DIARRHOEA, DYSENTERY, AND THE CLAP:
CONNECTING THE MILITARY LIFESTYLE TO LITERARY & SKELETAL EVIDENCE OF REACTIVE ARTHROPATHY INDUCED BY BACTERIAL INFECTIONS

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DECLARATION

I, Meghan E. Banton, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

ABSTRACT

Military combatants are frequently exposed to physical exertion, sleep deprivation, deficient diets, and stress, which can all reduce the immune system's ability to ward off infections. Making matters worse, combatants frequently inhabit overcrowded and unsanitary living conditions, which allow bacteria to thrive. As a result of these circumstances, the military lifestyle is associated with increased exposure and susceptibility to infectious diseases. This explains why epidemics are extremely common during times of war, especially in pre-twentieth century conflicts. Though military infectious diseases have been the topic of much research, bioarchaeological contributions have been limited, as most infectious diseases do not cause direct skeletal changes. For example, diarrhoea, dysentery, gonorrhea, and tonsillitis do not cause skeletal changes, but all are known to have been common among historical combatants. Though direct skeletal changes are not produced, the pathogenic bacteria causing these ailments can trigger reactive arthropathies (arthritic conditions caused by microbial infections), which includes the Spondyloarthropathies. Spondyloarthropathies cause skeletal changes and can be observed in archaeological remains. As such, the present research has chosen to explore the potential consequences of military infectious disease by answering the following question: were reactive arthropathies an occupational hazard to past military combatants? This question is answered through two methods. First, historical research methods were employed to investigate the primary research question and to provide a detailed medical history of the emblematic example of reactive arthropathy, Reactive Arthritis. Secondly, a palaeoepidemiological study was designed and implemented to understand the prevalence of reactive pathology in military skeletal assemblages; this is a novel bioarchaeological means of understanding the potential impact of military infectious diseases.

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DEDICATION

For Cpl. Jonathan Yale, U.S. Marine Corps.
A friend full of good humour and an exuberant spirit.

He gave the last full measure April 2008 in Ramadi, Iraq.
Awarded the Navy Cross, February 2009.

PREFACE

Farmville, Virginia is my hometown. Known as the 'Heart of Virginia,' this small college town is centrally located, meaning most areas of Virginia are no further than three hours' drive. Being history enthusiasts, my family often spent weekends (and the occasional 'sick day' from school) visiting historical sites. By age 16, I had visited most of Virginia's major historical parks. By college graduation (2011), I had visited many of the obscure locations and had participated in several archaeological excavations across the state. Virginia has a rich history, all of which I find interesting, but my primary focus has been directed toward military history. From battles between indigenous tribes and English colonials, the American Revolution, the War of 1812, the American Civil War, to the World Wars, Virginia has some form of connection.

My interest in military history paid off, as I obtained employment as a Historical Interpreter at Sailor's Creek Battlefield in Rice, Virginia. This area of Virginia has historical ties to the American Revolutionary War through British Lieutenant Colonel Banastre Tarleton's raids, but the site is most known for its role in the American Civil War. Sailor's Creek was the last major battle for Confederate General Robert E. Lee, as he lost a third of his Army of Northern Virginia at this engagement, forcing his surrender at Appomattox Court House three day later. When hired at Sailor's Creek, I was knowledgable of Revolutionary and Civil War military history and had spent considerable time in hoop skirts and petticoats as a reenactor; however, I had not explored the topic of Civil War medicine. This made me feel a bit inadequate for the position at Sailor's Creek. The Hillsman House is the primary building on site, a small farmhouse atop a grassy hill overlooking the battlefield. Though picturesque from the exterior, the interior of the house reveals a darker history, made apparent by blood-stained floorboards; a permanent reminder of its time as a Union Army field hospital (this has been confirmed through forensic analysis). I decided to do some basic background research into Civil War medicine because of this building, but basic research turned into an obsession. By the end of my seven-year employment with the park, eighteenth and nineteenth century medical practice had become my personal niche within the park. When I moved to London to pursue my MSc degree at UCL, I had not lost any of my enthusiasm for the subject.

Not long into the MSc course, my interest in military history was again brought to the fore. During Dr. Tony Waldron's palaeopathology lecture on Spondyloarthropathies, there was mention of Reiter, Fiessinger, and Leroy's discovery of reactive arthritis, as well as the condition's connection to bacterial triggers. I found it interesting that multiple researchers had described this condition simultaneously, with all descriptions involving World War I soldiers. Doing what I like best, I did some research. I realized you could copy the list of bacteria involved in the development of Spondyloarthropathies and paste it directly into a discussion of war epidemics. After connecting a few more dots between Spondyloarthropathies and military combatants, the present research project was created to investigate the possibility that these conditions were occupational hazards to historical combatants.

Occupational related injuries and diseases are also topics I consider important due to past experience. I am the daughter, cousin, niece, and grandniece of electrical linesman. This is an extremely dangerous occupation. With heavy equipment and electrical wires carrying voltages anywhere from 46kV to 230kV, accidents often end in death; 30 to 50 linemen in every 100,000 are killed in work-related accidents annually (Christie 2007; Mauldin 2015). Though seriously injured, my father is among the statistical few that survived a major work-related accident; a pole in excess of 6,000 pounds roll over him before slinging him into an 11-foot hole. To make complicated matters short, he qualified for compensation, but lawyers became necessary to obtain due funds. As many of my male relatives are linesman, this was not the first work-related injustice I had witnessed within this occupation. Such experiences have made me an activist for workers' rights and have directed my bioarchaeological interests toward occupational related skeletal features, diseases, and injuries.

As one reads the following pages, the influence of these interests and experiences become evident. For instance, though conflicts from the late medieval period forward are considered, there is particular focus on my personal areas of interest - eighteenth and nineteenth century medicine and conflicts (Napoleonic Wars, Crimean War, American Revolutionary War, and American Civil War). Essentially, this research was perused as a means of obtaining new information about old topics of personal interest. Having spent four years on this project, I have satisfied some of my curiosity, but I certainly plan to continue exploring occupational and military related topics in future bioarchaeology research.

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Credit must be given where due and there are many who have my utmost gratitude for making this project possible:

Dr. Tony Waldron: many thanks for all of your guidance through the research process. Your interest in interdisciplinary research gave me the encouragement and confidence needed to pursue this project. I count myself very lucky to have had you as my primary supervisor, as no one could understand or appreciate my obsession with old dusty medical texts as well as you!

Dr. Simon Hillson: thank you for being my technical advisor. As you have pointed out, my project is a bit different. This occasionally left us unsure of the overall direction to take, but your knowledge and advice always got me back on track.

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Dr. Carolyn Rando: I am extremely appreciative of your guidance, which helped me produce this document. Apologies for subjecting you to the inevitable Ph.D. stress breakdown, but you handled it well (the candy distraction method works wonders).

Dr. James Jordan: you have my gratitude and veneration for many reasons. For mentoring my interest in archaeology and anthropology from age 11 to present. For having faith in my abilities as a scholar and colleague. For spending many hours editing and providing feedback on every major academic document I've ever created, including this one.

In addition to individuals, this research would not have been possible without the aid of numerous institutions. The **UCL Institute of Archaeology** and the **UCL Graduate School** are owed sincere thanks for grant funding. Your generous financial aid made this project physically possible and provided assurance of UCL's confidence in my research goals.

In the early stages of this research, there were concerns about obtaining access to military skeletal assemblages, as they are not overly common. Fortunately, many institutions took an interest in this research and allowed access to their collections. As such, this project would not have been possible without …

The British Museum: for access to Nubian remains of pathological interest.

University of Bradford (BARC): for access to the Towton assemblage.

Oxford Archaeology & **Centre for Human Bioarchaeology (MOLA):** for access to the Greenwich Hospital assemblage.

Centre for Human Bioarchaeology (MOLA): for access to the Chelsea Old Church and St. Brides Lower assemblages.

University of Sheffield: for access to the All Saint's Church assemblage.

Bournemouth University: for access to the Plymouth Hospital assemblage.

National Museum of Health and Medicine: for access to Pvt. Cluckey's records and the invitation to examine and discuss his remains with Anatomical Collections Manager, **Brian Spatola**.

<u>Very truly, thank you!</u>

INTRODUCTION

This project explores how environmental exposures associated with the military lifestyle pathologically affected historical military combatants. It has long been acknowledged that historical combatants were susceptible to epidemics of infectious disease, as deadly epidemics have been a nearly universal component of war narratives throughout history. Historical documents also reveal that war epidemics were no trivial matter, as they greatly reduced the fighting strength of armies and has led to the withdrawal, postponement, or cancellation of military campaigns (Smallman-Raynor & Cliff 2004 [a]).

There is no mystery as to why war epidemics were more lethal than pre-twentieth century weaponry. Military combatants (past and present) are regularly exposed to physical exertion, sleep deprivation, deficient diets, and stress, which reduce the immune system's ability to ward off infections. In addition to a weakened immune system, combatants often inhabit overcrowded and unsanitary living conditions where bacteria thrive. As a result of these circumstances, the military lifestyle is associated with increased exposure and susceptibility to infectious diseases. Before the advent of germ theory, antibiotics, and other twentieth century medical advancements, the occurrence of military epidemics were largely an inevitable fact of war.

The relationship between the military lifestyle and epidemics has been the topic of much research, but there is room for further investigation. To date, the majority of research has been conducted by medical historians, analytical geographers, and bioarchaeologists; however, the bioarchaeological contributions have not been greatly diverse. Most bioarchaeological research into military infectious diseases do not focus on the diseases themselves. Instead, they provide evidence about environments or other living circumstances that would favour the occurrence of infectious diseases. The predominance of general bioarchaeological interpretations is not due to lack of interest, but an obstacle which is difficult to overcome: most infectious diseases common to combatants do not cause skeletal changes, meaning there is little direct evidence of their existence in archaeological human remains.

Though most infectious diseases leave little skeletal evidence, this research presents a novel bioarchaeological approach to understanding military infectious disease through a palaeoepidemiological study of reactive arthropathies (arthritic conditions triggered by microbial infections). Some of the most common military epidemics in history consist of gastrointestinal (diarrhoea, dysentery), urogenital (venereal diseases like gonorrhoea), and oropharyngeal (tonsillitis) infections. These infections are caused by bacteria known to trigger reactive arthropathies; for example, the Spondyloarthropathies (SpAs) [singular and general referral spondyloarthropathy (SpA)] are triggered by bacterial infections known to be associated with military epidemics. SpA produces skeletal changes and can be studied by bioarchaeologists. As military combatants would have frequently been exposed to arthritogenic (arthritis causing) bacteria know to trigger SpA and other forms of reactive arthropathy, these conditions likely occurred in historical military personnel, but was it a frequent occurrence? Is it permissible to consider reactive arthropathies an occupational hazard to historical combatants? In assessing the strength of the affinity between reactive arthropathies and military combatants, this research seeks to achieve several goals that will advance the field of bioarchaeology and provide valuable insight into particular aspects of the military experience.

