

Scurvy: A synthetic approach to the disease and its influence in the Great Irish Potato Famine, 1845-1852

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Scurvy is one of the most common nutritional diseases to have plagued humanity. As early as 1550 B.C., populations from diverse geographic regions began to recognize and document the disease. Afflicted individuals manifested illness signatures including fatigue, bleeding gums, and bone porosity due to the weakening of collagen in bone and blood vessels. With the absence of a single enzyme essential for synthesis, vitamin C cannot regulate the production of collagen, so the strength of these tissues is compromised. Ongoing research has documented ties between scurvy and historical famine episodes where access to a vitamin C-rich diet was limited. Most

notably is the Great Irish Potato Famine from 1845-1852, instigated by a fungal disease. Researchers Geber and Murphy investigated remains from the Kilkenny Union Workhouse cemetery, which was utilized by the Irish lower-class during the 1800's. Their research demonstrated that skeletal manifestations of scurvy were present in at least 52% of those studied. This paper draws on that research and other sources to present a paleopathological, historical, and biochemical overview of the Irish Potato Famine, in order to examine how nutritional deficiencies in vitamin C can lead to famine and scurvy in times of cultural and environmental stress.

As one of the oldest and most common nutritional diseases, scurvy has continuously tormented humans throughout antiquity on both land and sea. The disease appeared to have no preference between populations and would afflict large groups of people at one time (Magiorkinis et al., 2010. p. 147). Early in the disease's history, physicians realized the cause of scurvy was a deficiency in vitamin C; however, scurvy victims would often go misdiagnosed due to the disease mimicking common conditions like blood diseases and gingivitis (Pimentel, 2003. p. 328). Thus, the patients' symptoms would be treated incorrectly until they succumbed to death. Famines and depleted food supplies called attention to the importance of their diet for prevention of the disfiguring disease. One of the most significant cases of scurvy, the Great Irish Potato Famine of 1845 to 1852, proved the strength scurvy has in eliminating a population (Geber and Murphy, 2012. p. 513). With research and paleopathological analysis, anthropologists like Dr. Geber and Dr. Murphy have provided a new perspective on the famine victims' tragic lives.

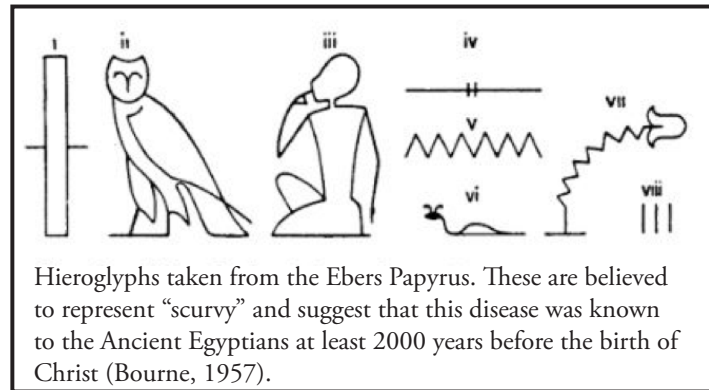
Scurvy in Antiquity

Scurvy is an ancient disease that has plagued humans throughout history. This disease was first recorded in hieroglyphics on an Egyptian medical papyrus of herbal knowledge called the Ebers Papyrus in 1550 B.C. The Egyptian document provided both a diagnosis and treatment of the disease, which included a diet of vegetables (Magiorkinis et al., 2010. p. 147). However, the first formal description of scurvy is attributed to Hippocrates nearly 1,100 years after the Ebers Papyrus (Magiorkinis et al., 2010. p. 147). Hippocrates describes individuals afflicted with "foetid breath, lax gums, and haemorrhage from the nose; ulcers sometimes on their legs" (Lind, 1772. p. 303). Unfortunately, Hippocrates had difficulty treating his patients, resulting in scurvy "accompany[ing] the patient to his death" (Lind, 1772. p. 284).

