemblages of Egyptian skeletal and mummified material. Within western museum collections, skeletons have usually been obtained and curated as a result of historical personal connections between excavators, patrons, and/or museum curators. Many large Egyptian skeletal collections exist, such as the Phoebe Hearst Museum of Anthropology (UC Berkeley), the Duckworth Collection (Cambridge University), the Smithsonian National Museum of Natural History (Washington DC), the Natural History Museum (London), the Peabody Museum (Harvard University), the Naturhistorisches Museum (Vienna), and the Kasr el Aini medical school (Cairo) collections, but none can be said to be truly representative of either a site, a period, or even a complete cemetery. Large collections of mummies are rarer, but do exist in locations such as the Egyptian Museum. More commonly, individual mummies or a few mummies are

found in a variety of different museums, often brought to the west as a result of family travels or business transactions in the eighteenth and nineteenth centuries. Such collections are therefore not random and are rarely suitable for demographic studies. Following the pioneering work of the Manchester Mummy Project, and its development of the International Ancient Egyptian Mummy Tissue Databank (David 2008), "virtual" collections are being developed, so that biological data may be available to multiple researchers.

The osteological paradox influences our understanding of ancient Egyptian demography and longevity. Wood et al. (1992) showed that the absence of skeletal evidence of disease does not mean that there was an absence of disease; individuals may have died at either an early or acute phase of the disease, which would mean that those people died before their body developed lesions as a result of the disease. Furthermore, the implication of the osteological paradox is that individuals who exhibit skeletal markers of chronic disease may actually reflect long-term survival with such chronic conditions, and therefore may be the healthier individuals within the overall population. Furthermore many diseases affect only the soft tissues and so do not leave osseous signatures. This means that aspects of health are very hard to ascertain from the skeletal and palaeopathological record. Individuals who survived repeated episodes of stress and infection may have many skeletal markers of such episodes of ill-health or stress upon their bodies. This is likely to impact unevenly on the sample, as individuals who lived longer have had more time to become exposed to, and develop markers of, such stresses and diseases. This does not mean that older-aged individuals within a group were less healthy than younger individuals, but rather may imply that the frailer individuals died when they were young, but before they developed skeletal lesions.

Meaning of Age and Life Expectancy

So how old was the average ancient Egyptian when he/she died? It is impossible to obtain

such an estimate, but arguments should focus instead on variations in patterns of age profiles across Egypt, both in terms of time and place, and in the actual importance of chronological, biological, and social age. Skeletal and mummy studies permit biological age estimates to be made for individuals. These are not chronological ages, as they mark and evaluate the biological changes occurring to that particular person. Chronological ages, in terms of years, may be obtained from documentary sources. It is, however, hard to compare and link these two types of age. In addition, of potentially greater importance is social age. At what age was an individual considered to be a "person," a "child," an "adult," or eligible for marriage or suitable to be a worker? How do these social ages correlate with either biological or chronological ages? Were there social or corporeal markers to delineate such social age categories? Certainly some Egyptian texts contain clear descriptions of what it meant both to be a child and to become old (Janssen and Janssen 2007; Szpakowska 2008; Frood 2010).

Life expectancy at birth can be estimated in certain situations, as undertaken by Bagnall and Frier (1994) for the Roman Period. The key is to remember that life expectancy rises after the child's survival of the early years, and that life expectancy at birth is not the average age at which adults died within the Egyptian population. Some individuals certainly lived to an old age, and there are plentiful artistic representations indicating respect for elderly men, such as in the tomb of Sennefer (TT96; Meskell 2000; Janssen and Janssen 2007: 146). Despite the clear evidence for an idealized life span of 110 years (Moftah 1983), one should not expect many ancient Egyptians to have ever reached the age of 100 or 110 years (see Janssen and Janssen 2007: 197-203).

When a cemetery is well excavated, using current bioarchaeological and bioanthropological methods, and the skeletal preservation is good, it is possible to obtain good estimates for age-at-death for most individuals. This is easier for subadults, but, apart from the Kellis 2 cemetery at Dakhla oasis (Wheeler et al. 2011), these are not always as well represented in the Egyptian

archaeological record. In these cemetery situations, life tables or Bayesian hazard analysis might be employed, and estimates of life expectancy and the age-at-death structure of the sample obtained. In certain situations, mortality profiles developed may then be linked with other archaeological evidence, such as the seasonal peaks in mortality at Kellis 2 in the Dakhla oasis (Williams 2008).