Research Objectives:

Foremost, this research pursues sound evidence to support the existence of an affinity between reactive arthropathies and military combatants, one that is worthy of being considered an occupational hazard. Previous historical research has led some medical scholars to suggest that certain reactive arthropathies may be a "soldier's disease" (Bollet 1991; Collison 2015; Hodgetts & Espinosa 1990; McSherry 1982). Adding to this work, the present project has conducted further investigation into descriptions of reactive arthropathy in historical medical documentation. Ultimately, historical research served two purposes. First, it was a starting point used to better understand how the background, living circumstances, and behaviours of historical military combatants relates to their increased susceptibility and exposure to arthritogenic bacteria. This was achieved by providing a military medical history of infectious diseases, which included relevant context about important scientific developments, essential works/individuals, recruitment habits, development of military medical systems, and common habits/behaviours. Secondly, as is frequently done in historical archaeology, the historical research was utilized as a means of enriching the bioarchaeological findings. This second purpose was achieved by investigating primary historical documents for evidence of a particular form of reactive arthropathy, reactive arthritis

Though the qualitative historical evidence is persuasive of a reactive arthropathy-military affinity and provides valuable contextual information, scientific investigations are concerned with establishing numerical relationships. For this reason, quantitative data is needed to definitively prove the presence of a military-reactive arthropathy affinity. To obtain this quantitative data, a bioarchaeological (palaeoepidemiological) investigation was conducted to determine the frequency (prevalence) of reactive arthropathies in historical military assemblages and the strength of the connection (odds ratios and Mantel-Haenszel X^2 tests).

Apart from proving a military-reactive arthropathy affinity through historical and bioarchaeological research methods, this project introduces new means of analysing erosive arthropathies. Bioarchaeologists frequently face issues with making specific diagnoses due to issues of preservation. This missing data means many skeletal remains must be excluded from statistical analysis, which undoubtedly leads to underestimation of disease frequency (prevalence) (Waldron 2007). Diagnosis of erosive arthropathies in skeletal material is no exception to this problem. To avoid the difficulties presented in obtaining reliable prevalence data due to issues of specific diagnosis, this research presents a broader means of analysing erosive athrtopathies by classifying pathology based on assessment of general patterns of expression to broadly categorize cases according to their likely aetiology (reactive or nonreactive). Though this broad form of analysis will not be appropriate for every study of erosive arthropathy, the application of this method will prove useful for projects interested in obtaining information about the commonality of SpA and bacterial infectious diseases in past societies; this method is also useful in formulating general conclusions about sanitation. Furthermore, discussion of erosive arthropathies is limited in bioarchaeology, so this research adds to the current body of data and, by mitigating the complications in researching erosive arthropathies, may encourage future investigation.

The subjects of this research, military combatants, are somewhat neglected in bioarchaeological research as well. Though military skeletal assemblages are far from non-existent, they cannot be described as abundant and, those which have been excavated, are not always available for research. Of the extant bioarchaeological research of military skeletal assemblages, there has been much fascination and focus on the circumstances of death. This is easily understood, as many military skeletal assemblages are from mass grave contexts which signifying a major death event, making analysis of trauma and cause of death a matter of importance. Nevertheless, bioarchaeological research focusing on military assemblages for the purpose of understanding life events and living circumstances have been limited. Such research is deserving of more attention due to its ability to shed light on the lifestyle, challenges, and practices of past military combatants. This research, being focused on potential occupational hazards resulting from exposures common to the military lifestyle, will serve as a contribution to this limited body of data.

The topic of this research, military reactive arthropathies, extends from the past into matters of modern importance. Bioarchaeological work focused in palaeopathology and palaeoepidemiology has an often overlooked ability to shed light upon the present. For example, bioarchaeological research can bring attention to neglected issues of modern relevance. This research seeks to identify if examination of the palaeopathology of reactive arthropathies among military combatants has any modern implications worth further consideration.

In sum this research seeks to:

1. Summarize historical and archaeological data collected in relation to a reactive arthropathy-military affinity and quantify these findings to confirm/negate consideration of reactive arthropathies as occupational hazards specific to historical military combatants.

2. Provide methods that are useful for data collection and analysis of erosive arthropathies in archaeological skeletal assemblages.

3. Expand upon the literature available for topics not commonly discussed in bioarchaeological research (erosive arthropathies and non-trauma/cause of death related analysis of military assemblages).

4. Bring the findings of this project full circle by relating it to matters of modern importance.

Research as an Interdisciplinary Endeavour: History & Archaeology

The disciplines of history and archaeology have a close, though not always friendly, relationship (Orser 2016; Robertshaw 2000; Stuart 2007; Vansina 1995; Yoffee & Crowell 2006). Historical archaeology draws heavily upon the discipline of history by using archival research methods and documents to interpret and understand their archaeological findings. (Little 2007; Hume 1964; Orser 2016; Yoffee & Crowell 2006). This has also been done in the present project. Historical research methods and historical documents aid this bioarchaeological research by providing information relevant to the primary research question and by providing contextual information useful in interpreting its results and implications. Though history can augment the bioarchaeological investigation, the information gathered by the bioarchaeological investigation can also enhance our understanding of history.

Archaeology has proven useful in understanding various aspect of history and past peoples. It has often been used to validate and reveal more than was previously known from the historical record (Little 2007; Hume 1964; Orser 2016; Reid 2016, 197; Spores 2015; Whitehorne 2010; Yoffee & Crowell 2006). For example, historical documents about the Medieval All Saint's Church in York (1093 – 1539) record the presence of an anchoress, Lady Isabel German, from 1428 to 1448 (McIntyre & Bruce 2010). An anchoress was an individual who would voluntarily withdraw from society to live an isolated and devoted religious life; they were sealed away in a room and would only be allowed very limited contact with the outside world (McIntyre & Bruce 2010). Lady Isabel German is known through seven wills in which money was left to her in exchange for prayers on their behalf (McIntyre & Bruce 2010; Raine 1955). It is also known that she had a servant who likely fulfilled simple tasks, such as bringing her food and water (McIntyre & Bruce 2010; Raine 1955). The historical account of her presence at All Saint's Church appears to be supported by archaeological excavations of the cemetery. The remains of a middle-aged woman were discovered in a crouched position inside the apse of the church. Her burial location suggest she was a woman of high social status, as wealthy church benefactors and their families were frequently buried inside medieval churches; however, her abnormal positioning (not prone, but crouched) “implies that this lady represented someone other than a church benefactor” (McIntyre & Bruce 2010, 34). McIntyre and Bruce (2010) suggest that this female set of remains may be those of Lady Isobel German.

Continuing with the possibility that the remains at All Saint’s Church were those of anchoress Lady Isobel German, her bones revealed interesting details about her personal story not previously known form historical documentation. For example, her remains displayed advanced indications of osteoporosis (McIntyre & Bruce 2010). The advanced state of her osteoporosis may have been partially attributed to her living situation. Since an anchoress would not have left the confines of her room, she would have had limited movement, which can be a contributing cause of osteoporosis (McIntyre & Bruce 2010). Also of great interest, this set of remains had pathological markers of syphilis. Given the advanced nature of the condition, it seems likely that she contracted syphilis as an adolescent or young adult (McIntyre & Bruce 2010). Given the combination of syphilis and advanced osteoporosis, she likely required care and aid from another individual; this care may have been provided by the servant known from the historical record or a family member (McIntyre & Bruce 2010). The presence of syphilis also presents many open ended questions. For example, Lady German lived at All Saint’s Church from 1428 to 1448, which would have been quite early for Europeans to recognize syphilis, so it raises the question as to whether her disease was known to have been sexually transmitted or possibly confused with other deforming condition like leprosy. Either way, deformity was frequently associated with sin during the medieval period, so this causes one to question if becoming an anchoress was somehow influenced by this condition (Metzler 2006).

For another example illustrating how archaeology teases “out the subtleties of a particular topic,” we can turn to previous research conducted by the present author in partnership with the Longwood University Archaeology Field School at Nomini Hall in Westmoreland, Virginia, US (Reid 2016). Data obtained from primary historical documentation and archaeological research carried out by the Longwood Archaeology Field School were combined in order to create a more accurate visualization and understanding of the landscape of Nomini Hall, a colonial plantation owned by Robert "Councillor" Carter, who is known historically for his eighteen years of service on the Governor's Council in Williamsburg and emancipation of his 600 slaves (beginning in 1792, his actions made him one of the largest private emancipators in North American history) (Banton 2011). The archaeology conducted on this site provided interesting details about the landscape of Nomini Hall that were not revealed in historical documentation. For instance, though there are no obvious remnants of colonial structures on the property today, a diary description provided by Philip Vickers Fithian (the Carter children's school teacher) meant a great deal was known about the colonial landscape, with special attention paid to the land immediately surrounding the plantation house; Fithian provides a very detailed description of the four outbuildings placed on the North-East, North-West, South-West, and South-East corners of the property (Fithian 1957). What was not mentioned in Fithian's description was the brick wall that connected two of the four main outbuildings, which was discovered through archaeological excavations and a ground penetrating radar survey; there is some archaeological evidence suggesting the possibility that similar walls continued around the plantation house to connect all four outbuildings (Banton 2011). Oyster shell utility roads unmentioned in historical documentation were also discovered through archaeological excavations (Banton 2011). Such findings help interpret the cultural landscape of this site – identification of the physical location of natural and man-made structures, their evolution over time, and context about the people and tasks closely linked to these structures. For instance, defining the boundaries of a colonial property, such as Nomini Hall, tells us much about who would have occupied these spaces and the types of tasks conducted in particular locations. The wall discovered to surround the plantation house and primary outbuildings sets a physical as well as social boundary on the landscape; inside the wall delineates the area primarily dedicated to workers of domestic labour (fixated on the function of the house and the needs of the Carter family), while outside the wall, where structures like the utility road were discovered, delineates the area primarily dedicated to workers of profitable labour (agriculture and trade).

Archaeology serves as a fact-checker for information provided by historical documents, which can frequently be bias or provide partial information (Hume 1964; Little 2007; Spores 2015; Stuart 2007; Wendrich *et al.* 2006). Written history, “can deliberately distort and obscure,” but archaeology has had success in illumining these instances (Hume 1964, 217; Little 2007). For example, General George Custer’s last stand at the battle of Little Big Horn has long been surrounded by a popular hero-story, with his men being described as “disciplined and unwavering, even in the face of certain death” (Fox 1993, 34). With none of Gen. Custer’s men surviving to tell their side of the story, this idea has been allowed to continue. As Fox (1993) points out, this popular image has also been portrayed in historical accounts of the battle; examples: *Custer’s Luck* (1955) by Edgar Stewart and *Legend into History: The Custer Mystery* (1951) by Charles Kuhlman both adhere to the hero-ideal of unfailing tactical stability during the battle. These interpretations of history ignore counter arguments presented by historical Native Americans accounts that described disorder and panic among Gen. Custer’s men (Fox 1993). Archaeological excavations of the battlefield brought forward new evidence which suggests the Native American accounts of this conflict were more accurate than the popular hero-story. Battlefield analysis indicates Native Americans never drove Gen. Custer’s men onto a particular piece of ground (no official location of a ‘last stand’) and that cohesion among Gen. Custer’s men did evaporate during the battle (Fox 1993).