The most well known example of scurvy affliction is of sailors and explorers, nicknamed "sea scurvy," towards the end of the Middle Ages (Mayberry, 2014). At the turn of the fifteenth century, Portuguese explorer Vasco da Gama took 140 men on the search for a route to the East Indies. Up to 80% of his men fell ill with "their feet and hands swelling, and their gums growing over their teeth" during the first six months at sea, leaving only seven or eight men fit to navigate each ship (Carpenter,

1988. p. 1). They landed on the southeastern coast of Africa and were approached by Moorish traders with oranges. Upon eating the fruit, most of the men recovered their health and only 30 had died (Carpenter, 1988. p. 2). It was not until the second incidence of this disease did da Gama and his men realize the oranges had a beneficial effect.

Often found in vegetables and citrus fruits, vitamin



C or ascorbic acid is essential in the proper formation of the protein collagen. Collagen is an elongated fibrous protein found in connective tissues like organic bone and blood vessel matrices and gives these structures strength and rigidity (Mays, 2014. p. 55). In the beginning of contracting scurvy, individuals are in a state of fatigue with discomfort and lethargy followed by weakening of the blood vessels. This failure of the blood vessel walls causes hemorrhages resulting in small red-purple spots on the skin, swollen and painful joints, and bleeding of the gums (Armelagos, 2014. p. 10). As the disease progresses, gums begin to rot, skin will become gangrenous, and the individual will develop high fevers. If left untreated, scurvy will be fatal, typically caused by rupturing of blood vessels in the brain and heart due to exertion (Mayberry, 2014). Afflicted individuals may regain their health even in the latest stages of the disease by being treated with a high vitamin C diet.

Skeletal Manifestations

Scurvy may initiate an osseous response in the skeletal system if the individual goes untreated for an extended period of time. These skeletal manifestations are often seen in archeological contexts of developing societies with poor nutrition (Mays, 2014. p. 57). They are caused by either a change in the skeletal tissue due to the disease itself, or secondary effects from issues with the associated blood vessels. Bleeding gums, which is characteristic of scurvy, is due to localized hemorrhages and inflammation of the gums. Capillaries will rapidly swell in the affected region resulting in bony porosities

in the jaw. This changes the morphology of the alveolar margin and often leads to tooth loss (Mays, 2014. p. 55). Malformation is seen in most of the long bones due to an increase in osteoclastic activity. The osteoclasts degrade the trabecular bone in the medullary cavity producing porosities. With a hollow space within the weight-supporting bones, bone strength is compromised, and the individual experiences severe pain and grinding of the bones (Armelagos, 2014. p. 10).

Diagnosing scurvy can be difficult because the disease displays symptoms that are similar to a variety of other diseases (Pimentel, 2003. p. 328). Also, scurvy can vary in severity, and all symptoms might not be present at the time of diagnosis. Bleeding gums from weakened blood vessels are often misattributed to ulcerative gingivitis due to bad hygiene, such as failing to brush one's teeth regularly. The failure of the blood vessel walls might be diagnosed as vasculitis, or blood vessel inflammation, which decreases blood flow. The breaks and decreased density of the long bones might be accredited to trauma (Pimentel, 2003. p. 331). Sometimes these malformations might be diagnosed as a result of osteogenesis imperfecta and the designated treatment might not be useful (Patterson, 1990. p. 73). If these incorrect diagnoses are not refined in the early stages of scurvy the individual can develop a more severe case. Meticulous and efficient analysis is necessary for eliminating possible diseases when determining a diagnosis for scurvy.

Biochemical Considerations

Unlike most animals, humans are unable to synthesize ascorbic acid naturally and must rely on nutritional supplements like fruits and vegetables for the necessary vitamin (Chatterjee, 2006. p. 36). Typically, vitamin C is produced within the liver by a multi-step reaction,

which is catalyzed by a variety of enzymes. Humans' inability to synthesize this biomolecule stems from the absence of the final enzyme for ascorbic acid's formation (Mayberry, 2014). The missing enzyme, L-gulonolactone oxidase, causes a negative feedback loop that blocks the entire synthesis process (Stone, 1966). While this vitamin deficiency is detrimental to the strength and function of the body, there is an evolutionary trade-off. Ascorbic acid is a chemically unstable biomolecule due to its tendency to become oxidized by transition metals (iron and copper) within the human body (Delanghe et al., 2007. p. 1397). Vitamin C is also extremely acidic which can be harmful to the body's overall basic environment. Therefore, scientists believe that the ability to synthesize vitamin C was either lost or never developed during human evolution, thus protecting the human body from a toxic chemical (National Center for Biotechnology Information, 2016).

