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The Economic Consequences of Childhood Anemia in Imperial Italy: The Evidence and Interpretation of Skeletal Remains.

In 2005, a mother brought a severely ill 11 month old infant into an Australian hospital. The doctor who examined the infant became so outraged by the condition of the infant and the cause of his condition that he published a case study of the infant in a major medical journal. His title, “Goat’s Milk Quackery”, highlights the central concern. The infant’s mother had stopped breastfeeding at two weeks, used a commercial formula for one week, and then switched to a recipe found in a new age childrearing publication, which happened to enjoy wide distribution. This homemade formula called for barley water, corn syrup, and goat’s milk. After 10 months on the formula, the unimmunized infant weighed in at the 10th percentile and had a body length at the 3rd percentile. Furthermore, he suffered from severe iron deficiency anemia.¹

This infant’s condition is of great interest for the study of child development and its attendant economic consequences in Roman Italy during the first four centuries A.D. Iron deficiency anemia represents the most important skeletal manifestation of nutritional and disease status identifiable from Greco-Roman antiquity. In nearly all paleopathological publications, osteoarchaeologists analyze the bone that constitutes the upper orbit of the eye for evidence of a lesion known as Cribra Orbitalia², a characteristic manifestation of iron deficiency anemia.³

¹ Ziegler, D.S. et.al. “Goat’s Milk Quackery.” *Journal of Pediatrics and Child Health*. v.41 no.11 (Nov. 2005) pp. 569-571.

² Archaeologists also record the presence of porotic hyperostosis, a lesion located on the surface of the skull, but too infrequently recorded in my samples to include in this discussion. See: Roberts, Charlotte and K. Manchester. *The Archaeology of Disease*. 2nd ed. (Ithaca, 1995). pp.165-171.

³ However, after nearly four decades as orthodoxy, iron deficiency anemia as the causal force behind porotic hyperostosis and cribra orbitalia has recently received a strong challenge based on physiological explanations of red blood cell production and destruction. “In this article, we have shown that iron-deficiency anemia does not provide a reasonable physiological explanation for the marrow hypertrophy that produces the pathological lesions paleopathologists refer to as porotic hyperostosis and cribra orbitalia. Humans respond to iron-deficiency anemia by restricting RBC production rather than increasing it. As a result, iron-deficiency anemia cannot logically be considered the cause of the marrow expansion that produces porotic hyperostosis and some forms of cribra orbitalia.” Walker, P. L., R.R. Bathurst, et al. “The Causes of Porotic Hyperostosis and Cribra Orbitalia: A Reappraisal of the Iron-Deficiency-Anemia Hypothesis.” *American Journal of Physical Anthropology*. 139 (2009), 109-125 at 119. Provided their conclusions, primarily that B-12 and B-9 deficiencies are responsible for anemia, achieve scientific

The exact nature of the interaction between nutrition and disease processes that produces these lesions remains a matter of scientific debate. Malnutrition through its own agency can create anemia, as evidenced by the above case, and if prolonged could produce changes in the bone structure. That the Australian infant presented with signs of severe anemia and no associated disease processes is unusual. Scientists believe that it is the combination of malnutrition and disease processes that lead to the chronic anemia which threatens infant survival (and would thus be severe enough to produce a reaction in the bone marrow sufficient to produce Cribra Orbitalia). Evidence from the modern developing world supports this point. Rarely do juveniles present evidence of iron deficiency anemia without an associated disease. Thus high rates of anemia often correlate with high rates of infectious disease.⁴ How exactly, malnutrition and disease interact to create higher morbidity and mortality can be quantified in epidemiologic and statistical models.⁵ From these models, scientists have substantiated the observed synergy between malnutrition and disease in the developing world. Whereas once malnutrition was believed to contribute to mortality in an additive fashion, new models demonstrate that:

the mortality rate at a given level of disease exposure depends on the potentiating effect of malnutrition... Thus you cannot partition malnutrition and cause of death. The relative contribution of malnutrition to mortality depends on morbidity rates, and the contribution of morbidity varies due to malnutrition... These results highlight the need to elucidate the mechanisms by which malnutrition increases the fatality rate per exposure.⁶

consensus, the model proposed here allows for substitutions that do not invalidate the methodology proposed. For a discussion of the science behind these developments, see: Borelli, P. et.al. "Reduction of Erythroid Progenitors in Protein-Energy Malnutrition." *British Journal of Nutrition* 97:2 (2007), 307-308. Another potential source of anemia in children is Glucose-6-Phosphate Deficiency. The genetic deficiency occurs most often in areas with endemic malaria (400 million living individuals carry the deficiency). In children, haemolysis (the destruction of red blood cells) as a result of infection can lead to severe and persistent anemia. Such persistent hemolytic anemia suggests a potential for hypertrophy in the marrow. See: Cappellini, F. "Glucose-6-Phosphate Deficiency." *Lancet* 371:9606 (2008), 64-74 and Yilidirim, Tulin et.al. "MRI Evaluation of Cranial Bone Marrow Signal Intensity and Thickness in Chronic Anemia." *European Journal of Radiology* 53:1 (2005), 125-130.

⁴ Lozoff, B. et.al. "Long Term Development Outcome of Infants with Iron Deficiency." *New England Journal of Medicine*. v.325 no.10 pp. 687-694. Ferreira, M.V. et.al. "Anemia and Iron Deficiency in Schoolchildren, Adolescents, and Adults: A Community Based Study in Rural Amazonia." *American Journal of Public Health*. v.97 no.2 (Feb, 2007) pp. 237-239.

⁵ Alter, George. "Height, Frailty, and the Standard of Living: Modelling the Effects of Diet and Disease on Declining Nutrition and Increasing Height." *Population Studies* 58:3 (2004), 265-279.

⁶ Pelletier, David. L. et.al. "Epidemiologic Evidence for a Potentiating Effect of Malnutrition on Child Mortality." *Amer. Journ. of Public Health*. v.83 no.8 (Aug,1993) pp.1130-1135 at 1132-1133.