Historical documents and archival research methods can also be used in archaeological sciences to achieve these and other goals. For example, interdisciplinary work branching between the disciplines of environmental archaeology, history, and ecology have proven beneficial in understanding human–ecosystem interactions, as it has become increasingly evident that ecosystems are influenced by ecological processes, historical events, and human actions; circumstances of human history influence the environment, just as environmental factors influence history (Briggs *et al.* 2006; Szabó 2010). Bioarchaeology is another archaeological science where incorporation of historical research methods benefits both disciplines (history and archaeology). Bioarchaeologists traditionally pair cultural and biological considerations. They seek to integrate information obtained from archaeological skeletal remains (age at death, sex, pathology, trauma, robusticity, stature) with information pertaining to the environment and culture of past peoples (Martin & Harrod 2013). In addition to considerations of culture and biology, the present bioarchaeological research incorporates history in a manner similar to that which has long been used in historical archaeology; historical documentation is used to contextualize the bioarchaeological research and aid in interpretation of the produced results.

The bioarchaeological investigation of this research will influence our understanding of history. Though some scholars have suggested the possibility that reactive arthritis is a 'soldier's disease' based on evidence from historical documentation, this suspicion has not been quantified or assessed in a manner that indicates the strength of this potential reactive arthropathy-military affinity (Hodgetts & Espinosa 1990). As frequently done in historical archaeology, this project seeks to validate (or discredit) what is recorded in historical documentation through the use of bioarchaeological research methods. A sub-speciality within bioarchaeology is palaeoepidemiology, which is used to statistically evaluate diseases and conditions in skeletal assemblages (Waldron 2007). Using palaeoepidemiological methods of investigation, bioarchaeology can numerically confirm or dispute suspicions of the presence of a reactive arthropathy-military affinity based on direct observation of pathology expressed in archaeological skeletal assemblages. Beyond possibly confirming a reactive arthropathy-military affinity, palaeoepidemiological methods of investigation can provide information about the odds of reactive arthropathy occurring when exposed to the military lifestyle, as well as establish the overall strength of this association. All of this information is provided by calculating prevalence, odds ratios, and Mantel-Haenszel X^2 tests, which produce numerically definitive data that could not be gathered from the historical record.

Additionally, the bioarchaeological investigation into reactive arthropathies in military skeletal assemblages can provide unique information to accompany the historical record; as historical archaeology often succeeds in doing, this research will provide historical details missing from historical documentation. By examining reactive arthropathies in archaeological skeletal assemblages, we can determine what particular pathological features (erosions, spinal fusion, enthesopathy, etc.) are most common. Identification of specific types of reactive arthropathies can also inform us about the bacterial environments that a particular combatant (or group of combatants) likely faced, as certain types of reactive arthropathies are linked to specific types of bacterial infections. Though archaeology and history go about their methods of investigation differently, joint use of methods from both disciplines creates a unique and thorough means of understanding the past; "archaeology and history together paint a picture substantially different from those composed from historical data alone" (Fox 1993, 34).

Keeping with the interdisciplinary theme, this research continues to utilize historical research and scientific observation to investigate the reactive arthropathy-military affinity through a case study. Private Peter Cluckey served in the U.S. Army during the early twentieth century. During his service he developed a form of arthritis that will later be argued is some form of SpA, albeit a very extreme case! His case is examined because it combines both forms of investigation previously discussed – use of historical resources and scientific osteological observation. Use of his medical records provided valuable knowledge of the circumstances and events related to his condition. In addition to historical records, Pvt. Cluckey's skeletal remains were available for examination, as they are displayed at the National Museum of Health and Medicine in Maryland, U.S.A. The historical and osteological information available pertaining to his case is unique. Unlike most archaeological remains, osteological analysis can be conducted alongside individual contextual information provided by his medical records. His case provides a specific example that favourably reflects upon the findings of both the historical and bioarchaeological investigations and provides a specific example that can be referred to when interpreting the wider implications of reactive arthropathies among military combatants.

Project Structure & Limitations:

The present research provides a detailed and holistic analysis illustrating the affinity between military combatants and reactive arthropathies while clearly narrating the story of rheumatic combatants throughout history. Though every attempt has been made to be thorough, there were some limitations due to matters of circumstance, time, and funds. Archaeologists always deal with problems of circumstance due to limited control over the materials being examined. In the case of bioarchaeology, perfect skeletal assemblages do not exist. Many skeletal assemblages are discovered by accident and bioarchaeologists do not always have a say on what assemblages are excavated. Nor is there any control over the individuals that were deposited into a given assemblage; bioarchaeologists have no control over who died and no control of where deceased individuals were buried in the past. For such reasons, skeletal assemblages will always be biased. The biases of the samples examined in this research primarily pertain to age and sample size. These issues have been identified and addressed to the best of ability (described in Chapter 6).

Time and funding were another constraint. In this research, these limitations somewhat influenced the assemblages examined. For instance, the focus of the bioarchaeological investigation of this research is placed on British skeletal assemblages due to the convenience of accessibility and affordability (travel and bench fees), though American and mainland European assemblages would have been equally appropriate. Furthermore, though this project could reasonably be focused on military groups throughout history, the entirety of history would be quite unmanageable for a three-year research project. As such, the focus remained on the researcher's primary areas of knowledge and interest – early modern and nineteenth century assemblages.

Though there have been limitations, the amount of research conducted over the course of this project has been extensive and branches across several disciplines. Archival research seeking primary referrals to reactive arthropathies in historical documentation was an ongoing effort, but much of this research was conducted within the first twelve months of research. The labour involved in locating and obtaining documents for this research varied. While many documents were easily accessed through online archives, retrieval of other documents (such as the *Medical and Surgical History of the British Army which Served in Turkey and the Crimea…*) took several months of persistent searching to obtain.

In addition to conducting historical research, the first six months of this project involved locating, obtaining permission, and making arrangements to examine appropriate skeletal assemblages. This was somewhat challenging, as military skeletal assemblages cannot be considered overly common and several of the assemblages were in early stages of research. In spite of these challenges, this process went far better than anticipated; all requests to examine British assemblages were granted, though special arrangments were occasionally necessary.

Once arrangements had been made, examination of skeletal assemblages took an additional six months. When studying erosive arthropathies, it is important that all joints be carefully observed. Though remains may fit sex and age qualifications for inclusion into the study, their preservation may prevent their ultimate inclusion; nevertheless, these remains must still be examined for erosive pathology before they can be confidently excluded (Waldron 2007). Though 306 skeletal remains met the qualifications needed to enter this study, the need to observe all remains fitting age and sex qualifications means double this amount were actually examined (approximately 611 sets of skeletal remains). These remains were examined at six locations throughout the U.K.:

1. Oxford Archaeology, Oxford, U.K. (Greenwich Royal Naval Hospital assemblage)
2. University of Sheffield, Sheffield, U.K. (All Saints Church assemblage)
3. Biological Anthropology Research Centre, Bradford, U.K. (Towton assemblage)
4. Bournemouth University, Bournemouth U.K. (Stonehouse Royal Naval Hospital assemblage)

5. Museum of London, London, U.K. (Chelsea Old Church and St. Brides Lower assemblages)
6. British Museum, London, U.K. (Sudanese Assemblage, pilot study in pathology recognition)

The results of this research project are now presented. The structure of this document uses a scientific progression of five main sections: Background (Chapters 1 – 4), Materials and Methods (Chapters 5 – 6), Results (Chapters 7 – 10), Discussion (Chapter 11), and Conclusions (Chapter 12). The background chapters of this document begin with basic and separate concepts (clinical aspects of reactive arthropathy and military medical history) before identifying their potential correlation (why a reactive arthropathy-military affinity is suspected). The remaining background information relates to understanding the bioarchaeological and palaeopathological context and contributions of this research.

Chapter 1 describes the clinical aspects of erosive arthropathies, which encompass several conditions with complex aetiology and pathogenesis. Their aetiology and pathogenesis are closely linked to disease expression, which must be understood for identification and classification of pathology in archaeological skeletal remains. As such, this chapter is aimed at providing a basic understanding of the cause, expression, and differential diagnosis of erosive arthropathies. Furthermore, this chapter later provides the background needed to comprehend 'why' military assemblages have been selected for reactive arthropathy research.

Increased susceptibility and exposure to particular arthritogenic bacteria is behind the suspicion that reactive arthropathies were a problem among historical combatants. Chapter 2: The Military Lifestyle, Infectious Disease, & Rheumatism sets out to explain 'why' and 'how common' these infections were among historical combatants. This chapter utilizes both primary and secondary historical resources pertaining to social and medical military history (as well as modern clinical research) to establish the wider historical context of this research.

With an understanding of the clinical aspects of reactive arthropathies, bacterial infections, and military medical history, the primary research question can be properly explained and addressed in Chapter 3. Using quantitative historical and bioarchaeological research methods, can a strong connection between reactive arthropathies and historical military combatants be established? Were reactive arthropathies an occupational hazard to historical military combatants? Hypotheses and secondary research questions are also explained in this chapter.

Previous palaeopathological and bioarchaeological research is considered in Chapter 4. Research relating to erosive arthropathy and military skeletal assemblage research is summarized before being compared to the goals and approaches taken by the present project. This comparison of past and present research identifies where this work expands upon present knowledge to serves as a valuable contribution to the fields of palaeopathology and bioarchaeology.

Materials and Methods are then identified. Chapter 5 describes the skeletal assemblages that were utilized to investigate the primary research question. It provides background on the history, socioeconomic status, archaeological context, and biological profiles of each assemblage. Chapter 6 describes the methodology used during the historical and skeletal investigations. Chapter 6 also identifies areas where the study design was limited and addresses how these issues were mitigated or tested.

As already made clear, this is an interdisciplinary research project that utilizes bioarchaeological and historical research methods, so the design of the results chapters differ. Chapter 7 presents the results of the historical investigation. Historical references, both those previously known and newly identified, are summarized. The quality of the content and quantity of these resources is then considered to determine if the suggestion of a reactive arthropathy-military affinity is supported by historical documentation.

Chapter 8 presents the data gathered during the skeletal investigation and the results for prevalence, odds ratios, and methodological considerations. As is typical of scientific writing, no interpretation is made of these results; this chapter is merely a report of the calculated statistics. Elaboration and interpretation of these statistical results occurs in chapter 9 to determine if the suggestion of a reactive arthropathy-military affinity is supported by statistical analysis of skeletal assemblages.

Chapter 10 presents the case study of Pvt. Peter Cluckey. Though his case is used in the discussion chapter to help interpret the potential experience of military combatants affected by reactive arthropathies, his case is also a result. His case serves as a specific example that illustrates the validity of a potential reactive arthropathy-military affinity. Furthermore, this chapter is the first official evaluation of his case since 1955.