Bibliographic Notes

Many of the references for palaeodemography are technical. Andrew Chamberlain's (2006) volume, *Demography in Archaeology*, is highly recommended as it explains the key concepts in an understandable format. An older text by Fekri Hassan (1981), *Demographic Archaeology*, also provides a clear introduction. A valuable reference on palaeodemography is the book by Hoppa and Vaupel (2002), entitled *Paleodemography*, which includes many papers of interest. Serious concerns have been raised about the validity of palaeodemography. The famous article by Bocquet-Appel and Masset (1982), who predicted the "death" of paleodemography, points out various theoretical problems with skeletal samples and is helpful in showing the bias inherent in a priori assumptions equating the age-at-death of a skeletal sample with the reference samples of life tables. Konigsberg and Frankenberg (1997), however, argue that palaeodemography is "not quite dead" using more sophisticated statistical methods based on Bayesian statistics and models. Their 2013 article also explains and clarifies such methods.

Bagnall and Frier (1994) provide detailed explanations of the use of Roman census data to obtain demographic information for Roman Egypt. Primarily using census data, they include calculations of fertility and mortality rates and estimates of age-at-marriage. Scheidel (2001) has developed these studies and applied demographic methods to mortality and disease in Roman Egypt. Concepts of age in ancient Egyptians are well considered by Janssen and Janssen (2007) in *Growing up and Getting old in Ancient Egypt* and more specialized treatment is provided by Frood (2007), *Biographical Texts from Ramessid Egypt*. They provide detailed sources from the literature as to how people of different ages and social standings were treated.

The methods used for assessing and estimating age and sex from skeletal markers are well presented in a variety of commonly available bioarchaeological texts. A recent book, edited by DiGangi and Moore (2013), *Research Methods in Human Skeletal Biology*, which includes the 2013 paper by Konigsberg and Frankenberg, provides a detailed critique of most commonly applied methods, and, as such, is recommended. Furthermore Milner et al. (2008) describe clearly the issues and recent advances in paleodemography and its application to skeletal samples.

Recent doctoral research using skeletons from cemetery HK43 at Hierakonpolis by Batey (2012) demonstrates the potential of such studies of demography and longevity, and might act as a valuable guide for future research into Egyptian life expectancy. Williams (2008) has pioneered such linking of mortality patterns with archaeological evidence from cemetery remains.

References

Bagnall, Roger, and Bruce Frier
 1994 *The demography of Roman Egypt.* Cambridge: Cambridge University Press.

Batey, Ernest King
 2012 *Population dynamics in Predynastic Upper Egypt: Paleodemography of cemetery HK43 at Hierakonpolis.* Unpublished PhD thesis, University of Arkansas.

Binder, Michaela
 2014 *Health and diet in Upper Nubia through climate and political change: A bioarchaeological investigation of health and living conditions at ancient Amara West between 1300 and 800 BC.* Unpublished PhD thesis, Durham University.

Binder, Michaela, Neal Spencer, and Marie Millet
 2011 Cemetery D at Amara West: The Ramesside Period and its aftermath. *British Museum Studies in Ancient Egypt and Sudan* 16, pp. 47-99.

Bocquet-Appel, Jean-Pierre, and Claude Masset
 1982 Farewell to paleodemography. *Journal of Human Evolution* 11, pp. 321-333.

Boldsen, Jesper, George Milner, Lyle Konigsberg, and James Wood
 2002 Transition analysis: A new method for estimating age from skeletons. In *Paleodemography: Age distributions from skeletal samples,* ed. Robert Hoppa and James Vaupel, pp. 73-106. Cambridge: Cambridge University Press.

Brooks, Sheilagh, and Judy Suchey
 1990 Skeletal age determination based on the os pubis: A comparison of the Acsádi-Nemeskéri and Suchey-Brooks methods. *Human Evolution* 5(3), pp. 227-238.

Brothwell, Don
 1981 *Digging up bones.* Ithaca: Cornell University Press.