One of the aims of this paper is to come to some understanding of the characteristic lesions on skeletons recovered from Imperial Italy. How anemic are the children of Imperial Italy? At what rate can we expect anemic children to survive? How do these children acquire anemia? What is the role of disease and the role of nutrition in this process?

Paleopathology does not yet provide a sufficient data set to answer any of these questions directly.⁷ It is debatable as to whether it ever will. Not only are the sample sizes generally very small, but the biases of the data are readily apparent; Skeletons recovered from graveyards highlight only those who died at a particular age and their related health circumstances. The living population cannot be accessed through the sample except by complicated statistical models, whose creators often acknowledge the vast limitations imposed on the models by the nature of the evidence.⁸ Furthermore, the data sets recovered recently in Imperial Italy are too scattered throughout time to allow for reasonable generalizations from the evidence itself.

These limitations highlight the need to build a body of comparable evidence in order to generate the necessary data set to take advantage of modern epidemiologic models. Most importantly, the WHO has developed a model that allows for estimation of the disease burden of malnutrition, which highlights interaction between childhood malnutrition, disease, and mortality (discussed and elaborated below). If this model could be adapted and applied to the specific conditions of antiquity, then scholars would have a new resource that would allow them to make more careful and detailed demographic models of the population. Whereas the majority of modern epidemiologic models require data inputs that no skeletons from antiquity can reveal or even approximate, the WHO model allows for the easy quantification of malnutrition through the input of anthropometry as part of the model. In living populations this can be done with weight-for-age. However, length/height-for-age is also widely recognized as an indicator of childhood nutritional and disease status. Thus the model will allow for a substitution that

⁷ Koepke, Nikola and Joerg Baten. "The Biological Standard of Living in Europe during the last Two Millennia." *European Review of Economic History*. v.9 (2005) pp. 61-95. When the authors set out to estimate the height of the populations of antiquity during the 1st four centuries A.D., they were only able to collect 160 total skeletons on which to conduct height measurements from the "Mediterranean", which they defined as Spain, Italy, and the Balkans.

⁸ Boquet-Appel, J.P. and C. Masset. "Paleodemography: Expectancy and False Hope." *Am. Journ. of Physical Anthropology*. v.99 no.4 (1996) pp.571-583.

could permit the input of skeletons from antiquity augmented by reasonably derived comparative data in order to complete the necessary steps. Furthermore, many of the diseases, for which the model provides standardized relative risk estimates, were common in antiquity: diarrhea, malaria, and acute respiratory infections.⁹ If this model could be applied to antiquity, then historians would have a better understanding the intersection of childhood malnutrition, morbidity, and mortality. Such data could be used to correct many of the long standing problems with current demographic models of the Roman population, particularly the Coale-Demeny models that have come under increasing criticism.¹⁰ In addition, the data derived from the WHO model allows for a better understanding of the potential work output of a population. Recent studies have shown a direct correlation between childhood health and long term health. Height, weight, and constitution all affect a worker's ability to produce labor or food to feed his family.¹¹ Simply put, "most jobs require a substantial amount of physical exertion [in both developing and pre-modern contexts]. Work capacity, as measured by maximal oxygen consumption, is closely related to body size, including height."¹²

The general applicability of the WHO model stems from the circumstances of its creation. Anthropometric measures (height, weight) are now accepted as measures of

⁹ Blossner, Monika et.al. *Malnutrition: Quantifying the Health Impact at National and Local Levels*. WHO Environmental Burden of Disease Series no. 12 (Geneva, 2005).

¹⁰ See Scheidel, Walter. "Roman Age Structure: Evidence and Models." *JRS*. v. 91 (2001) pp.1-26. Scheidel makes very important points about the nature of the evidence that is used to build the Coale-Demeny models. He successfully, in my opinion, shows that they fail to capture the mortality regime of the pre-modern world due to their decision to leave out certain data sets (epidemic, famine, war) that would have resulted in life tables more akin to the demographic environment of the Roman world. His solution to the problem is to conduct a series of highly local studies in their specific ecological contexts. From these it is hoped that more accurate life tables could be constructed. I am, however, not as sure about the need for highly local studies Even if we were able to establish a series of studies for particular regions, in what manner could the data be compared. The model proposed for use by this study can be used at both local and national levels which indicates that the specificity of ecological circumstances required by Scheidel is not shared by the frontline workers of the developing world (the WHO). Moreover, the WHO model is applicable across the modern world and is used currently to compare the health status of distinct nations. If applied in this way to specific Roman contexts: Imperial Italy, Imperial Greece, Imperial Egypt, the data sets from each of these studies would be comparable due the use of the same methodology. Highly localized archaeological studies, as will be shown by my discussion of Herculaneum, do not often produce the relevant data sets for generalization because archaeologists seek specific answers to their own questions. Thus the published data from many highly local excavations is insufficient for questions about health and demography unless specific data sets are recorded and published.

¹¹ Blackwell, D.L. et.al. "Does Childhood Health Affect Morbidity in Later Life?" *Social Science and Medicine*. v.52 no.8 (April,2001) pp.1269-1284. Komlos, John. "Patterns of Children's Growth in East-Central Europe in the Eighteenth Century." *Annals of Human Biology*. v.13 no.1 (Feb, 1986) pp.33-48.

¹² Elo, Irma T. et.al. "Effects of Early Life Conditions on Adult Mortality: A Review." *Population Index*. v.58 no.2 (Sum, 1992). pp.186-212 at p. 194.

childhood health status. Recent studies have examined the correlation between childhood height and mortality. In one modern study, conducted in Indonesia, children, who were under 90% height for age during the first year experienced an infant mortality rate of 173.9 per 1000, whereas those infants above 95% height-for-age experienced an infant mortality rate of 28.7 per 1000. For those infants who fell into the middle category (90-94% height-for-age) infant mortality still showed evidence of increased risk (84.8 per 1000). 90% height-for-age represents severe growth retardation (more than two standard deviations from the mean according to the most recent WHO child development charts)¹³ and highlights the increased risk of mortality to undersized infants and children.¹⁴ Thus the height of infants represents one measure of their nutritional and disease status.