Chapter 11 takes the finding of chapters 7 – 10 and discusses their bioarchaeological, historical, and modern implications. While largely focused on the archaeological and historical implications of this research, this chapter compares the similarities and differences between past and present cases of military SpA. This comparison illustrates how the present can emulate the past and exemplifies how bioarchaeological research can draw attention to modern issues of importance.

Finally, Chapter 12 summarizes all of the findings and contributions made by this research. The present project could not address every question or potential avenue relevant to bioarchaeological investigations of reactive arthropathies. As such, the final section of this chapter outlines further questions and investigations that can be pursued in future research.

CHAPTER 1:
Clinical Background

Though the heart of this research is set on determining information about reactive arthropathies in the past, a reasonably thorough grasp on the clinical background of these conditions is necessary. Reactive arthropathies have an intricate pathogenesis and affect the body in differing ways; for instance, some reactive arthropathies affect the heart, some the muscles, and others the skeleton. Understanding the clinical background involved in the aetiology, expression, and differential diagnosis of these conditions is vital to the current research project for several reasons.

Comprehension of the aetiology of these conditions is directly linked to the rationale of why reactive arthropathies are suspected to have been an occupational hazard to historical military combatants (addressed in 'Chapter 2: The Military Lifestyle, Infectious Disease, & Rheumatism'). For the palaeoepidemiological investigation, it is important to understand how these conditions skeletally express themselves, as this has influenced the methodology used for identification and classification of pathology in skeletal remains (addressed in 'Chapter 6: Methods'). Finally, for differential diagnosis, one must be knowledgeable of the skeletal changes produced by reactive arthropathies, as well as the changes created by conditions of possible confusion, as incorrect pathological identification may result in inaccurate statistical figures.

Reactive Arthropathies: Bacterial Infection & Arthritis

As previously stated in the Introduction, a reactive arthropathy is an arthritic condition that occurs as a result of a microbial infectious agent (bacteria, virus, parasite, etc.). Under this definition, there are many conditions that could potentially be considered reactive, but this research has focused firmly on reactive arthropathies that fulfil several criteria, which are listed in **Table 1**.

Table 1: this table describes the features used to define 'reactive arthropathy' in this research. Source: created by the author.

Features of Reactive Arthropathy	
1	Are triggered by bacterial infections
2	The pathogenesis involves a genetic predisposition for developing inflammatory arthritis
3	Can be described as autoimmune or autoinflammatory
4	A direct bacterial invasion of the joint is not necessary for arthritis

Point four of the above table automatically excludes several conditions that are triggered by bacteria. For example, septic arthritis results from a direct bacterial invasion of the joint capsule, meaning the presence of bacteria can *always* be demonstrated in a test of synovial fluid (García-Arias *et al.* 2011). In contrast, the reactive conditions considered for this project may be sterile; synovial fluid test may or may not demonstrate the presence of bacteria. Arthritis produced in sterile reactive arthropathies result from genetic predispositions (**Table 1** - point two) for particular immune responses to bacterial invasion; some individuals have abnormal immune responses (inflammatory) to bacterial invasion, which ultimately produces arthritis. In short, reactive arthropathies are immunological disorders frequently affecting multiple body systems and joints, but conditions like septic arthritis cause direct joint irritation, so changes are often localized to a specific area (Dawes & Sheeran 2012).

Table 2: this table describes the differentiating features of 'autoinflammatory' and 'autoimmune' diseases. Source: table adapted from Ambarus *et al.* 2012, 352.

Autoinflammatory Diseases vs. Autoimmune Diseases	
Autoinflammatory	**Autoimmune**
Involves innate immunity	Involves autoimmunity
Recurrent attacks/spells; Local triggers	Continuous progression
No autoantibodies present	Autoantibodies present
Genes involved in cytokine pathways and pathogen recognition	Genes involved in adaptive immune response (ability to adapt to the presence of an infectious agent)

This touches on point three of **Table 1** - the condition can be described as autoimmune or autoinflammatory. Autoimmune and autoinflammatory diseases share basic features. Though the immune system's primary function is to protect against infections, this function goes drastically wrong with autoimmune and autoinflammatory conditions; pathological processes produce inflammatory changes that damage the host's musculoskeletal system (Ambarus *et al.* 2012; Doria et al. 2012). Where autoimmune and autoinflammatory conditions differ is in the process of *how* inflammatory changes are produced and expressed (see **Table 2**).

Acute Rheumatic Fever (ARF), which is also referred to by some clinicians as Rheumatic Fever, is an illustrative example of a reactive arthropathy meeting all of the criteria listed in **Table 1**. ARF is triggered by *Streptococcus pyogenes,* which causes infections like tonsillopharyngitis ('strep throat') and scarlet fever (Bollet 2002; Chakravarty *et al.* 2014; Cunningham 2014; Dawes & Sheeran 2012; Gunzenhauser *et al.* 1995; Thomas *et al.* 1988). In some genetically predispositioned individuals, infection by *S. pyogenes* can trigger an autoimmune response that produces arthritis, carditis, and Sydenham chorea (Chakravarty *et al.* 2014). This combination of symptoms is not only unpleasant but potentially deadly.

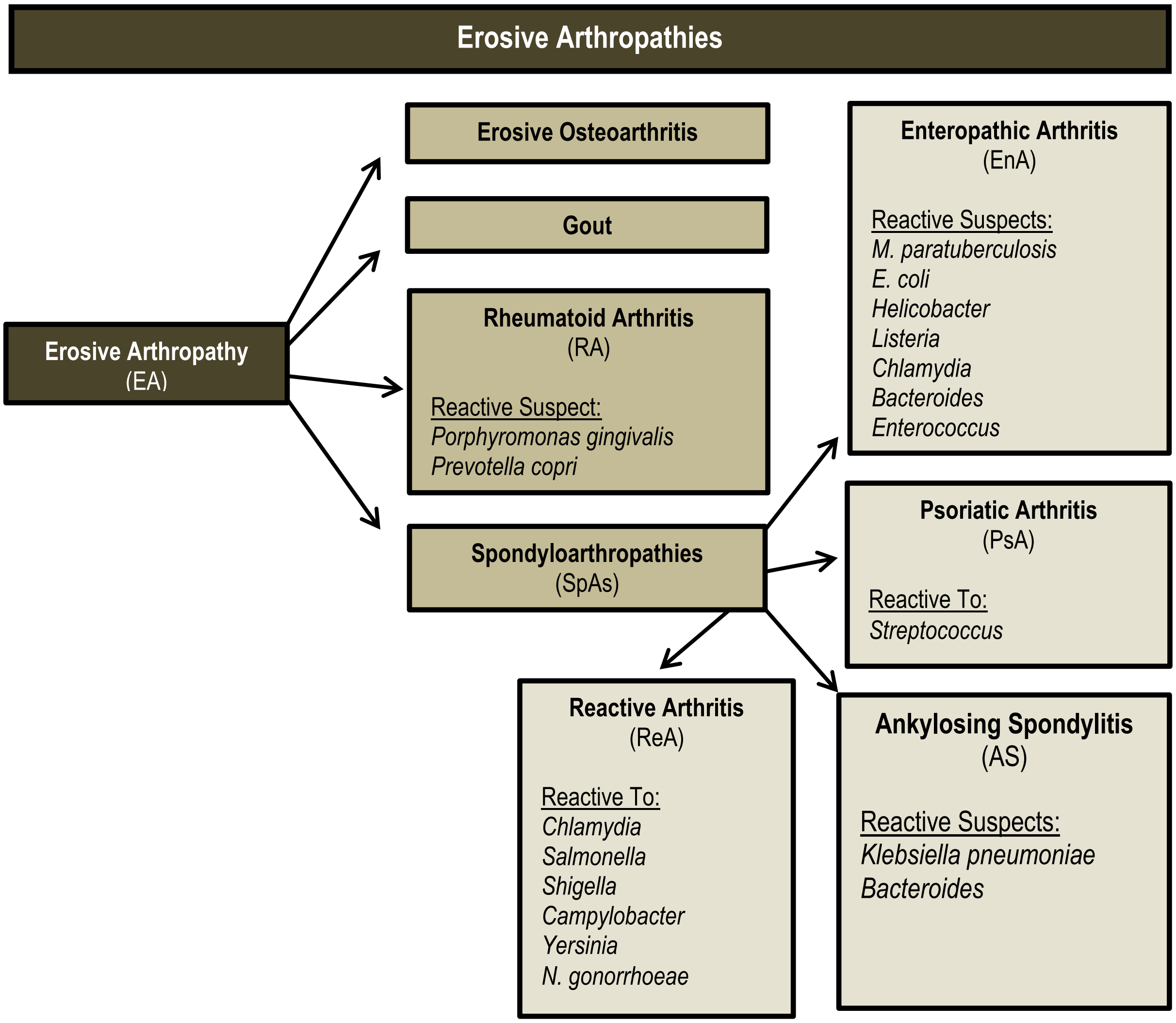
Clinicians have not been completely successful in pinpointing the exact genetic feature that causes streptococcal infections to generate an autoimmune response, but a genetic component is most certainly involved in ARF pathogenesis (Chakravarty *et al.* 2014; Cunningham 2014; Hilário & Terreri 2002). One form of evidence that indicates a genetic component is the tendency for family aggregation, "family members of RF [rheumatic fever] patients have a higher probability of developing disease, independent of environmental factors, [which] has led to the hypothesis of a genetic predisposition" (Hilário & Terreri 2002, 482). More current research has pinpointed several suspects, including several major histocompatibility complex class II alleles: HLA-DR4, HLA-DR2, HLA-DR1, HLA-DRW6, HLA-DR7, and HLA-DW53 (Chakravarty *et al.* 2014; Guilherme *et al.* 2007). With sound evidence in favour of many different genetic features, it is highly possible that the genetics behind ARF is polygenic (controlled by multiple genes) (Chakravarty *et al.* 2014). Whatever genetic element(s) involved, it appears that autoimmune mechanisms related to molecular mimicry produce the symptoms of ARF. The foreign antigens of *S. pyogenes* have sequences or structural similarities that are confused with the self-antigens of the host, leading to mix-ups in the immune response to the invading non-self-pathogen *S. pyogenes* (Chakravarty *et al.* 2014; Cunningham 2014; Cusick 2012).

Of the ARF symptoms, carditis and Sydenham chorea often receive the most attention in clinical research, largely because they are the most harmful; carditis (inflammation of the heart tissues) may cause heart failure and Sydenham chorea (a neurological disorder) may cause non-rhythmic and involuntary movements, weakness in the muscles, and emotional fluctuations (Chakravarty *et al.* 2014, 896). Though these symptoms are the most concerning, one of the first symptoms noticed in ARF cases is inflammatory arthritis. Arthritis in ARF is made evident through joint swelling, which affects several joints in quick succession, moving from one joint to another with some overlap (Chakravarty *et al.* 2014). The most common joints to be affected in ARF are the knees, ankles, elbows, and wrists (Chakravarty *et al.* 2014). Though the arthritis can be substantial (enough to cause restriction of movement), it does not last for extended periods of time (1 to 3 days per joint and 2 to 3 weeks in total) (Chakravarty *et al.* 2014; Cunningham 2014). Due to the short duration of arthritis, ARF does not cause skeletal changes, so this condition is not useful to a bioarchaeological investigation, but it exemplifies the pathogenesis followed by reactive arthropathies considered in this research (Chakravarty *et al.* 2014; Cunningham 2014). For an investigation of reactive arthropathy in skeletal material, the conditions of primary interest are found among the erosive arthropathies.