Buckberry Jo, and Andrew Chamberlain
 2002 Age estimation from the auricular surface of the ilium: A revised method. *American Journal of Physical Anthropology* 119, pp. 231-239.

Buzon, Michele
 2006 Health of the non-elites at Tombos: Nutritional and disease stress in New Kingdom Nubia. *American Journal of Physical Anthropology* 130, pp. 26-37.
 2008 A bioarchaeological perspective on Egyptian colonialism in Nubia during the New Kingdom. *Journal of Egyptian Archaeology* 94, pp. 165-181.

Chamberlain, Andrew
 2006 *Demography in archaeology.* Cambridge: Cambridge University Press.

Coale, Ansley, and Paul Demeny
 1983 *Regional model life tables and stable populations.* 2nd edition. New York: Academic Press.

David, Rosalie
 2008 The background of the Manchester Mummy Project. In *Egyptian mummies and modern science*, ed. Rosalie David, pp. 3-9. Cambridge: Cambridge University Press.

DiGangi, Elizabeth, and Megan Moore (eds.)
 2013 *Research methods in human skeletal biology.* New York: Academic Press.

Dodson, Aidan, and Salima Ikram
 2008 *The tomb in ancient Egypt.* London: Thames & Hudson.

Duhig, Corinne
 2000 *"They are eating people here!" Skeletal indicators of stress in the Egyptian First Intermediate Period.* Unpublished PhD thesis, University of Cambridge.

Frood, Elizabeth
  2007   *Biographical texts from Ramessid Egypt.* Atlanta: Society of Biblical Literature.
  2010   Social structure and daily life: Pharaonic. In *A companion to ancient Egypt*, Vol. 1, ed. Alan B. Lloyd, pp. 469-490. Oxford: Wiley-Blackwell.

Haddow, Scott
  2012   *Dental morphological analysis of Roman era burials from the Dakhleh Oasis, Egypt.* Unpublished PhD thesis, University College London.

Hassan, Fekri
  1981   *Demographic archaeology.* New York: Academic Press.

Hoffman, Michael
  1979   *Egypt before the pharaohs.* New York: Knopf.

Hoppa, Robert, and James Vaupel (eds.)
  2002   *Paleodemography: Age distributions from skeletal samples.* Cambridge: Cambridge University Press.

İşcan, M. Yaşar, Susan Loth, and Ronald Wright
  1984   Metamorphosis at the sternal rib end: A new method to estimate age-at-death in white males. *American Journal of Physical Anthropology* 65, pp. 147-156.

Jansen-Winkeln, Karl
  1993   The career of the Egyptian high priest Bakenkhons. *Journal of Near Eastern Studies* 52, pp. 221-225.

Janssen, Rosalind, and Jac. J. Janssen
  2007   *Growing up and getting old in ancient Egypt.* London: GHP.

Judd, Margaret
  2012   *Gabati: A Meroitic, Post-Meroitic and Medieval cemetery in Central Sudan. Vol 2: The physical anthropology.* London: Sudan Archaeological Research Society.

Kemp, Barry, Anna Stevens, Gretchen Dabbs, Melissa Zabecki, and Jerome Rose
  2013   Life, death and beyond in Akhenaten's Egypt: Excavating the South Tombs Cemetery at Amarna. *Antiquity* 87 pp. 64-78.

Konigsberg, Lyle, and Susan Frankenberg
  1997   Paleodemography: "Not quite dead". *Evolutionary Anthropology* 3, pp. 92-105.
  2013   Demography. In *Research methods in human skeletal biology*, ed. Elizabeth DiGangi and Megan Moore, pp. 293-322. New York: Academic Press.

Lovejoy, C. Owen, Richard Meindl, Thomas Przybeck, and Robert Mensforth
  1985   Chronological metamorphosis of the auricular surface of the ilium: A new method for the determination of adult skeletal age-at-death. *American Journal of Physical Anthropology* 68, pp. 15-28.

Marlow, Emily
  2013   The applicability of modern forensic anthropological techniques to ancient Egyptian skeletal remains. In *Current research in Egyptology 2012: Proceedings of the Thirteenth Annual Symposium, University of Birmingham 2012*, ed. Carl Graves, Gabrielle Heffernan, Luke McGarrity, Emily Millward, and Marsia Sfakianou Bealby, pp. 103-116. Oxford: Archaeopress.

