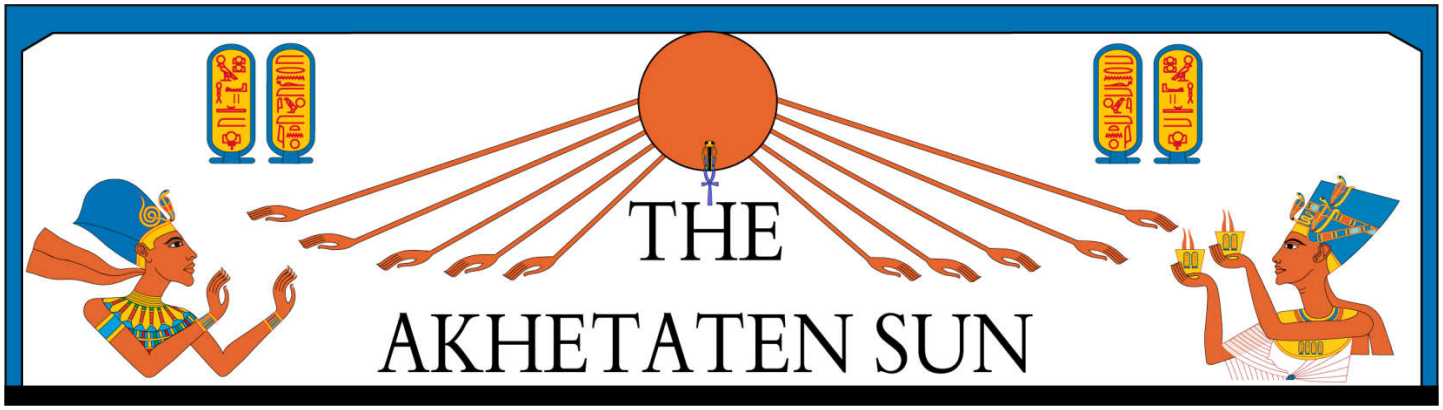

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Officers and Directors

The President's Papyrus

Greetings Amarnaphiles,

I hope that you are enjoying your summer and that it is not to hot where you live.

In a recent communication from Barry Kemp, he told us that plans for a season of work at Amarna have been approved by the Egyptian Ministry of Antiquities and will commence September 20. This is good news because there is so much yet to be done and you may remember that not too long ago, Barry was not allowed to work at Amarna because of "security reasons". The same was true for many foreign archeological missions. But it would appear that things have stabilized in Egypt politically and things seem to be getting back to a state of normalcy.

As you all know now, this is the season for membership renewals. For those of you who have done so, I want to thank you. And for those of you that have yet to do so, I sincerely hope that you will. I hope that you continue to enjoy our newsletter and believe that what continues to be accomplished at Amarna, as reported in the articles of our newsletter still deserve your financial support. I helped found this organization over twenty years ago and I still believe in its mission to day as when we started. Thanks for your support.

I wish all of our member's good health, prosperity and a great summer.

Best wishes to you all,
Floyd

Tracking Malaria at Amarna

By Nicole E. Smith-Guzmán, Ph.D.
Smithsonian Tropical Research Institute

How can we detect malaria in the human skeletal remains excavated from Amarna's South Tombs Cemetery? What is the likelihood that malaria at Amarna (the center of modern-day Egypt) could spawn a twenty-year epidemic more than 2,000 kilometers away in the Hittite capital of Ḫattuša (the center of modern-day Turkey)? These were the questions that I faced as I began my job as research assistant for Amarna Project bioarchaeologist Jerry Rose in August of 2011 As I very quickly discovered, these questions were anything but simple, leading me to spend the next four years of my life dedicated to the pursuit of their answers.