Erosive arthropathies (EAs) are usually caused by chemical imbalances or disruptions to the immune system. Generally, these conditions are classified in accordance with the location(s) affected, the biochemical or genetic components involved, and the amount of bone formation that is present (Ortner 2003). Several of the EAs are highly suspected or known to be reactive arthropathies, but several are not. **Figure 1** shows the classification and relationship of EAs. This figure also lists the bacteria connected to the conditions that are known to be reactive or are suspected to be so. The four main categories are Erosive Osteoarthritis (nonreactive), Gout (nonreactive), Rheumatoid Arthritis (potentially reactive), and the Spondyloarthropathies (reactive).

The following sections of chapter 1 provide a general background about EAs, which includes descriptions of the general skeletal changes they produce, the likelihood they would be encountered in male dominant military skeletal assemblages, and whether or not they are reactive.

Figure 1: the diagram below shows the classification of EAs and lists bacteria involved in the pathogenesis of reactive or potentially reactive conditions. Source: created by author.



1.2 Nonreactive Erosive Arthropathies: Erosive Osteoarthritis & Gout

Erosive osteoarthritis and Gout are not triggered by bacterial infections. Erosive osteoarthritis presents with the same changes of normal osteoarthritis (eburnation, marginal osteophyte, and pitting/bone growth on the joint surface), but an inflammatory response leads to additional erosive changes (Waldron 2009). This condition occurs exclusively in the hands, with the distal interphalangeal joints being the most commonly affected, followed by the proximal interphalangeal joints (see **Fig. 2** for hand and feet anatomy) (Belhorn & Hess 1993; Rogers *et al.* 1991; Waldron 2009). Erosions originate from the joint's centre, causing the 'gull wing' and 'saw tooth' signs on radiographs (see **Fig. 3**) (Belhorn & Hess 1993; Rogers *et al.* 1991; Waldron 2009).

For a few reasons, one should not expect to find many (if any) cases of this particular EA in military skeletal assemblages. Though not uncommon in modern populations (observed in 4-15% of people with OA of the hands), erosive osteoarthritis is a condition that has rarely been observed in archaeological skeletal remains, which is reason to suspect it may have been less common in the past (Ortner 2003; Rogers *et al.* 1991; Waldron 2009, 53). Furthermore, erosive osteoarthritis occurs almost exclusively among women (Belhorn & Hess 1993; Waldron 2009). Women have always been involved in wars, but historical female combatants are relatively few. This is reflected in the predominantly male demographic seen in military skeletal assemblages, so observation of erosive osteoarthritis is unlikely.

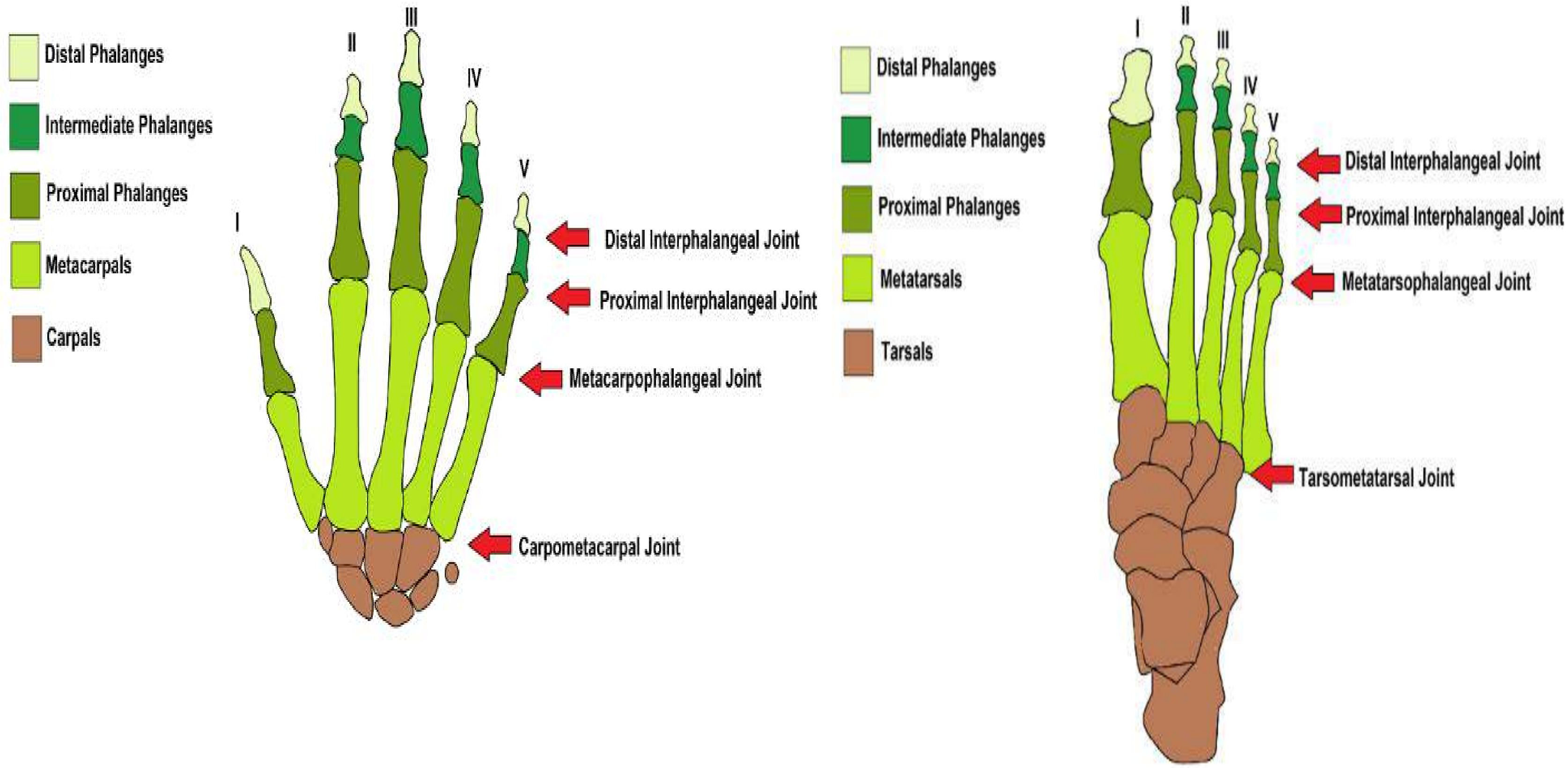
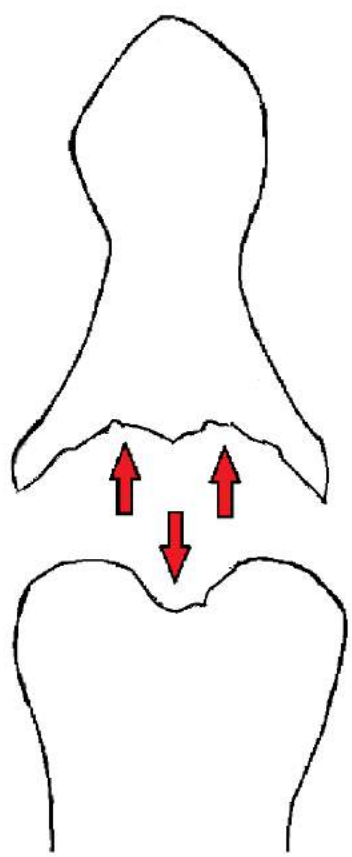


Figure 2: this diagram shows the basic anatomy of the hands and feet. The bones are labeled by color, the number of the digit by roman numerals, and the type of joint by red arrows. Source: created by author.

Though erosive OA is not likely to be found among military combatants, gout has no such limitations. Gout is one of the oldest diseases to be clinically recognized, with the first case being recorded by the Egyptians in 2640 BC under the name 'podagra' (Nuki & Simkin 2006). There is a rich historical record of gout, giving the clear impression that it was a rather common condition. Though cases of gout are not unprecedented in archaeological skeletal remains, its appearance in the skeletal record appears highly understated when compared to the historical record (Waldron 2009). Gout remains a frequent condition in modern populations, affecting 3 per 1,000 individuals in the 1970's; since then, the trend has displayed increasing prevalence (Doherty 2009; Waldron 2009). Besides being a rather common condition, men are more prone to developing gout, further increasing the likelihood that cases could be discovered in military skeletal assemblages (Doherty 2009).

Figure 3: central erosions in erosive osteoarthritis create a 'gull wing' shape in the distal phalanx. Source: adapted from Zhang *et al.* 2009.



The arthritic changes associated with gout are brought about by an excess build-up of uric acid, which creates crystals within the tissues and fluids of the body (Doherty 2009; Waldron 2009). When this occurs around the joints, it triggers an inflammatory response that causes erosive changes (Waldron 2009). The development of gout is connected to a number of environmental factors, including: diet (excess of red meats, seafood, and sugars), obesity, high consumption of purine-rich alcoholic beverages (like beer), diuretic drugs, and Hyperuricemia (Doherty 2009; Roddy *et al.* 2007; Minozzi *et al.* 2013; Nuki & Simkin 2006; Waldron 2009, 68).

The erosive changes observed in gout are usually asymmetric and para-articular (adjacent to the joint) and/or articular (on the joint surface). The lesions of gout are often well-defined with a round/oval shape; these lesions may also be sclerotic (thickened edges) and have a ‘punched out’ appearance (Minozzi *et al.* 2013; Ortner 2003; Rothschild & Heathcote 1995; Waldron 2009). The joints most commonly affected are located in the feet (especially the first metatarsophalangeal joint), ankles, knees, hands, and wrists (review foot anatomy in **Fig. 2**) (Doherty 2009; Waldron 2009). A last telling feature of gout is the potential presence of a ‘Martel Hook’ (a hook of bone that overhangs the edge of an erosion); this hook forms around the clustered uric acid crystals and inflammatory tissues known as a tophi (see **Fig. 4**) (Doherty 2009; Nuki & Simkin 2006; Waldron 2009).

Figure 4: the magnetic resonance image below shows a case of gout in a 55 year-old male. The red arrow indicates a very round erosion on the mediodistal surface of the right 1st metatarsal with overhanging edges (blue arrow). Source: Simon 2011.

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1.3 A Probable Reactive Arthropathy: Rheumatoid Arthritis

Rheumatoid arthritis (RA) is a polygenic, autoimmune condition associated with an autoantibody known as Rheumatoid Factor. RA is two to three times more common in women than men (Jacobson *et al.* 2008; Litwack 2008; Waldron 2009). This means RA is not totally absent in males and, as such, could possibly be found in military skeletal assemblages.