Adult heights, in contrast, lack the same comparability. One recent study has shown that simple increase in the nutritional status of a population can have a vast increase on attained adult heights over the course of one generation.¹⁵ Further studies have revealed that differences in height caused by factors (genetics, altitude, etc) beyond malnutrition and disease do not truly manifest themselves until after the age of five. Thus children under the age of five should share comparable development patterns in the modern world and are compared with reference to single series of growth charts developed by the WHO. No current argument exists as to why the information would not be relevant for juvenile development in antiquity.¹⁶

Consequently, the recovery of juvenile skeletons represents the most important potential data set for the reconstruction of the burdens of disease and its relationship to malnutrition on the mortality profile of Roman Italy. Peter Garnsey presaged this development nearly 20 years ago:

We might have completely passed over the matter of infant malnutrition, under the influence of the mainstream medical writers of antiquity, who do not notice, or fail to comment on the phenomenon. Yet in contemporary developing countries infants are easily identifiable as a group especially at risk, notably during the early periods of fast growth. Armed with this information, we can search the ancient evidence for relevant deficiency diseases.¹⁷

¹³ http://www.who.int/childgrowth/standards/height_for_age/en/index.html

¹⁴ Pelletier, D.L. "The Relationship between Child Anthropometry and Mortality in Developing Countries." *Journal of Nutrition*. v.124 (2004) Supplement. pp. 2047-2081.

¹⁵ Noguero, Luiz P. et.al. "Seis Centímetros: Uma Análise Antropométrica da POF 2002-2003" *XXXIII Encontro Nacional de Economia*. pp.1-17. Available at www.anpec.org.br/encontro-2005.htm.

¹⁶ Blossner, p.4.

¹⁷ Garnsey, Peter. *Cities, Peasants, and Food in Classical Antiquity* (Cambridge, 1998). p.251. reprint of "Mass Diet and Nutrition in the City of Rome" from: *Nourrir la Plebe...* ed. F.Reinhardt (Basel, 1991).

Paleopathological publications for antiquity have not followed these developments. In a recent study of the victims discovered on the beach at Herculaneum, Luigi Capasso chose not to publish any anthropometric data for the juvenile skeletons recovered. The adult skeletons were subjected to perhaps the most thorough treatment available from modern science (including x-rays, ct-scans, etc...) but the evidence from adult skeletons only shows the end result of childhood growth processes. The absence of anthropometric data for juveniles is exacerbated by the fact that Capasso choose not to publish a single measurement of the long bones typically used to reconstruct height from skeletons. Instead, he focused his height measurement methods on cranial size, which precludes juveniles from the analysis. Consequently, the most important paleopathological sample from antiquity, due to its special circumstances of deposition, offers no help for this investigation. Only a complete restudy of the juvenile skeletons and the production of height estimates for those skeletons will allow for any interpretation of the average heights in Herculaneum, which for adults were 163.8 cm for males and 151.6 for females.¹⁸ For present purposes, tentative reconstruction must be made from the adult heights provided by the Herculaneum excavation, though any conclusion must be regarded as more speculative. The WHO child growth reference charts state that a healthy male should reach a mean height of 176.5 cm with standard deviations being 169.2 (-SD1) to 183.8 (SD1). A healthy adult female should reach a mean height of 163.2 cm with standard deviations being 156.6 cm (-SD1) and 169.7 (SD1). Herculaneum would appear therefore to be a characteristically unhealthy population given the current data on height and mortality.

Moreover, the nature of the deposition prohibits any easy demographic solutions that might provide direct reconstructions of the infant mortality profile from the skeletons, highlighting the further need for an adequate model. Simply put, the sample does not appear to be random. The age structure of the skeletons does not fit any known or hypothesized demographic projection from antiquity, nor should it (those that died on a beach for whatever reason). Capasso has forgotten this important point, and his

¹⁸ Capasso, Luigi. *I Fuggiaschi di Ercolano: Paleobiologia delle Vittime dell'Eruzione Vesuviana del 79 d.C.* (Rome, 2001). See pg. 927 for the height averages.

interpretation of even the adult data set has the potential to confuse further research. “The age distribution of these individuals, and the reconstruction of the demographic profile of the whole population, demonstrates high infant mortality (20.3% are under 10 years) and few people over 50 years, or about 8.4%.”¹⁹ In a separate study of the same skeletons from Herculaneum, Capasso lists the ages at death of the skeletons found on the beach and then proceeds to act as if the numbers from this sample can be directly equated to the age structure of the assumed population of 5000. The age cohort 15-19.9 years is significantly underrepresented based on the accepted age structures of pre-modern populations when compared to surrounding age cohorts. The beach skeletons only contain 7 individuals in this age category. Surrounding cohorts have 14 and 17 representatives. Capasso chooses to explain the discrepancy by arguing that an earthquake of 62 A.D. killed many of the inhabitants and thus changed the expected age structure of the population.²⁰ His interpretation seems exceptionally weak, and perhaps not even plausible. Given that the sample at Herculaneum cannot be generalized for the entire population of the town directly, and any statistical model will only produce hypothetical reconstructions, the evidence still can benefit our reconstruction of the disease profile in the area if we assume that beach skeletons provide a mere snapshot of the population not a random sample. The picture created shows an unexpectedly low number of individuals in the 15-20 year old age group. What factors could explain their low number outside of migration or earthquakes? Certain respiratory diseases, such as tuberculosis and malaria, are known to have greater mortality and higher infection rates in post adolescent males.²¹ A more credible argument, therefore, for Roman Italy in the first century would have explored the influence of malaria, tuberculosis and other respiratory illnesses on this population.

For any study of Imperial Italy in the 1st-4th centuries A.D., malaria must stand as a central focus of investigation. It has very powerful effects on the demography of a population. In 19th century Italy, communities separated by small difference in altitude could evince distinct patterns of mortality, which could skew life expectancy at birth

¹⁹ Capasso, L. “Infectious Disease and Eating Habits at Herculaneum.” *Int. Journ. of Osteoarchaeology*. v.17 (2007) pp.350-357.