Meindl, Richard, and C. Owen Lovejoy
  1985   Ectocranial suture closure: A revised method for the determination of skeletal age-at-death based on the lateral-anterior sutures. *American Journal of Physical Anthropology* 68, pp. 57-66.

Meskell, Lynn
  2000   Cycles of life and death: Narrative homology and archaeological realities. *World Archaeology* 31, pp. 423-441.

Milner George, James Wood, and Jesper Boldsen
  2008   Advances in paleodemography. In *Biological anthropology of the human skeleton*, 2nd edition, ed. M. Anne Katzenberg and Shelley Saunders, pp. 561-600. Hoboken: Wiley-Liss.

Moftah, Ramses
  1983   Lebenszeit und Verheissungen in den Biographien. *Annales du Service des Antiquités de l'Égypte* 65, pp. 91-109.

Phenice, Terrell W.
  1969   A newly developed visual method of sexing the os pubis. *American Journal of Physical Anthropology* 30, pp. 297-301.

Podzorski, Patricia
  1990   *Their bones shall not perish.* New Malden: SIA Publishing.

Rashed, Tamer Gad
  2010   *Biological relationships of ancient Egyptians.* Saarbrücken: Lambert Academic.

Scheidel, Walter
  1998   The meaning of dates on mummy labels: Seasonal mortality and mortuary practice in Roman Egypt. *Journal of Roman Archaeology* 11, pp. 285-292.
  2001   *Death on the Nile: Disease and the demography of Roman Egypt.* Leiden: Brill.
  2012   Age and health. In *The Oxford handbook of Roman Egypt*, ed. Christina Riggs, pp. 305-316. Oxford: Oxford University Press.

Scheuer, Louise, and Sue Black
  2000   *Developmental juvenile osteology.* San Diego: Academic Press.

Szpakowska, Kasia
  2008   *Daily life in ancient Egypt.* Oxford: Wiley-Blackwell.

Uhl, Natalie, Nicholas Passalacqua, and Lyle Konigsberg
  2011   A Bayesian approach to multifactorial age-at-death estimation. *Proceedings of the American Academy of Forensic Sciences (AAFS) Annual Meetings* 17, p. 339.

Waldron, Tony
  1994   *Counting the dead.* New York: John Wiley.
  2007   *Palaeoepidemiology.* Walnut Creek: Left Coast Press.

Walker, Phillip, John Johnson, and Patricia Lambert
  1988   Age and sex biases in the preservation of human skeletal remains. *American Journal of Physical Anthropology* 76, pp. 183-188.

Wheeler, Sandra, Lana Williams, Tosha Dupras, Matthew Tocheri, and J.El Molto
  2011   Childhood in Roman Egypt: Bioarchaeology of the Kellis 2 Cemetery, Dakhleh Oasis, Egypt. In *(Re)Thinking the little ancestor: New perspectives on the archaeology of infancy and childhood*, BAR International Series 2271, ed. Mike Lally and Alison Moore, pp. 110-121. Archaeopress: Oxford.

Williams, Lana
  2008   *Investigating seasonality of death at Kellis 2 Cemetery using solar alignment and isotopic analysis of mummified tissues.* Unpublished PhD thesis, University of Western Ontario.

Wood, James, George Milner, Henry Harpending, and Kenneth Weiss
  1992   The osteological paradox: Problems of inferring prehistoric health from skeletal remains. *Current Anthropology* 33, pp. 343-370.

Zakrzewski, Sonia
  2001   *Continuity and change: A biological history of ancient Egypt.* Unpublished PhD thesis, University of Cambridge.

Image Credits

Figure 1. Mortality profile (A) and survivorship curve assuming a cohort of 100,000 (B) for Roman women (derived from Bagnall and Frier 1994).

Figure 2. Distribution of Roman female deaths by age, calculated from life table using a theoretical population of 100,000 females from Bagnall and Frier (1994). e_0 = life expectancy at birth; e_5 = life expectancy at age 5; e_{20} = life expectancy at 20.

Figure 3. Diagrammatic representation of the reduction in skeletons or mummies available for study as a result of human and taphonomic processes.