Past research has determined this deficiency is most significantly due to a combination of hereditary and nutritional factors. The absence of the L-gulonolactone oxidase enzyme is due to a genetic mutation, either a substitution or deletion, of the gene coding for the formation the synthesis' final enzyme (Stone, 1966). This mutation is found in all humans regardless of sex, age, or race.

Some individuals have an additional mutation of the gene coding for the protein haptoglobin (Hp). Haptoglobin is an antioxidant in the body that prevents damage of the red blood cells from oxidation (Delanghe et al., 2007. p. 1397). If Hp is absent, vitamin C can take on the role as antioxidant. The mutation causes a polymorphism with three phenotypes, which results from the expression of the two alleles Hp 1 and Hp 2. Those with the Hp 1 allele expression have a higher presence of haptoglobin in the body and are able to



Skin spots/rash due to hemorrhages (MedicalLook, 2016); inflammation and of the gums (Center for Disease Control, 2016); small fractures and hollow bone shafts (Noordin et al., 2012.)

survive on low vitamin C diets. However, individuals with the Hp 2 allele expression have low levels of haptoglobin (Delanghe et al., 2011. p. 1397). When those individuals have poor vitamin C diets, they lack both biomolecules to protect red blood cells from oxidation. Those with Hp 2 are more likely to develop vitamin C deficiency and in extreme cases, scurvy. In 2007, Delanghe and colleagues found the highest frequency of the Hp 2 allele in southeast Asia, which they assumed was a result of unequal crossing-over between Hp 1 alleles. The Hp 2 frequencies decrease further from southeast Asia suggesting that those populations who migrated long distances, especially by boat, had the advantage of the Hp 1 allele for their survival (Delanghe et al., 2007. p. 1398).

Famine and the Kilkenny Union Workhouse

Scurvy is often attributed to dietary problems and a deficiency in fruits and vegetables that supply vitamin C. These issues occur most frequently when a population, or sometimes a whole country, experiences a devastating famine. In the past, humanity has endured multiple famines caused by drought, crop failures, natural disasters, food shortages, war, and many other factors. Some of the most significant modern famines include the Great Potato Famine of Ireland of 1845 to 1852, the Russian famine of 1921, and the Great Chinese Famine of 1958 to 1962. These disasters resulted in an excess mortality of 1, 9, and 33 million people respectively (Roser, 2016). While it is likely that the individuals alive during the famines suffered from scurvy, only the Great Irish Potato Famine has multiple historic literary records of the disease.



Map of Hp1 allele frequency. The numbers represent the Hp1 allele frequency (as a percentage). The arrows represent the direction of human migration in pre-historical times. Four exceptions on the normal Hp allele distribution with extremely high Hp1 allele frequencies are found around the Hudson Bay, Easter Island, Madagascar, and Papua New Guinea (Delanghe et al., 2011).

The first wave of the potato famine hit Ireland late in the harvesting season of 1845. Potatoes were affected with a fungal disease, *Phytophthora infestans* (potato blight), which blackened the leaves of the plant and caused the tubers in the ground to rot (Clarkson and Crawford, 2001. p. 86; Crawford, 1988. p. 281). However, the timing of the potato blight was not as threatening since it arrived late in the harvest season and infected only forty percent of the potato crop (Schumann and D’Arcy, 2000). Those whose diets consisted almost exclusively of potatoes, especially the poorest third of the Irish population, struggled to survive. It was not until the following year when the potato blight returned significantly stronger and earlier in the harvest season that Ireland and Continental Europe began to panic (Ó Gráda, 2007. p. 7). Since potatoes were their primary source of food and did not store well, the Irish were the most notably impacted population in Europe. By 1852 Ireland had a twenty-five percent decline in overall population due to one million famine-associated deaths and emigration of famine victims to the Americas (Geber and Murphy, 2012. p. 513).