I began my research by learning as much as I could about the disease and its behavior in modern populations. Malaria is a fascinating disease, whose long co-evolution with humans (and likely our hominin ancestors) advanced a myriad of techniques by which the pathogen – protozoans of the genus *Plasmodium* – continues to wreak havoc on human populations today. Each of the four human malaria species generates a similar but unique reaction in the body, with each having different incubation periods, fever wave rates, and potential to cause a relapse by hiding parasites in the liver. Acute diseases (i.e., those which do not remain active in the body for months or years on end) typically do not leave their trace on the human skeleton; however, malaria is a special case given that it is both an acute and chronic disease simultaneously. Each infection lasts around one month, depending on the species of malaria, but individuals may be infected multiple times, causing chronic illness. In other words, based on malaria's disease ecology, it *should* be possible for malaria to leave its trace on bones. The reason why this skeletal manifestation of malaria had never been investigated in the paleopathological literature was likely the same reason we still do not have a functional malaria vaccine – it is a highly complex and highly variable disease.

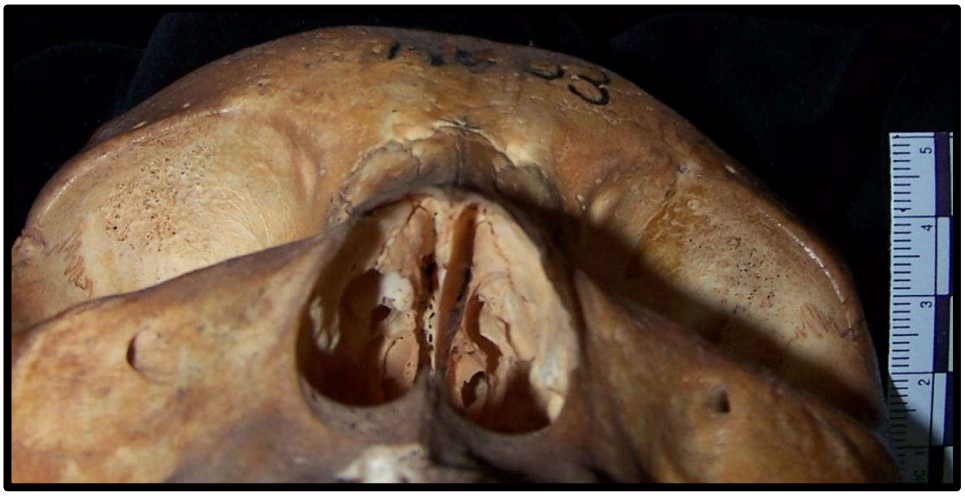

Figure 1. Inferior view of the cranium from a Galloway collection individual showing cribra orbitalia.

The hemolytic stage of malarial infection is what makes us feel sick. It is the simultaneous explosion of red blood cells in our bodies, releasing thousands of parasite clones and their waste products into the blood stream, provoking severe malarial anemia in addition to the typical symptoms of fevers, chills, and malaise. Anemia has long been connected with porous lesions on the cranial vault and eye orbits called porotic hyperostosis and cribra orbitalia, respectively. Although these anemic lesions were thought to be caused principally by a diet deficient in iron, some authors have pushed back on this theory recently, implicating megaloblastic anemia (like that caused by vitamin B deficiency) and hemolytic anemia (caused by malaria

and other infectious diseases) as the primary causative agents. In this scenario, we would expect to see drastic differences in the frequencies of skeletal indicators of anemia between areas of the world with rampant malaria and those places with no malaria.