²⁰ Capasso, L. “Mortality in Herculaneum before the Volcanic Eruption of 79 A.D.” *Lancet* v.354 Issue. 9192 (Nov, 1999) p.1826.

²¹ Elo, p.187.

from 20 to 37 years of age depending on the effects of malaria. Malaria has its greatest effect around the age of 20, when populations in very malarial areas begin to deviate from expected mortality patterns. One recent study found that certain areas in 19th century Italy could match the Coale-Demeny Life Table Model West 6 for the population under 20, but revert to Model West 2 or even 1 for the population over 20.²² When the WHO applied its model to Nepal (not exactly a hotbed of malaria compared to the Pontine Marshes of Imperial Italy), the model showed that 4% or nearly 3000 child fatalities per year could be attributed to the synergistic effects of malaria and malnutrition in Nepal. Malaria was a significant problem in Imperial Italy, responsible for vastly more childhood fatalities than 4% per annum.²³

The WHO model offers one excellent possibility of coming to grips with the reality of the disease burden of malnutrition in the Roman period. If Roman historians could hypothetically quantify the impact of malnutrition and diseases on the population, then a whole series of potential further studies are possible. The effects of epidemic disease become far easier to understand. The work output of the average citizen can be quantified given known statures and disease conditions. Unfortunately, the current state of paleopathological evidence from Imperial Italy prohibits even a cursory execution of the model. However, our current inability to run the model fully does not preclude a useful investigation of the data sets required to fulfill the conditions of Step 1 of the WHO model. As will become evident, the inputs for Step 1 can be discovered and estimated for Roman Italy, but the exact method by which the numbers are created requires careful thought and debate.

In abbreviated form, the WHO lists the model procedure as follows²⁴:

Step 1: Assess exposure in the study population (by population based surveys or surveillance systems) in terms of:

- the percentage of children younger than five who have low weight-for-age²⁵ (here substitute height-for-age for antiquity) compared to the median of the WHO international growth reference charts
- the percentage of low weight newborns
- the mean and the SD of the BMI for women 15-44 years old.

²² Sallares, Robert. *Malaria and Rome: A History of Malaria in Ancient Italy* (Oxford, 2002). p.3.

²³ Blossner, p.32.

²⁴ Blossner, p.9.

²⁵ The WHO defines low weight-for-age as those juveniles who are greater than -2SD from the mean according to the WHO international growth reference charts.

Steps 2-11 use this data by processing it through a series of worksheets that produce estimations based on the mathematics underlying the model. For example:

Step 2: Derive the percentages of children who are severely, moderately, and mildly malnourished. This is done by estimation using the worksheet “exposure”.

Step 3: Derive the attributable fractions for child mortality by estimation. Use the worksheet labeled “PAFs” and the worksheet “Mortality”.

Step 1 assesses the level of malnutrition in the population by anthropometry. Malnutrition correlates directly to disease due to the fact that unhealthy bodies are subjected to more successful exposures to diseases. The subsequent steps employ a series of standard risk estimates for certain diseases based on a global survey by the WHO. The model continues to build until the data are fully compiled and the burden of disease, its relationship to malnutrition, and the total mortality due to disease and nutrition can be compiled. Step 1 is by far the most important step and the most interesting. Any quantification or approximation of the level of malnutrition in a population is important and this paper provides preliminary estimates for the three subcategories of Step 1 and thus some estimation of malnutrition in Imperial Italy (see conclusion).

The first part of Step 1 requires that one identify the percentage of children in a study population who have low weight-for-age. An immediate problem arises for the study of antiquity because we lack reported ages, which must be contrasted against the anthropometric data in order to develop a distinction between real age and skeletal growth. In this way, the WHO calculates the percentage of undersized children. This problem is not insurmountable. Dentition is preprogrammed genetically. Thus the growth of teeth does not respond to nutritional or disease stress. Rather, characteristic lines develop in the enamel, known as an Enamel Hypoplasia, during periods of nutritional stress. Studies of pre modern populations have found that dental age and skeletal age show their greatest divergence in sub-adult males exposed to nutritional and disease stress (skeletal ages in one study averaged 13.4% below dental age).²⁶ Thus juvenile

²⁶ Van Gervan, D.P. et.al. “The Health and Nutrition of a Medieval Nubian Population: The Impact of Political and Economic Change.” *American Anthropologist*. ns. v.97 no. 3 (Sept, 1995) pp. 468-480 at pp.474-475.

skeletons from antiquity should be classified both according to dental age, a process not currently undertaken.

In the absence of teeth, cribra orbitalia may represent the only method for indicating any variation between the age of skeleton and the real age of the victim. Thankfully, most excavations employ a classification scale that ranks the severity of Cribra Orbitalia. In this manner, it is possible to determine whether the individual was currently suffering from an onset of anemia and thus some combination of malnutrition and disease, how long the individual had suffered, and what the potential effects may have been on his/her growth. One recent study of the Roman necropolis at Vallerano illustrates the potential of such a classification system. Vallerano is situated to the southeast of Rome, in what the authors term the *Suburbium* to illustrate its geographical proximity to the city, and the skeletons come from the 2nd and 3rd centuries A.D. The authors employed a 0-7 grading system for Cribra Orbitalia lesions in excavated skeletons. They found that the degree of intensity in their sample (69.2% of which had Cribra) is inversely related to the age at death. Moreover, the sample revealed a much higher and more intense incidence of Cribra Orbitalia in adult females (85.7%) than adult males (50%). Subadults showed by far the greatest incidence (100%) and the highest degree of intensity (gradable lesions were between grades 4-7). Furthermore, one third of adult male skeletons have Grade 0 classified Cribra Orbitalia. Grade 0 lesions represent those lesions that were active in childhood but have healed over time normally due to decreased nutritional requirements.²⁷

The profile of Cribra Orbitalia discovered at Vallerano conforms to expected predictions based on modern understandings of dietary requirements. Pregnant women and children have the highest iron requirements. A pregnant woman requires 3.5 mg of iron beyond the normal dietary requirements. In the modern world, this is often met through iron supplementation as few meat sources offer enough iron.²⁸ The iron requirements of developing children are 10 mg per day, and the sources of food at Vallerano were clearly insufficient for these at risk populations, resulting in high incidences of malnutrition and disease. That the juvenile skeletons all show active Cribra

²⁷ Cucina, A. et.al. "The Necropolis of Vallerano: An Anthropological Perspective on the Ancient Romans in the Suburbium." *Int. Journ. of Osteoarchaeology*. v.16 (2006) pp.104-117.