Despite the abundance of historical records on scurvy and the Great Irish Potato Famine, there were no case studies defining the paleopathological presence of scurvy in Britain prior to the work of Dr. Jonny Geber and Dr. Eileen Murphy, archeologists at Queen’s University in Northern Ireland (2012. p. 512). Geber and Murphy analyzed a minimum of 970 individuals from the Kilkenny Union Workhouse cemetery in Ireland (Geber and Murphy, 2012. p. 515). The workhouse was created in response to the Poor Law introduced in 1838 to address Ireland’s chronic pauperism and provide “relief” for the idle lower class (Geber and Murphy, 2012. p. 514). During the Great Irish Potato Famine, the Kilkenny Workhouse inmate population swelled to 4,357 people desperate for food (Geber and Murphy, 2012. p. 514). With the rapid influx of inmates came an increase in mortality at the workhouse, and inmates were buried in the intramural burial ground. A minimum of sixty-three mass burial pits, with the dead buried in simple pine coffins, were discovered at the time of excavation (Geber and Murphy, 2012. p. 514). This collection provides great insight into the poorest of the lower class, who were unable to afford and properly feed themselves during the Great Irish Potato Famine in Kilkenny City.

To assess the remains for the population characteristics, Geber and Murphy used macroscopic

analysis of the bones for determining age, sex, and stature. The juveniles were identified primarily using dental development and eruption patterns from Broadbent et al. (1975), and the degree of epiphyseal fusion (Scheuer and Black, 2000). For adults, degenerative changes of the pubic symphysis and auricular surfaces of the pelvis were analyzed (Lovejoy et al., 1985; Brooks and Suchey, 1990). Living stature was estimated by measuring the left femur (if absent, the bone which gave the best correlation to the results given from the left femur) and using the regression equations of Trotter and Gleser (1952, 1958). A total of 545 of the 970 individuals died before the age of eighteen, and most of the adults were within the range of 26 to 45 years of age. The mean age-at death was estimated as 19 years. The sex ratio of the populations was approximately equal with a total of 200 females and 216 males. Estimated living stature in males was a mean height of 171 cm, and 158 cm for females, which is within the range of 19th-century individuals from Britain (Geber and Murphy, 2012 p. 517). These estimations correlate with the target demographic of the workhouse: young, able-bodied men, women, and families.

The diagnosis for scurvy was sectioned into three categories based on a combination of scorbutic, or scurvy associated, lesions observed. A definite category of diagnosis is most reliable and includes active porosities on the greater wings of the sphenoid, posterior surface of the maxillae, and medial surface of the mandibular ramii, which corresponds to scurvy affecting the mastication muscles and bones. Some porosities around the alveolar bone and palatine suggests hemorrhaging and gingivitis of the teeth and gums (Geber and Murphy, 2012 p. 515-516).