Many clinicians suspect that RA is reactive to some form of microbe (likely a bacterium), but narrowing down any particular trigger has been difficult (Dörner *et al.* 2004*;* Koziel *et al* 2014; Scher & Abramson 2011; Vaahtovuo *et al.* 2008). One bacterium currently of interest is *Porphyromonas gingivalis*, which causes deterioration of the periodontal tissues that support the teeth (Joseph *et al*. 2013; Koziel *et al.* 2014; Martinez-Martinez *et al.* 2009; Mikuls *et al*. 2014). The interest in *P. gingivalis* comes from the bacterium's ability to generate inflammatory changes and that its presence has being demonstrated in synovial fluid pulled from joint capsules of RA patients (Joseph *et al*. 2013; Martinez-Martinez *et al.* 2009).

While *P. gingivalis* has proven of interest, more recent animal studies indicate that future research should focus on intestinal microbes (Brusca *et al.* 2014; Scher & Abramson 2011; Vaahtovuo *et al.* 2008). Gut microbes have, "a considerable impact on the maintenance of a local homeostatic balance owing to its proximity to the host's intestinal immunity and its ability to influence immune responses" (Scher & Abramson 2011, 574). It is now thought that microbial dysbiosis (microbial imbalance) in the gut may play a role in the pathogenesis of RA; a trigger causing imbalance and disruption to normal homeostasis of the gut microbiome may cause an irregular inflammatory response leading to RA (Brusca *et al.* 2014; Scher & Abramson 2011). Environmental factors, such as bacterial infections, could trigger an imbalance in the gut microbiome leading to dysbiosis. None of the bacterial suspects currently being examined in relation to RA would be specific to military populations. Though suspected to potentially be reactive, RA was not considered a reactive arthropathy in the skeletal analysis of this research, as the current evidence is far from definitive.

RA is a condition of bone destruction with very little or no bone formation involved (see **Fig. 5**) (Rothschild *et al.* 1990; Waldron 2009). Diagnosis in skeletal material is largely limited to the general appearance and distribution of erosions, but also includes consideration of what pathology is absent. RA erosions primarily affect the small joints of the hand and feet, are bilaterally symmetrical, marginal (surrounding the joint margins), and sclerotic. Secondary erosions may present in secondary location outside of the hands and feet, which most commonly include the wrists, ankles, elbows, shoulders, knees, and hips (Jacobson *et al.* 2008; Rothschild *et al.* 1990; Waldron 2009). As RA is associated with extensive bone destruction, osteoporosis is not uncommon (Jacobson *et al.* 2008; Rothschild *et al.* 1990; Waldron 2009).

Figure 5: this radiograph shows the destructive nature of RA erosions. The arrows indicate joint space narrowing, bone erosions, and osteopenia. These features are common in RA. Source: Jacobson *et al.* 2008, 382.

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1.4 Reactive Erosive Arthropathies: Spondyloarthropathies

1.4.1 Pathological Expression

Four different conditions which cause chronic inflammatory arthritis make up the grouping known as the Spondyloarthropathies[1] (SpAs) [singular and general reference, spondyloarthropathy (SpA)] (Gill *et al.* 2015). The four SpAs are reactive arthritis (ReA), psoriatic arthritis (PsA), ankylosing spondylitis (AS), and enteropathic arthritis (EnA). Though separate conditions, all share a few common features, which are listed in **Table 3**.

Table 3: this table lists the common features shared between the SpAs. Source: created by author.

Common Features of SpA
Sacroiliitis; inflammatory changes that affect the sacroiliac joint(s) (SIJ), often resulting in fusion
Spinal involvement (fusion and, in some instances, erosion)
Marginal joint involvement (erosions, often asymmetric)
Enthesopathy (in skeletal material this is made evident by bone formation at the insertion points of tendons and ligaments; in layman terminology – a bone spur)
Their pathogenesis involves bacterial triggers, though the associated species vary between the specific conditions
They share an association with human-leukocyte-antigen (HLA) B27, though the strength of this association varies between the specific conditions
They are seronegative (they do not test positive for Rheumatoid Factor)

The differences occurring between the various SpAs (ReA, PsA, AS, and EnA) largely pertain to the distribution and patterning of the pathology throughout the body. For instance, if the pathological changes are heavily focused in the axial skeleton (bone formation and erosions) with minimum changes to the peripheral skeleton, then the condition will likely fall in line with AS or EnA (Tubergen & Weber 2012). Alternatively, if extensive changes are observed in the peripheral skeleton

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[1] Also referred to as Spondyloarthritides [singular spondyloarthritis].

(enthesopathy and erosions), ReA and PsA are stronger suspects (Rothschild *et al.* 1999; Tubergen & Weber 2012).

A brief description of the basic changes seen in all of the SpAs are listed below, but more extensive descriptions, operational definitions, and sources of information can be found in 'Appendix A: Operational Definitions.'

The changes typically seen in ReA include…

1. Spinal fusion takes the form of chunky paravertebral syndesmophyte formation (bone growth originating inside spinal ligaments) that is not limited to the right side; spinal fusion is not continuous (skip lesions are present) (see **Fig. 6**); there is a preference for the lumbar and thoracic vertebrae

2. Changes in the SIJ usually consist of fusion that can be unilateral or bilateral; sacroiliitis may be present (see Appendix A for definition)

3. Bone formation occurs at the entheses (the insertion points of tendon and ligament on bone, see **Fig. 7**) and shows a preference for the lower extremities; other forms of bone proliferation, such as periostitis (bone formation associated with inflammation of the periosteum), may also be observed in the hands and/or feet

4. Erosions are marginal, asymmetric, and show a preference for the lower extremities, especially the small joints of the feet

The changes typically seen in PsA include…

1. Axial involvement does not always occur in PsA (only about 20-40% of cases), but when it does, spinal fusion takes the form of chunky paravertebral syndesmophyte formation that is not limited to the right side; spinal fusion is not continuous (skip lesions are present); there is a preference for the lumbar and thoracic vertebrae, but the cervical spine can also be involved.

2. Changes in the SIJ (if they occur) are variable; the changes may be symmetric, asymmetric, bilateral, or unilateral; signs of sacroiliitis may present without actual fusion

3. Bone formation occurs at the entheses and is commonly observed in the hands and/or feet; other forms of bone proliferation, such as periostitis, may also be observed in the hands and/or feet

4. Erosions are marginal and show a strong preference for the distal interphalangeal joints of the hands and/or feet (review **Fig. 2**); the erosions may be asymmetric, symmetric, unilateral, or bilateral; resorption of the distal tuffs may occur; some specific erosions seen in PsA include: 'cup-in-pencil,' arthritis mutilans, and 'licked candy stick' (see definition for PsA in Appendix A for descriptions)

Figure 6: this image shows the spinal fusion observed in skeleton 2705 from All Saint's Church. This case displays paravertebral chunky syndesmophyte formation that is characteristic of ReA and PsA. This case also shows characteristic 'skip lesions' (area of unfused vertebrae separating sections of fused vertebrae). Source: photo taken by author, permitted by University of Sheffield.

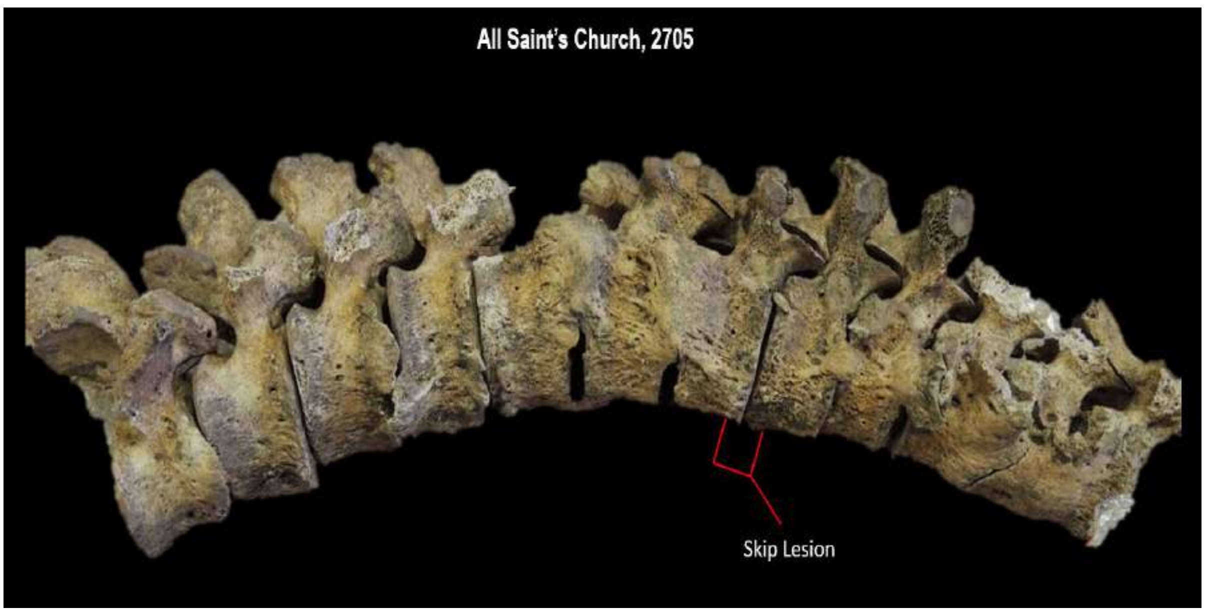
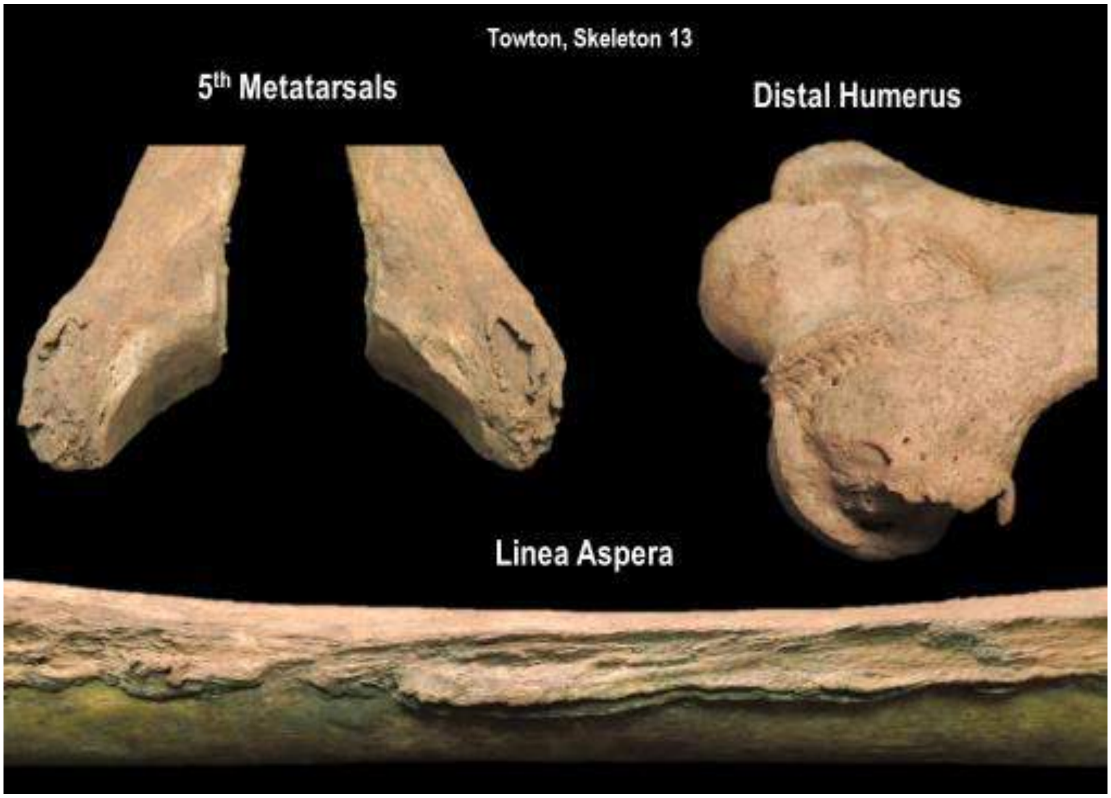


Figure 7: this image shows some of the enthesopathy observed in Towton 13, which was given a SpA classification. Source: photos taken by author, permitted by the University of Bradford's Biological Anthropology Research Center (BARC).