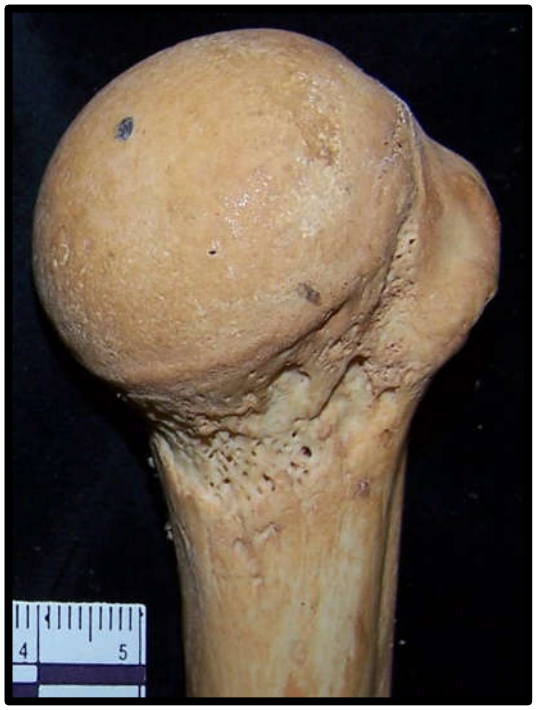

Figure 2. Medial view of the left humerus from a Galloway collection individual showing humeral cribra.

This theory of increased anemic lesions in malarial areas was demonstrated just six months after I began my malarial research in an article focused on malarial prevalence in Britain. In their 2012 article, Gowland and Western showed that higher rates of porous cranial lesions followed spatial patterns of low, marshy environments, historical cases of "fever and ague," and modern distribution of the malaria mosquito vector. Such a meta-analysis should be possible using the vast published literature on cribra orbitalia in the Nile Valley, Jerry Rose encouraged during a discussion of the article. So I set out to do just that in the summer of 2012, with Rose's cabinets of accumulated articles on Egyptian and Nubian skeletons as an invaluable resource. The study, which I later published in 2015, showed a steady rate of cribra orbitalia over time and space in the Nile Valley – a steady *high* rate. With an overall mean of 43% of individuals showing evidence of the porous orbital lesions, cribra orbitalia was much more frequent than at any of the sites surveyed by Gowland and Western in Britain. What could account for this difference in anemia? There were several possibilities including differences in nutrition, exposure to tropical diseases, and the virulence of the malaria species (i.e., *P. falciparum* malaria in Africa would have been much more severe than *P. vivax* malaria in the British Isles). For me, this study emphasized the need for better diagnostic criteria for malarial infection on the skeleton, one which considered not only the cranium, but postcranial lesions and their dynamic interaction. As malaria paleopathologist Teddi Setzer reasoned over coffee with me in April 2012, someone needed to go study a skeletal sample of known malarial exposure to see what lesions showed up. That someone, I thought, might as well be me.

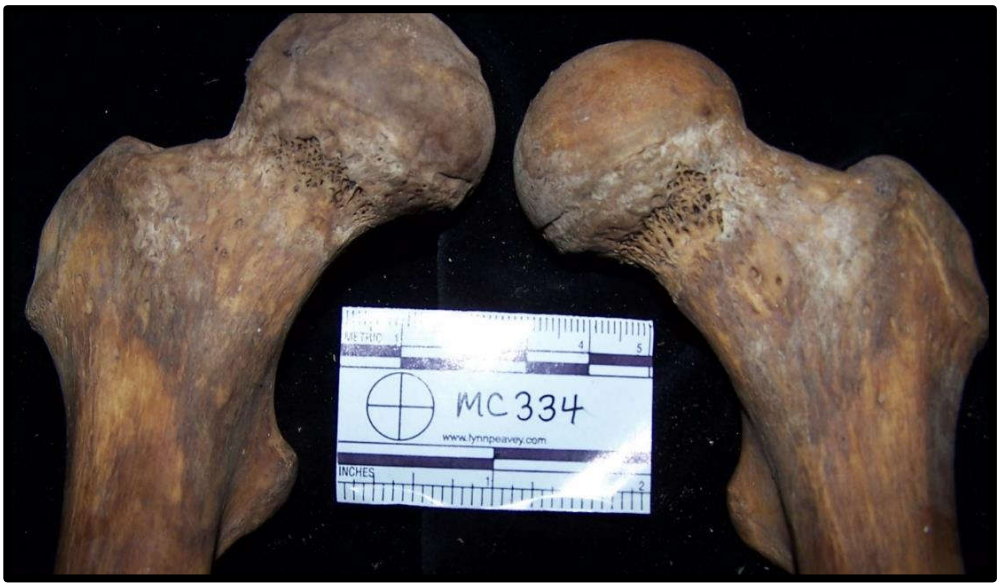

Figure 3. Anterior view of the proximal femora from a Galloway collection individual who died of anemia showing bilateral femoral cribra.