²⁸ Van Gerven, p.297.

Orbitalia of the highest grades indicates that their levels of anemia were moderate to severe, but the actual cause of these lesions and of death (disease or malnutrition) cannot be specifically determined. Cribras do not develop in periods of epidemic disease or as a result of famine. Instead, they illustrate more long term processes at work in the body that are persistent for a long enough period to affect the development of the bone. The severity of the lesion, therefore, indicates the severity and duration of the anemia that underlies it.

The pattern of Cribra Orbitalia from Vallerano can be found in many other excavations from Imperial Italy. At Ravenna and Rimini (1-4th c. A.D.), Cribra Orbitalia was found in 85% of juvenile skeletons, 40% of adult male skeletons, and 55% of adult female skeletons. This excavation rated the severity of the lesions on a scale from 1-3. Adult males concentrate in the lowest grade, with juveniles and adult females possessing the majority of grade 2 and 3 lesions.²⁹

Historians have often explained this pattern by reference to the generally accepted conditions of the Italian diet. Imperial Italians ate lots of grain, in some estimates 70-75% of food energy came from this source. In addition, wheat does not lack in many of the nutrients necessary for healthy functioning of a male adult. A single kilogram of soft wheat can provide more than 3,000 calories of energy, and contains four milligrams of iron, which could meet an adult male requirement with little assistance from other food sources.³⁰ Consumption, for the poor, was augmented by the addition of lentils and other legumes.³¹ Oil and Wine added more calories to the diet, but the only source generally available source of animal protein came from pork and pork products.³² Pork is a poor source of iron, a fact which was only discovered in the early 20th century. The scientists who conducted the initial studies of iron content in proteins discovered that “Beef and

²⁹ Facchini, F. et.al. “Cribra Orbitalia and Cribra Cranii in Roman Skeletal Remains from the Ravenna Area and Rimini.” *Int. Journ. of Osteoarchaeology*. v.14 (2004) pp.126-136.

³⁰ Garnsey, Peter. *Food and Society in Classical Antiquity* (Cambridge, 1999) pp.19-21.

³¹ Flint-Hamilton, K.B. “Legumes in Ancient Greece and Rome: Food, Medicine, or Poison?” *Hesperia*. v.68 no.3 (July-Sept, 1999).

³² Garnsey, *Food*, p.126. See also. King, Anthony. “The Romanization of Diet in the Western Empire: Comparative Archaeozoological Studies.” In ed. Terrenato. *Italy and the West: Comparative Issues in Romanization* (Oxford, 2001). pp.210-224. King argues that pig consumption extended down the social scale in Roman Italy, but he offers inconclusive evidence to demonstrate exactly how far down the scale such meat consumption extended.

veal contain two-thirds more iron than do pork and lamb.”³³ Fish do not offer any assistance, so those nearest to the coast cannot have benefited too greatly over their counterparts in the interior. Three ounces of fish in fact have one-sixth the iron of a cup of lentils. As such, women and children, who have higher iron requirements, would have experienced episodic iron deficiency absent any diseases.

In addition, a diet high in cereals is also a diet high in the phytates that accompany any grain. Phytates inhibit the absorption of much of the high iron content in the grains themselves or any other iron sources in the diet. High quality naked grains have fewer phytates, whereas barley and other coarse grains have high phytate content. Current research suggests that the Roman population in general ate coarser grains at lower levels of income. Consequently, the data suggest, given the high incidence of Cribra in our samples, that Italians on average had difficulty regulating their iron needs, and that the diet they consumed put at risk groups into a nearly permanent state of malnutrition until their own bodies alleviated their dietary needs by the end of growth or menopause.³⁴

The introduction of disease further complicates this picture. Malaria requires iron for reproduction within the human body. For the study of Imperial Italy this creates a paradox in our evidence, which suggests two possible reasons for the high incidence of malaria known from Imperial Italy: low iron absorption creating free iron in the bloodstream or higher iron consumption than hypothesized. Either cause would produce equally deleterious effects,³⁵ and studies of molecular biology have demonstrated that in areas of Italy, malaria infection was an endemic problem during antiquity.³⁶ Thus males,

³³ Forbes, E.W. et.al. “The Iron Content of Meats.” *Journal of Biological Chemistry*. v.67 (Feb, 1926) pp.517-521 at p.521.

³⁴ Garnsey, Food. p.21, Facchini. p.133.

³⁵ Cucina, p.114. The sample from Vallerano, a Villa near Rome, exhibited very few oral pathologies, especially cavities. Given that cavities are most commonly associated with a diet high in cereals, the authors believe that those at Vallerano had next to no access to refined grains. As a result, their teeth were in vastly better shape than other cohorts excavated around Rome. However, the nature of the diet at Vallerano did not preclude the development of Cribra Orbitalia on a general scale. In fact, the population at Vallerano is the unhealthiest of any sample recovered from antiquity. The mixture of high class and low class burials suggest an intensive farming villa with use of slave or peasant labor.