The changes typically seen in AS include…

1. Spinal fusion is continuous (skip lesions are absent) and begins in the lower spine (usually the lumbar) and progresses up the spinal column; syndesmophytes are smoother than those of PsA and ReA and occur closer to the vertebral body margins; early syndesmophyte formation targets the anterior and posterior corners of the vertebral body (see **Fig. 8**); other spinal features include: Bamboo Spine (see definition for AS in Appendix A), spinal osteoporosis, and ankylosis of the costovertebral joints in the thoracic vertebrae.

2. Changes in the SIJ produce symmetrical and bilateral fusion (see **Fig. 9**)

3. Bone formation occurs at the entheses and is usually limited to the spine and pelvis, but may occur elsewhere.

4. Erosions occur on the vertebral bodies of the spine, but due to the extensive amount of spinal bone formation in AS, these erosions can be difficult to

observe without radiography; when extra-spinal erosions do occur, they are marginal and show a preference for large joints like the shoulder or hip.

<u>The changes typically seen in EnA include…</u>

1. Spinal bone formation is in the form of syndesmophytes (most similar to those of AS) and is continuous (skip lesions are absent).

2. Changes in the SIJ produce symmetrical and bilateral fusion

3. Peripheral bone formation may or may not be present, but when present, it occurs at the entheses.

4. Erosions are marginal, often monarticular, and show a preference for the knee and spine.

Figure 8: this image shows the spine of OCU00 713. Smooth syndesmophyte formation occurs near the intervertebral disk margins from T1 (far right) to L2. Spinal fusion is continuous (breaks occurred postmortem). Costovertebral joint fusion is present (red arrow). Kyphosis (blue arrow) is also present. Fusion shows preference for the posterior and anterior corners in some locations (example between T8 & T9), while other vertebrae show more advanced fusion with the whole joint space involved (example between T6 &T7). All of these features are characteristic of AS. Source: photo taken by author, permitted by Museum of London Archaeology (MOLA).

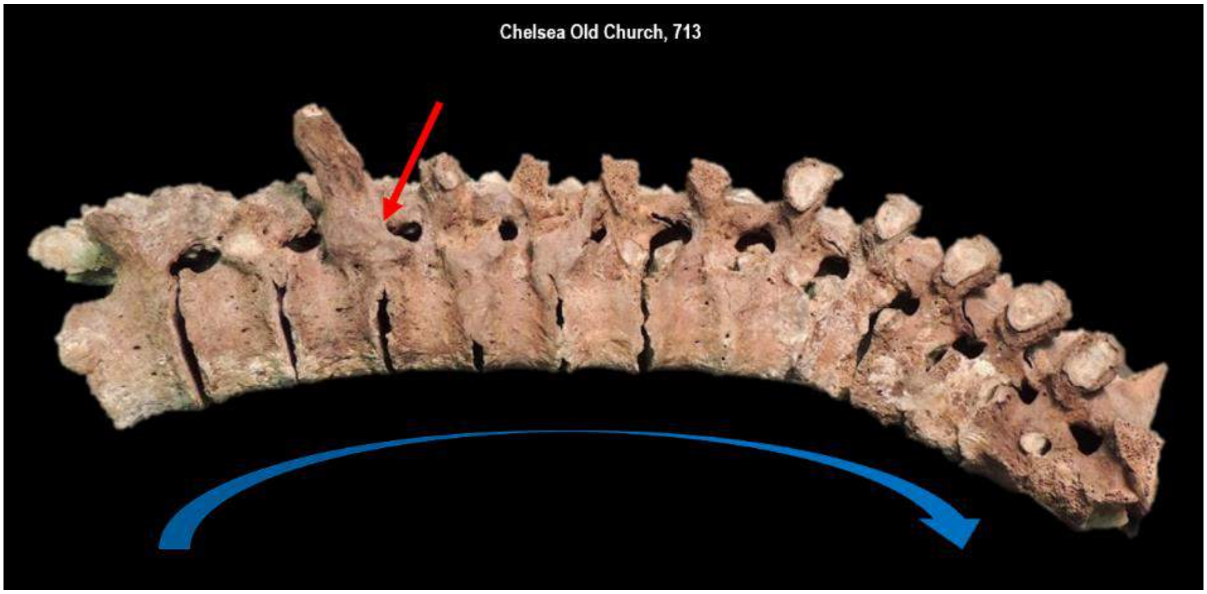
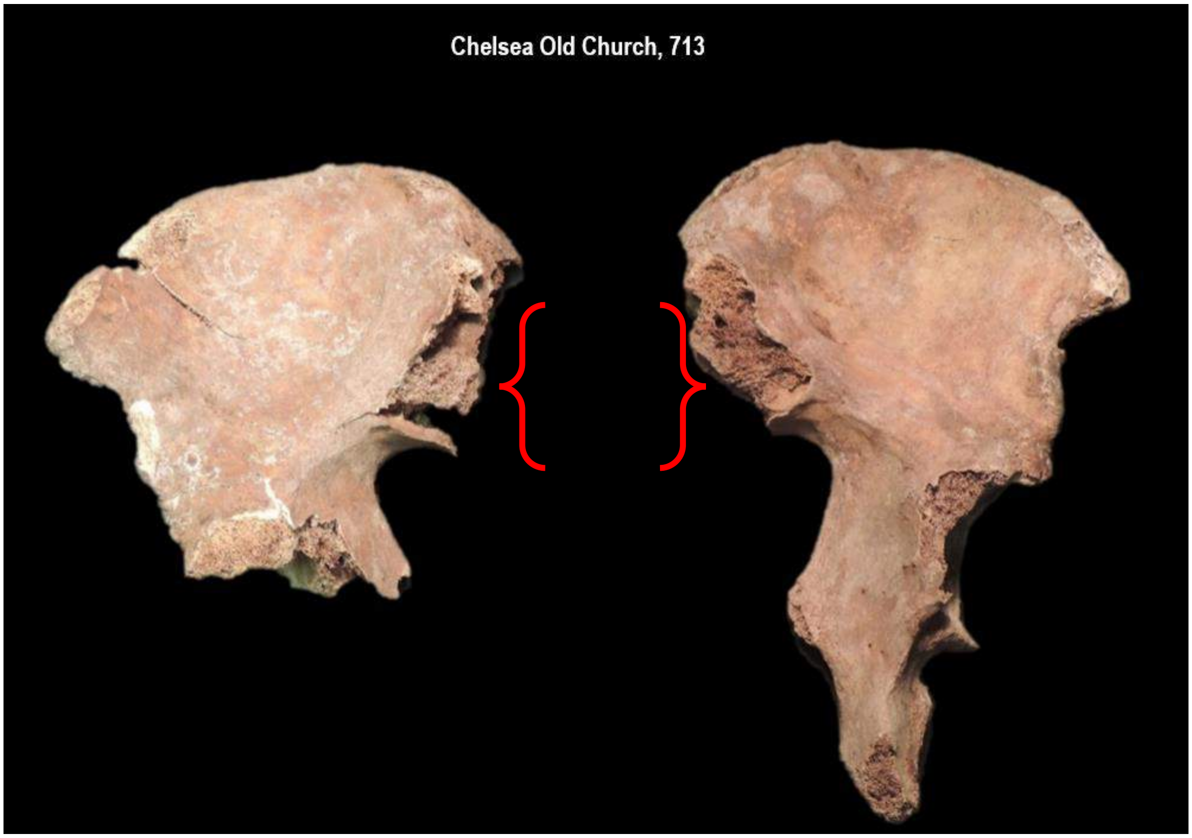


Figure 9: this photo shows symmetrical, bilateral SIJ fusion observed in skeleton OCU00 713. The sacrum was separated from the ilia by postmortem fragmentation, which is indicated by the trabecular bone exposed where the auricular surfaces should be (red brackets). This is characteristic of AS. Source: photo taken by author, permitted by MOLA.



1.4.2 Bacterial Infections

All the SpAs are considered reactive, though the bacterial agents involved in ReA and PsA are better understood than those of AS and EnA (Carter 2010; Sener & Afsar 2012). The bacterial species most commonly referred to as triggers of ReA include *Salmonella enteritidis, Campylobactera jejuni, Yersinia enterocolitica, Shigella dysenteriae, Shigella flexneri, Escherichia coli, Clostridium difficile, Chlamydia trachomatis,* and *Neisseria gonorrhoea*. ReA is also associated with other bacteria, though they are considered to be atypical, which include *Clostridium difficile* and *Streptococcus pyogenes* (Morris & Inman 2012; Sarakbi *et al.* 2010). *Chlamydia pneumoniae* is also debated as a potential cause (a respiratory infection) (Rizzo *et al.* 2012). Involvement of *S. pyogenes* in ReA is interesting, as this particular pathogen is normally associated with a different form of SpA.

S. pyogenes is the bacteria capable of triggering ARF, but is also strongly associated with the PsA variety of SpA (Carter 2010; Gill *et al.* 2015; Hannu 2011; Manasson & Scher 2015; Singh & Karrar 2014). *S.* p*yogenes* is also related to the condition in which PsA gets its name, psoriasis (see **Fig. 10**). PsA has been reported to occur in 10% to 40% of patients with psoriasis (Veale & Fearon 2007). In addition to *S. pyogenes*, joint trauma has also been considered as a possible causative trigger for psoriasis and PsA (Carter 2010; Ritchlin & FitzGerald 2007; Thorleifsdottir *et al.* 2012).

Figure 10: this photo shows the hands of a PsA patient. The skin lesions (black arrows) and nail deformity is caused by psoriasis. The swelling observable in the 3rd digit (white arrow) is due to PsA. Source: Lenman & Abraham 2014, 424.