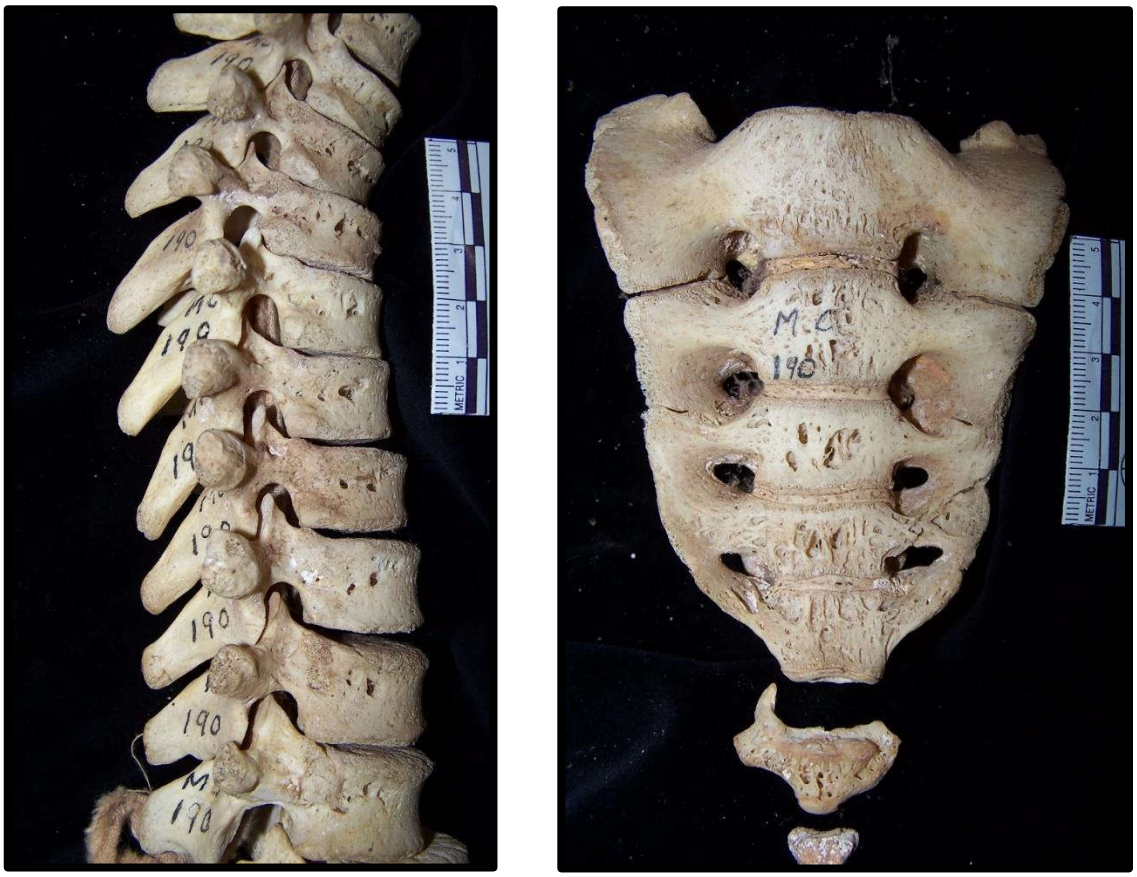

Figure 4 . Right lateral view of the thoracic vertebrae (left) and anterior view of the sacrum (right) from a Galloway collection individual who died of anemia,
showing large porous lesions to the bodies.