³⁶ Sallares, Robert and Susan Gomzi. “The Biomolecular Archaeology of Malaria.” *Ancient Biomolecules*. v.3 (2001) pp.195-213. Sallares is a proponent of the use of PCR chain reactions in soft tissues in order to assess the nature of disease in the past. He argues that through these DNA studies we can come to a better understanding of the nature of ancient disease and human immuno-response to such a disease environment. The validity of the use of PCR in paleopathology stands at the center of current debates in the field. Most of the debate has been conducted around Plague and its bacillus, *Yersinia Pestis*. Some scholars claimed to have sequenced a DNA strand of the bacterium from the Justinianic Period. Other scholars have claimed

and not just at risk groups, would also be subject to episodes of malarial infection because iron deficiency results from absorption, not just consumption. Brent Shaw noticed characteristic patterns of death for Northern and Southern Italy during the Late Antique Period. August to October, the months during which Malaria most easily reproduces (needing temperatures above 20 degrees C. for the most virulent strand), are the months during which the risk of infection is greatest, a fact which even the ancients themselves recognized.³⁷ The CDC currently argues that the most important factor in malaria transmission is ambient temperature and humidity.³⁸ It comes as no surprise to find that mortality was highest in these contexts during the Imperial period.³⁹

Yet, the level of malarial infection and its attendant impact of these areas cannot be quantified until a reliable understanding is achieved of malnutrition. In the future, it is hoped that better data sets from archaeological excavations or at minimum an independent review of existing skeletons could produce the direct data necessary to calculate height-for-age directly from Imperial Italy. Until such work is undertaken, a comparative example must be found to supply proximate data. Unfortunately, the modern third world does not supply completely adequate data sets. Rates of anemia are not quite as high in these areas when compared against the evidence from antiquity, though in some cases modern population are experiencing near Roman levels of anemia. Stature is also not as small in adulthood when compared to the pre-modern estimates, as measured for the purposes of this study from Herculaneum, of 1.63m (male) and 1.52m (female).⁴⁰ Thus comparative examples must be sought elsewhere.

A possible comparative example comes from the historical demography of the British Colony of Trinidad. Data was collected on the slave population of the island

that this process yields false results based on problems of contamination and the process of recombination itself. For the debate see. Achtman, M. et.al. "Microevolution and History of the Plague Bacillus, *Yersinia Pestis*." *PNAS*. v.101 no. 51 (Dec, 2004). Drancourt, M. et.al. "Paleomicrobiology: Current Issues and Perspectives." *Nature Reviews: Microbiology*. v.3 (Jan, 2005) pp.23-35.

³⁷ Sallares, *Malaria*, p.61. Columella. *De Re Rustica*. 1.5.

³⁸ <http://www.cdc.gov/malaria/biology/index.htm>

³⁹ Shaw, Brent D. "Seasons of Death: Aspects of Mortality in Imperial Rome." *JRS*. v.86 (1996) pp.100-138.

⁴⁰ Kasili, E.G. "Malnutrition and Infection as Causes of Childhood Anemia in Tropical Africa." *American Journal of Pediatric Hematology and Oncology*. v.12 no.3 (Fall, 1990) pp.375-377. I choose to use the Herculaneum measurements of Capasso because none of the other studies captures a living population. Skeletons as noted capture on those who died and thus do not approximate the actual height and thus health of the surviving population.

between 1813-1816. During this time, the British Empire had already closed off the importation of new slaves to the island, and the existing slaves worked in intensive agriculture based on the estate/plantation model. The disease conditions are broadly similar to those of Imperial Italy: malaria, dysentery, leprosy, fevers, parasites, etc... Nutrition came in the form of starchy staples, fish, and vegetables that could be raised on plots assigned to slave families, as required by the British slave code. If the owner chose not to allow the slave to grow food, then monetary compensation was required. In addition, the owner was required to see that the slave received up to 60 plantains a week as a staple for the diet. Under these conditions, the slave population was measured twice and the results of those investigations are incredibly interesting for our reconstruction of juvenile height in Imperial Italy. All male slaves over 15 averaged 162.6 cm in height. Females averaged 153.9. In short, the slave populations of Trinidad attained an adult height that correlates with one recorded measure from Imperial Italy. The British government measured children as well. The statistics published do not provide individual heights but rather the mean of age and the mean of height. 25 months represents the mean age for both juvenile male and female slave, the mean heights were 77.5 cm and 76.4 cm respectively.⁴¹ If this data is compared against the current WHO growth estimates for healthy children (Mean=88.0cm (Male) and Mean=86.6cm (Female) at 25 months) then the juvenile population at Trinidad would fall at its mean almost squarely on the -SD3 dividing line for modern populations (-SD3=78.6cm (Male) and -SD3=76.8 (Female) at 25 months). Thus the average child in Trinidad existed in a state of severe growth retardation during his youth, which is supported by the information available on dietary conditions and the reconstructed life tables from the total population. In fact, infant mortality rates were estimated at 365 per 1000. 58% of girls and 55% of boys died before their fifth birthday. -SD3 according to the WHO represents a severe state of growth retardation. In Trinidad, if we suppose a normal distribution for this mean, c.97% of all 25 month aged children were below the recommended mean height-for-age according to modern WHO estimates. In fact, some of these children would appear much

⁴¹ Meredith, John A. "Plantation Slave Mortality in Trinidad." *Population Studies*. v.42 no.2 (1988) pp.161-182.

like the infant from the start of this paper. Their heights are below the 3rd percentile for their age.

Consequently, for the purposes of the WHO model, in which low height for age is measured as all those greater than -2SD from the mean, we can assume that c. 70% of children are below their height-for-age under the age of 5 for the purposes of historical reconstruction. Can these numbers be generalized for Imperial Italy and assist in completing the first necessary measurement for step 1 of the WHO model? On a general level, the levels of malnutrition and disease appear broadly similar in both contexts as judged by the similar heights of the adult populations. The vast majority of the skeletons recovered from antiquity highlight rural/town rather than truly urban contexts, including the study of Vallerano. Intensive agriculture, as represented by the villa system in Italy and estate slavery in Trinidad, could produce much of the same effect on the health and nutrition on a population. While no factor can be decisive, the historical demography of Trinidad shows many of the same features as the hypothesized reconstructions of Roman demography.