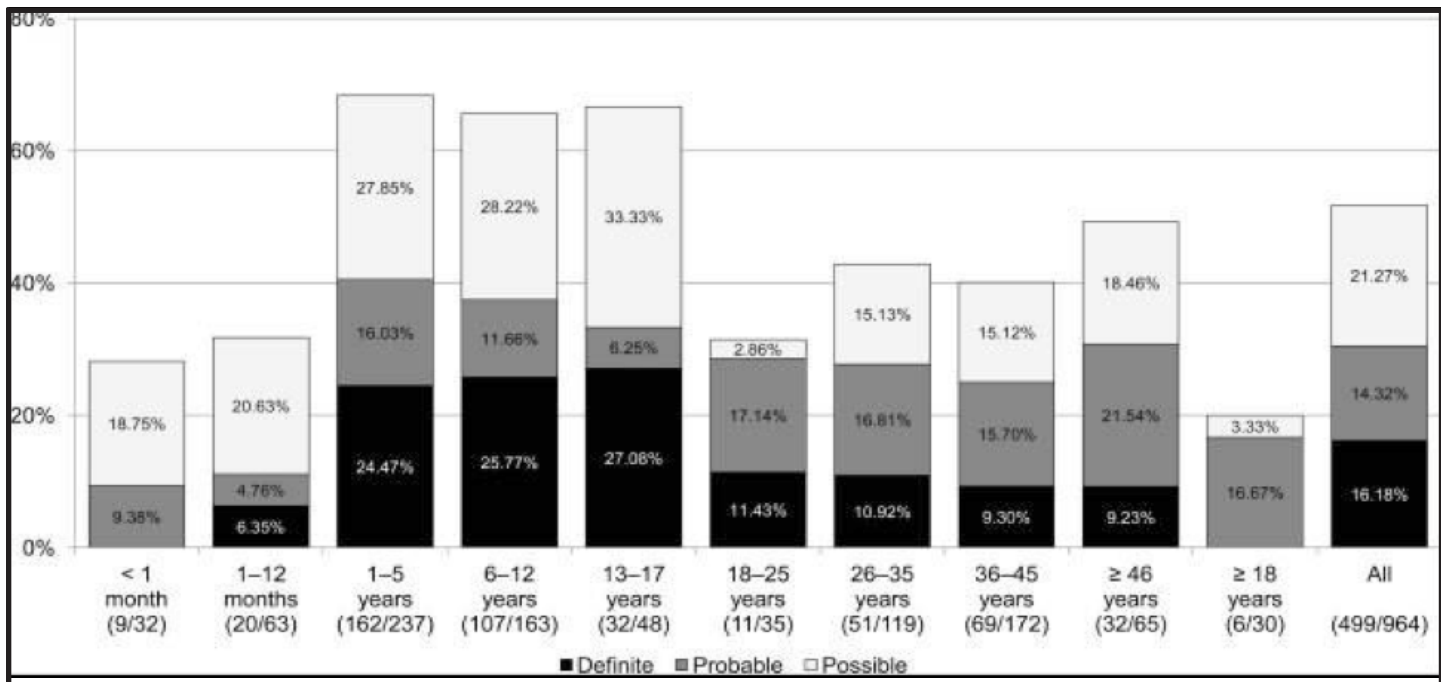
A category of probable diagnosis relies on at least two of the remaining lesions of scurvy being present. For juveniles, probable diagnoses consist of endocranial lesions of the frontal, porosities on the lesser wings of the sphenoid, orbital surface of the zygoma, infraorbital foramina, and supraspinous area of the scapula. Periosteal new bone growth of the radii, ulnae, coxae, tibiae, fibulae and on the diaphysis, and particularly along the linea asperae, of the femora is also seen for probable scurvy diagnoses in adults (Geber and Murphy, 2012 p. 516).

Nonspecific lesions, such as active endocranial lesions of the cranial vault, further porosity of the sphenoid, and very fine proliferative new bone formation on the limbs, were defined as a possible diagnosis of scurvy when at least one scorbutic lesion was present (Geber and

Murphy, 2012 p. 516). This three-categorical diagnosis allowed Geber and Murphy to have a more consistent approach by considering all lesions present. Their analysis gives an overall prevalence of approximately 52%, with a definite 16% (N=156), probable 14% (N=138), and possible 21% (N=205) scurvy diagnosis. Geber and Murphy acknowledged the presence of lesions due to rickets (N=14 and 9) and tuberculosis (N=3 and 1) in juveniles and adults, respectively (2012. p. 517-518).

By comparing the presence of scorbutic lesions between age, sex, and stature groups, Geber and Murphy were able to better define how the disease presented itself and affected the Kilkenny Workhouse population. Children and adolescents showed the highest prevalence for the disease ranging from 66% to 68% afflicted. Older adults (≥ 46 years of age) followed with 49% afflicted, and the lowest frequency was observed in neonates and infants (29% and 32%, respectively). Scurvy also appeared to affect the mean age-at-death for young adults. Those diagnosed with scurvy died at a mean age of 17 years while the non-scorbutic skeletons lived until a mean age of 22 years. The mean age-at-death for older adults was not significant enough between groups for scurvy to be a determining factor. Men were more frequently diagnosed with scurvy than their female counterparts across all age groups with the highest difference among the older adults. This may be due to the biological variation and daily vitamin C requirements that differ between sexes. Physical stature also appears to be only statistically significant for males. The mean height for individuals diagnosed with scurvy was 2 cm taller than those without scurvy (Geber and Murphy, 2012. p. 520).