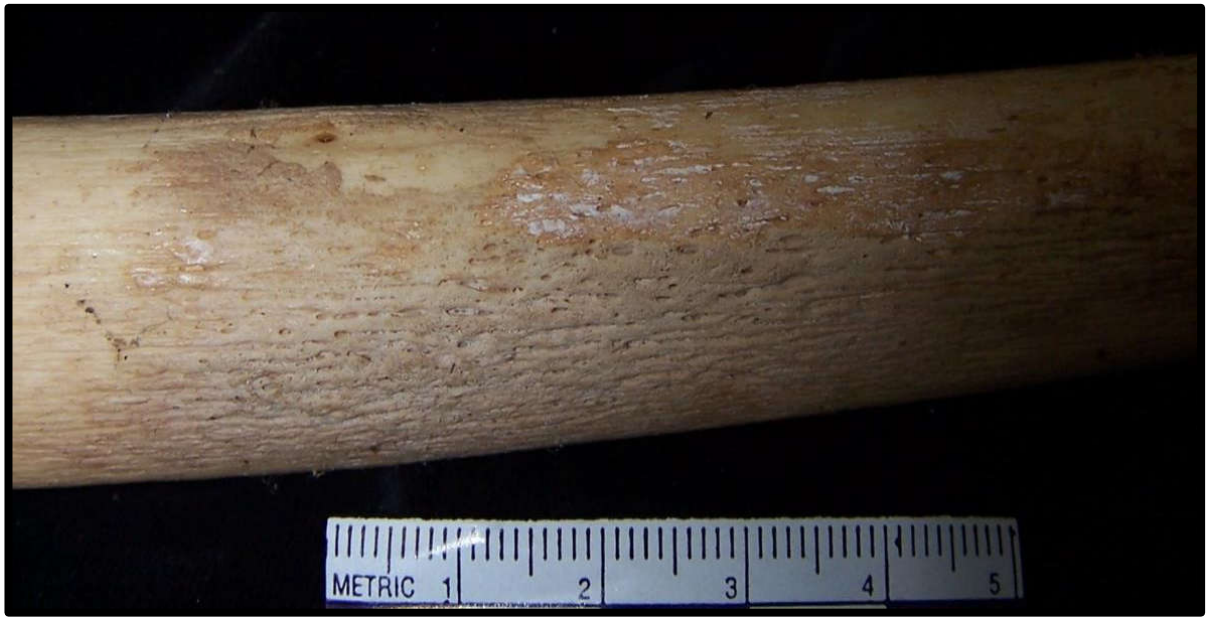

Figure 5. Medial view of the right tibia from a Galloway collection individual showing periosteal new bone formation.

Through contacts with my dissertation committee member, paleoanthropologist Mike Plavcan, I was directed to the Galloway osteological collection, housed in the basement of the Anatomy Department at the Makerere University Medical School in Kampala, Uganda. Here, I was assured, I would find that most individuals would have had malaria and would have received treatment only in severe cases. Since these were individuals who had died in a hospital, most were associated with a specific cause of death. As I prepared for a six-week research trip studying the collection in Uganda, I received two pieces of advice that allowed my research to take a more epidemiological approach. First, Jerry Rose recommended that I set up my data as a cohort study – for every individual I analyzed who had died of malaria, I would analyze another individual of the same age and sex who had died of something else. This way I could be sure that demographical factors were not influencing my results. The second piece of advice came from Cambridge paleoparasitologist Piers Mitchell, who suggested that I compare my findings with a similar reference collection from a non-malarial area as a control sample. I decided to use data I had already collected on the lesions present in the forensic collection at Louisiana State University's FACES laboratory for this critical comparative sample. So in July of 2013, off I went to Kampala.

Figure 6. A view of Kampala from the tower of the Uganda National Mosque.