In Trinidad, the small size of infants and juveniles had profound demographic consequences. For a newborn plantation slave in 1813, life expectancy at birth was 17. An infant at the age of one had a life expectancy of 26. For those who escaped the harsh realities of childhood, the conditions improved, and life expectancy at 15 for boys was 41 years of age, for girls 45 years of age. As evidenced, the extremely harsh realities of childhood had a great effect even on those who survive. Poor childhood health correlates to chronic morbidity in later life, and even vast improvements in socio-economic status cannot rectify the problems of childhood malnutrition and disease.⁴² The general demographic pattern broadly matches the accepted reconstructions of antiquity, which provide estimates of life expectancy at birth between 20-30 and infant mortality ranges of 200-400 per 1000.⁴³

⁴² Blackwell, p.1280. For a slightly different conclusion see Steckel, R. H. "A Peculiar Population: The Nutrition, Health, and Mortality of American Slaves from Childhood to Maturity." *Journal of Economic History* 46:3 (1986), 721-741. Steckel's study of American Slaves, whose heights were recorded between 1820-1860, showed that an increase in nutrition, coming when slaves entered the labor force, allowed for catch up growth that eliminated the dramatic stunting of slave children. Such a comparable change in nutrition did not occur in Trinidad nor is it hypothesized for the general conditions of Imperial Italy.

⁴³ Scheidel, p.1.

The pattern of adult mortality on Trinidad relates to an important debate in Roman Demography, and can help clarify the applicability of the information to Roman Italy. The age distribution in a population and mean life expectancy are rather different measurements, and the fixed age distribution predicted by life tables based on life expectancy at birth does not always reflect lived reality.⁴⁴ Nearly 20 years ago, Bruce Frier attempted to rehabilitate Ulpian's life table⁴⁵, already greatly maligned by Keith Hopkins.⁴⁶ At issue stands the life table's precipitous increase in mortality between the ages of 40-50. Such a mortality profile matched no known population or hypothesized life table. Frier, in his attempt to rehabilitate Ulpian's evidence, did find one population, Mauritius in the 1940s, illustrating such a precipitous increase; however, Frier only wanted to illustrate the demographic possibility of Ulpian's evidence and did not look at the conditions under which those mortality regimes were created. Trinidad, at the start of the 19th century, shows a similar increase in mortality between the ages of 40-50. Given that the nutrition and disease conditions produce similar estimates of infant mortality and height, this data set offers a more interesting comparison for Ulpian's evidence, one which cannot be explored fully here, but one which helps to support a hypothetical generalization for the purposes of model building not complete historical accuracy. Ulpian's evidence derives in theory from his immediate surroundings, the imperial court and Rome. Thus one would expect his expectations of mortality to show some proximity to his observed reality, if not the complete truth. The symmetry between adult mortality in the life table and the historical population in Trinidad, highlights the long term influence of malnutrition and disease on adult populations which are characterized by chronic morbidity and greater risk of death before the age of 50 than any hypothetical Coale-Demeny model can predict.

In addition to the percentage of undersize juveniles, the WHO model requires the percentage of low weight newborns in order to fulfill the second part of the data set required for step 1. Neither excavations from Italy nor comparative historical data can provide this information. However, the unique preservation conditions of Egypt offer a

⁴⁴ Ibid, p.2.

⁴⁵ Frier, Bruce. "Roman Life Expectancy: Ulpian's Evidence" *HSCP*. v.86 (1982) pp.213-251.

⁴⁶ Hopkins, Keith. "On the Probable Age Structure of the Roman Population." *Population Studies*. v.20 no.2 (1966) pp.245-264.

window into fetal growth during the Roman period. The excavators of the site Kellis 2 in the Dakhleh Oasis have published full anthropometric data for 82 fetal skeletons and neo-natal skeletons recovered in the excavation of the cemetery.⁴⁷ When the lengths of these bones are turned into ages, the cohort judged to be in the 37th week is the most important for comparative purposes, as these skeletons encapsulate the growth of these fetuses at the normal time of birth. No direct methods exists for converting the results from fetal/neonatal skeletons into a general description of the infant population as we only have access to those who died before, during, or shortly after birth.⁴⁸ However, the data do give an impression of the general size of Roman infants, which can assist in a reconstruction of the percentage of low birth weight births given the general set of pre-modern diet and disease restrictions.

I have chosen to compare the results from Kellis 2 to those of modern Guatemala. A recent study of fetuses in Guatemala used ultrasound technology in order to map the development of fetal skeletons. In the 37th week, the Guatemalan fetuses had mean humerus lengths of 61.9mm, mean femur lengths of 72.7mm and mean tibia lengths of 60.5. The same averages for the Roman period skeletons recovered from Kellis and dated to the 37th week are: humerus (63.1mm), femur (70.5mm) and tibia (60.6mm). In sum, the data from both samples reveals a similar size of fetus at the moment of expected birth. The birth weights for the infants in Guatemala averaged 3.06kg with a standard deviation of .46kg.⁴⁹ In order for a newborn to be classified as underweight by the WHO standards, it must weigh 2.5kg or less. In the Guatemalan sample, only those infants who were greater than one standard deviation from the mean weight would classify as low birth

⁴⁷ Tocheri, M.W. et.al. "Roman Period Fetal Skeletons from the East Cemetery (Kellis 2) of Kellis, Egypt." *International Journal of Osteoarchaeology*. v. 15 (2005) pp. 326-341.

⁴⁸ The skeletons dated to the 37th week at Kellis 2, in all probability, capture a cross section of all infants born, not just those that were undersized. Complicated demographic models derived from studies of historical demography in early modern and modern Europe have led certain scholars to estimate that still births and neo natal (first week) deaths consumed up to 20% of all infants born in 17th century England. Fetal skeletons, therefore, represent an important percentage of total births. Woods, Robert. "The Measurement of Historical Trends in Fetal Mortality in England and Wales." *Population Studies* 59:2 (2005), 147-162. Moreover, the causes of neo-natal mortality vary. Thus fetal skeletons should not capture a particularly small or undersized percentage of infants. A recent modern study in Pakistan found that neo-natal mortality resulted from immaturity/development complications in only 26% of cases. Asphyxia (26%), infections (23%) and congenital abnormalities (8%) constitute the other major causes of neo-natal deaths. See: Jehan, Imtiaz et.al. "Neo-natal Mortality, Risk Factors, and Causes: A Prospective Population Based Cohort Study in Urban Pakistan." *Bulletin of the WHO* 87 (2009), 130-138.