The results suggest scurvy was highly prevalent within the Kilkenny Union Workhouse population. The variation of the disease in different age groups can most likely be attributed to quantity of food provided in the daily ration. As seen in past research, the Kilkenny inmates probably had their relief food portions dependent on age, so adults were given the largest portions and the youngest children were given the least (O'Connor, 1995. p. 136). Consequently, those individuals of the optimal age to work (early to middle adults) received the most food. The Kilkenny Union Workhouse did not record a difference in ration sizes, like many other workhouses frequently did, but the men appeared to have suffered from scurvy more than women. Geber and Murphy speculate that the men received inadequate daily portions and suffered a greater



Prevalence rate of scorbutic skeletons with a definite, probable and possible diagnosis, by age. (Geber and Murphy, 2012).

loss of their necessary nutritional intake (2012, p. 520). Similar to Ivanovsky's study (1923, p. 331) of pre- and post-famine population of Ukraine in the 1920's, the taller individuals were more frequently afflicted since their bodies required a relatively higher proportion of nutrients compared to smaller individuals to subsist.

Of course, any researcher must acknowledge the paradoxes of studying human remains to reconstruct a society. The most significant point is discussing what is observed versus what was actually prevalent at the time the individuals lived. This is defined as Wood et al's Osteological Paradox, where many individuals who suffered from a disease died before the disease could produce a visible skeletal lesion (1992). Consequently, the archeologist can only assume from what he or she observes on the skeletal collection. Those observations may be affected by taphonomic conditions previous to being excavated. For Geber and Murphy's skeletal collection, their analysis is only applicable for the lower class during the Great Irish Potato Famine and cannot provide information about groups from different classes or locations. The Kilkenny Union Workhouse burials do, however, provide a large collection of individuals that can provide a relatively representative sample of the inmate population between the years of 1845 to 1852.

Looking Towards Future Research

Recent research has added on to the work established by Drs. Geber and Murphy in 2012. Dr. Julia Bradford has published several papers on using isotopic analysis

to examine diet and migration during the Great Irish Potato Famine. Bradford compared the remains from the Kilkenny workhouse burials to those of the Lukin Street cemetery in London. She found different nitrogen and carbon isotopes signatures between the two groups and within individuals buried in the Lukin Street cemetery suggesting that people had migrated to London during the famine (Beaumont et al., 2012, p. 92-93). Beaumont also observed a transition from C3 to C4 plants after the introduction of maize from America to the Irish diet by analyzing collagenous proteins in bone and tooth dentine (Beaumont 2013, Beaumont and Montgomery 2016). Geber continued his work with the Kilkenny Union Workhouse collection by examining the prevalence of enamel hypoplasia, Harris lines, and growth retardation in the child population. He found that Harris lines and signs of growth retardation are extremely prevalent, especially within the child and adolescent age range previously determined (Geber, 2014, p. 153). However, Geber realizes psychosocial stress relating to institutionalization in the workhouse may have helped cause these skeletal lesions along with the famine.

The research performed with the Kilkenny Union Workhouse collection has taken significant steps in curating archeological samples with lesions correctly diagnosed as scurvy. Before Geber and Murphy's work, there were little to no archeological records of the disease in human history, and most of the literature was from recent case studies. Their work has created an interest

and necessity for further research of scurvy in human antiquity across the globe. The next step is for researchers to examine current collections using the methods outlined in Geber and Murphy (2012) to increase the known population of archeological scurvy victims. By doing so, the global perspective of the disease and its prevalence and mortality rates can be better defined. Presence of the disease in a variety of socioeconomic, ethnic, sex, and age groups would provide a diverse profile of scurvy. This new knowledge will offer more information about scurvy's history, influence on humans, and future in the modern world.

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