In the Ugandan collection, I found that indeed porous lesions were common, not just in the cranium, but in focal areas of the humeral and femoral necks, as well as in the spine. These were accompanied by periosteal new bone formation in the lower limb bones, signaling generalized inflammation. All lesions were found at higher frequencies in individuals who had died of malaria. In comparison with the control sample, I found that the Louisiana skeletons had much lower rates of porous and inflammatory bone lesions than the Ugandan skeletons in general. To account for the potential of other nutritional and infectious causes of these lesions, I developed an outcome algorithm using the Ugandan malarial individuals as a gold standard for positive malarial diagnosis. I tried different combinations of lesions until I found the one with the least false positives. Individuals most likely to have had malaria needed at least one lesion of anemia, and one inflammatory lesion. This made sense with what I knew about malaria – illness involved high fevers causing general inflammation, and hemolysis causing severe anemia.

At this point I was finally ready to address the possibility of malaria's impact on the individuals buried at Amarna's South Tombs Cemetery. The presence of malaria during the Amarna period had recently been demonstrated through the ancient DNA of the pharaoh Tutankhamun and other royal family members who once lived at Amarna. Tutankhamun himself was found to have a double infection of two different strains of *P. falciparum* malaria at his time of death. Thus, the city was likely endemic for malaria during the Amarna period. If my meta-analysis of cribra orbitalia in the Nile Valley was any indication, malaria had been present in ancient Egypt since before dynastic times. To calculate a probable prevalence of the disease on the non-elite population, Amarna Project bioarchaeologists Jerry Rose, Gretchen Dabbs, and Heidi Davis worked to record each of the lesions identified as being associated with malaria for each of the South Tombs Cemetery individuals. By inputting this data into the outcome algorithm, I calculated that approximately half of the Amarna individuals showed evidence of a recent malarial infection on their skeletons. New data from the North Tombs Cemetery, currently being excavated and analyzed by Anna Stevens and Gretchen Dabbs, suggests an even higher prevalence of malaria in the individuals buried there.

Figure 7. Map of the Near East showing the probable walking route from Amarna to Hattusa with likely site of conflict marked in between. Map created and modified using ArcGIS® software by Esri.

But what of the Hittite plague? From the ancient texts left by both Egyptians and Hittites, we know the two civilizations maintained contact, and that just previous to the aforementioned plague in approximately 1320 BCE, Egyptian prisoners of war had been brought into the capital city of Ḫattuša, which purportedly spawned the epidemic. After the plague killed the Hittite king and his successor, the third in line Mursili II describes the epidemic as affecting all peoples, regardless of age or class. Although many possibilities have been suggested as to the cause of this plague, malaria fits the profile – having a long incubation period of around two weeks and being indiscriminate of age or class, particularly in naïve populations with little or no previous exposure to the parasite. Paleoclimate reconstructions suggest a warm and wet period between 1500 and 1100 BCE, allowing for increased mosquito population size and geographical range. The dominant malaria vector in Anatolia today is *Anopheles sacharovi* – a mosquito whose ability to live at high altitudes and overwinter would have allowed *P. falciparum* malaria to gain a foothold in the capital city of Ḫattuša at the height of the Hittite Empire. Movement of the population into and out of the rural outskirts and surrounding villages would have provided the fuel needed to keep the epidemic going for 20 years, as lamented by Mursili II.

So what does Amarna have to do with it? Since the city was abandoned around 1332 BCE, the former inhabitants, perhaps carrying the malaria parasite, would have had time to move throughout ancient Egypt, including the region from which the Hittites took Egyptian prisoners-of-war ten years later. The high prevalence of malaria in the population as suggested by the skeletal lesions at the Amarna non-elite cemeteries make it likely that this disease at least featured in this and other noted epidemics in the Near East at this time. We are still trying to understand the dynamics of malaria's impact on the population at Amarna through the analysis of the human skeletal remains from the North and South Tombs Cemeteries. A heavier burden of disease on certain demographic sub-groups could reveal whether this disease was endemic, epidemic, or both. What is increasingly clear is that malaria loomed large in the daily lives of ancient Egyptians during the Amarna period and beyond.

Further reading:

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