⁴⁹ Neufeld, L.M. et.al. "Ultrasound Measurement of Fetal Size in Rural Guatemala." *International Journal of Gynecology and Obstetrics*. v.84 no. 3 (March,2004) pp.220-228.

weight, which calculates to nearly 15%. The symmetry between the numbers from Kellis and Guatemala provides one method, though far from perfect, that is currently available to reconstruct birth weight estimates for a population in antiquity. A whole host of methodological problems ensue from the comparison of fetal skeletons (Egypt) and fetuses subjected to an ultrasound (Guatemala). However, Roman demography never achieves a perfect symmetry between the sources of information from antiquity and the specificity of more modern data set. The broad correlations in the data sets between the Guatemalan evidence and the evidence from Kellis 2 can at minimum provide an impetus for future study in this area, and a broad number that can be used to understand Step 1 of the WHO model and its assessment of malnutrition.

The last piece of required information for Step 1 is the mean and SD of the BMI for women 15-44 years old. Female BMI serves as an approximate measure of nutrition, which has been shown to have significant effects on fetal development and infant health. BMI requires both a height and weight measurement. For Imperial Italy, the mean height can stand as the measure from Herculaneum of 151.6cm, which supplies half of the information required for BMI though not its standard deviation. To reconstruct such a standard deviation and weight measurements requires identifying a good comparative measurement based on generally similar diet and nutritional characteristics. At this point, our evidence from the modern world fails to supply a truly strong or even potentially strong comparison. The proliferation of modern aid workers, antibiotics, and other assistance for poorer nations means that the average height of currently living adult females in the developing world cannot serve as any sort of direct proxy for antiquity. The following example is thus the most subject to revision. The average height of women in modern India is 1.52m and will suffice for this reconstruction based on broadly similar nutritional characteristics.⁵⁰ The mean BMI for Indian women is 19.0 and the standard deviation 7.41.⁵¹ These figures mean that in India, 33% of women have a body mass index below normal. Other population characteristics indicate broad enough health and nutrition statistics to support this use of Indian evidence. 80% of children are anemic as

⁵⁰ Deaton, Angus. "Height, Health, and Inequality: The Distribution of Adult Heights in India." *American Economic Review* 98:2 (May, 2008), 468-474.

⁵¹ Naidu, A. National Institute of Nutrition India.
<http://www.unu.edu/unupress/food2/UID10E/uid10e10.htm>

are 60% of adult women, which approximates the anemia already cited from Roman Italy.⁵²

Conclusion

The data for Roman Italy (1-4th c. AD) that this study therefore compiles for Step 1 of the WHO model is as follows: 70% of children younger than five have low weight for age, 15% of infants who were brought to term were low birth weight, and the mean BMI for reproductive women is 19.0 with a standard deviation of 7.41. Such a population would be highly susceptible to death from disease or infection. For juveniles who are severely undersized (-SD3 or greater, here estimated at 50% of the juvenile population in Roman Italy) the relative risk of death from diarrhea is alone 12 times greater per exposure with respiratory diseases having 8 times greater relative risk of death per exposure.⁵³ As such, between 50%- 60% of all Imperial Italian births died before the age of 5.

For the population of Roman Italy, this precarious state of health created severe impacts on juvenile health and growth. Juvenile health, in turn, affected adult productivity which is not only affected by one's own labor capacity but also incidents of sickness. Studies of populations in Africa have shown that labor productivity increases with nutritional intake. In short, the more nutrition available to a family farm, the more labor the family farm will generate. But nutrition for growth can be lost due to the demands placed on body by the exigencies of disease and infection.⁵⁴ The population described above, as extracted for Roman Italy, highlights a near permanent state of malnutrition and sickness that would have severely inhibited agricultural productivity. Further research into the percentage of the population under five and underweight, the percentage of low birth weight babies, and the body mass index of adult female women promises to illuminate further the exact economic consequences of malnutrition and disease on the population of Imperial Italy. For the vast majority of the Roman population living in the coastal regions of Italy during first four centuries, the amount of

⁵² National Family Health Survey. <http://www.nfhsindia.org/pdf/IN.pdf>

⁵³ Blossner, p.20.

⁵⁴ Strauss, John. "Does Better Nutrition Raise Farm Productivity?" *Journal of Political Economy*. v.92 no.4 (Apr, 1986) pp.297-320. For a general discussion of the intersection of height and standard of living see: Steckel, R.H. "Stature and the Standard of Living." *Journal of Economic Literature* 33 (1995), 1903-1940.

food mattered less than the quality of the nutrients contained in the food and the body's ability to absorb those nutrients. No amount of wheat or vegetable produce could make up for the short fall in high quality animal proteins. In fact, a diet high in cereals may create the perfect conditions for malaria reproduction. Pork consumption produced unhealthy children who became even healthier adults if they managed to survive the high rates of infant mortality and juvenile mortality. Girls, who became women, faced a permanent battle with anemia during their reproductive years that effectively limited the quantity and quality of infants born into the population. Only adult males seem adequately suited to the diet of Imperial Italy, as brought out by the paleopathological evidence of healed Cribra Orbitalia. Their low iron requirement allowed a diet high in cereals and legumes to suffice for their general caloric and nutritional needs.

In terms of methodology, the study of modern and historic populations offers clear paths forward when comparison is based on anthropometric data. Mounting scientific evidence suggests that height and other anthropometric measurements are more influenced by diet and health than genetic coding. Throughout my analysis, I have labored to draw my comparative evidence based on the anthropometric measurements and tentative reconstructions of disease history. I have attempted to focus on populations that show similar dietary and disease histories to Roman Italy. The results of these comparisons vary in their efficacy. Historical data that predates the modern demographic transition is the most valuable, and the information from colonial settings cannot be dismissed due to the assumed differences between the nutritional regimes of chattel slaves and free peasants. In point of fact, the anthropometric data highlight two groups of humans separated by over a millennia whose physiology responds in a similar fashion to the ravages of malaria, tuberculosis, worm infestation, and malnutrition.

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