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Though the triggers of AS and EnA are not as well established, there are strong suspects. For AS, *Klebsiella* and *Bacteroides* have been suggested, while EnA suspects include *Mycobacterium paratuberculosis, Escherichia coli, Helicobacter, Listeria, Chlamydia trachomatis, Bacteroides*, and *Enterococcus* (Carter 2010; Gill *et al.* 2015; Manasson & Scher 2015; Rashid *et al.* 2013; Sartor 2007). EnA is associated with Inflammatory Bowel Syndrome (IBD) and is now often referred to as IBD arthritis. Similar to RA, dysbiosis in the gut microbiome is suspected to play an important role in EnA pathogenesis; gut dysbiosis may also play a role in other forms of SpA (Asquith *et al.* 2014; Garg *et al.* 2014).

Though all of these conditions appear to have different triggering bacteria, there is some overlap. *S. pyogenes* is most strongly connected to PsA, but has been noted in ReA, while *E. coli* and *C. trachomatis* have been connected to both ReA and EnA (Carter 2010; Morris & Inman 2012; Sarakbi *et al.* 2010). The overlap in the bacterial triggers support a hypothesis generated by Denys Ford in 1987, that "one infectious agent may cause different clinical syndromes and one syndrome may be due to many infectious agents" (Carter 2010, 709). It is also suspected that the vast array of organisms involved in SpA may be responsible for the rather erratic expression of SpA pathology; though SpA ultimately causes the same basic pathological features, the pattern in which these features are expressed vary between the SpAs, as well as within the varieties. For example, ReA may present in a chronic form or an acute form, it may express itself with a traditional triad of symptoms (arthritis, urethritis, conjunctivitis) or it may not (Carter 2010). This suggests that bacteria play a vital and complex role in SpA pathogenesis. Though differences exist, it is highly interesting that all SpAs ultimately share phenotypic features largely considered to be more similar than different (for instance, those of **Table 3**)(Carter 2010; Tubergen 2014; Tubergen & Weber 2012). This leads to the complicated matter of SpA classification.

1.4.3 Matters of Classification

The number of similarities between the differing SpAs are increasing rather than decreasing as clinical research progresses. As mentioned, there is some overlap in the bacteria associated with ReA, PsA, and EnA. This interconnectedness also extends to AS and ReA, as up to 20% of patients with ReA are later reported to develop AS within a 10 - 20 year period (Asquith *et al.* 2014). These details, in addition to the shared features listed in **Table 3**, can make specific diagnosis (ReA, PsA, AS, EnA) difficult. To add to the confusion, SpA does not always progress in a manner characteristic of any particular variety, which has led to another commonly used categorization, Undifferentiated Spondyloarthropathy (USpA). Cases placed into this categorization express all or most of the traditional features associated with SpA, but they do not progress in a pattern that fits the four traditional subgroups (Waldron 2009; Zochling *et al.* 2005).

The overlap between the SpAs makes for a highly interesting topic of debate, as some would argue a broader system of classification is called for. Since the SpAs have often shown more similarities than differences, it has been suggested that, "the SpAs represent a common end point for a number of diverse starting points" (Carter 2010, 703; Asquith *et al.* 2014). In other words, the different subtypes (AS, EnA, PsA, ReA) are actually different presentations of the same disorder (Asquith *et al.* 2014; Carter 2010; Nash *et al.* 2005; Paramarta *et al.* 2013, 1873; Rohekar & Pope 2010). Others have suggested there should be just two groups of classification: Axial SpA (cases predominantly causing spondylitis and sacroiliitis in early disease presentation) and Peripheral SpA (cases predominantly causing changes like erosions, enthesopathy, and dactylitis in early disease presentation) (Tubergen 2014; Tubergen & Weber 2012). Though some have indeed adopted this approach (example: Lories & Haroon 2014), others still prefer to consider the conditions separately (example: Manasson & Scher 2015), and some do a bit of both (example: Garg *et al.* 2015). Typically, clinicians adopt the form of classification that best suits their research purposes (Nash *et al.* 2005). Though this is useful on an individual basis, it does generate problems for epidemiological research of SpA conditions; use of differing systems of classification make it exceedingly difficult to make comparisons (Nash *et al.* 2005; Reveille 2011; Stolwijk *et al.* 2012). Indeed, any article attempting to describe the prevalence of SpA will cite this difficulty and often present the prevalence as an average or range (Reveille 2011; Stolwijk *et al.* 2012; van Tubergen 2014).

1.4.4 The Link to HLA-B27

The SpAs serve as excellent examples of a disease aetiology involving both environmental and genetic components. All of the SpAs fit the same general criteria previously described in **Table 1**, as they are caused by a genetic predisposition for inflammatory changes that is initially triggered by a bacterial infection. The SpAs are most accurately described as being autoinflammatory because they lack autoantibodies and their disease pathogenesis involves cytokine pathways and pathogen recognition rather than adaptive immune responses (review **Table 2**). The common genetic factor associated with the SpAs (that which generates disruption in cytokine pathways and/or pathogen recognition) is positivity for human leukocyte antigen (HLA)-B27.

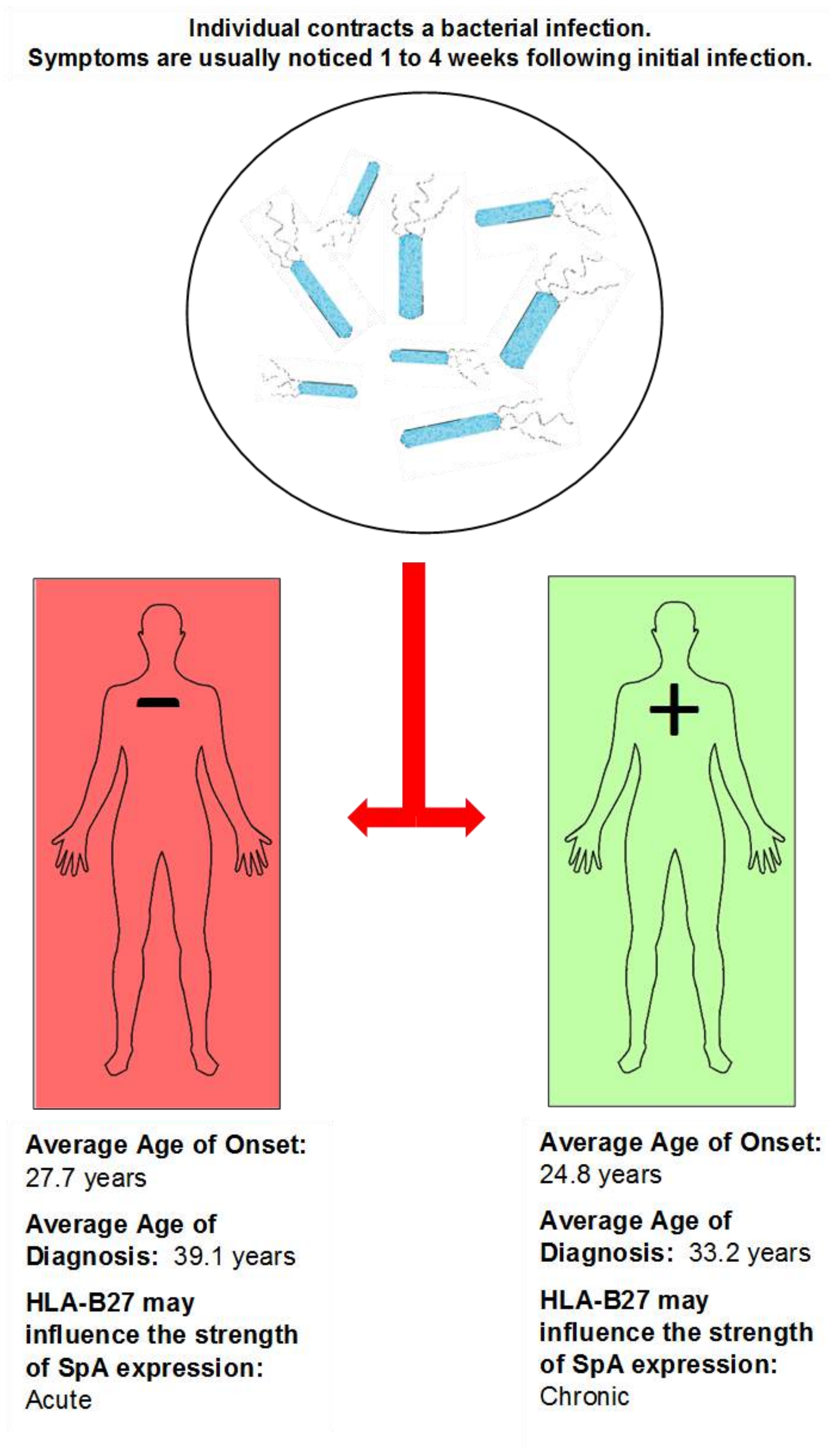
The actual mechanism that HLA-B27 has to play in the pathogenesis of the SpAs is not fully understood, but this is a topic of much clinical research (Bowness 2015; Colmegna *et al.* 2004; López de Castro 2007; McHugh & Bowness 2012; Reveille & Alkassab 2007; Reveille 2010). Though the specifics of its involvement are still the topic of research and debate, HLA-B27 has shown a link to all of the SpAs, though some are more tightly linked than others. For instance, AS has been linked to HLA-B27 in 90% of cases, ReA to 70% of cases, and PsA to 60-70% of cases (Reveille & Alkassab 2007; Reveille 2010; Waldron 2009).

The connection between HLA-B27 and SpA becomes undeniably clear when examining the correlation between the prevalence of HLA-B27 and the prevalence of SpA in populations throughout the world, with the prevalence of one directly reflecting upon the prevalence of the other (Ehrenfeld 2012, 139; Stolwijk *et al.* 2012; van

Tubergen 2014). In Japan, SpA is virtually non-existent (<0.5%), which is due to the very low prevalence of HLA-B27 (1% of the Japanese population) (Stolwijk *et al.* 2012, 453; Waldron 2009). Conversely, among the Canadian Haida Native American population, the prevalence of SpA is 4.5 to 6.1%, which is explained by the high prevalence of HLA-B27 (nearly 50% of the population tests positive) (Ehrenfeld 2012; Olivieri *et al.* 1998; Waldron 2009). Other populations with a high prevalence of HLA-B27 are Papua New Guinea (53%), Chukotka Eskimos in Eastern Russia (40%), Northern Scandinavian countries (15%–25%), and Western European populations (10-13%) (Kuhn & Yokoyama 2012; Olivieri *et al.* 1998; Stolwijk *et al.* 2012; van Tubergen 2014).

Though HLA-B27 is connected to SpA, it has nothing to do with susceptibility to bacterial infections; someone HLA-B27 positive is not any more likely to be infected by a bacterium than someone testing negative (Reveille & Alkassab 2007). On the other hand, if someone positive for HLA-B27 happens to contract an infection caused by arthritogenic bacteria, they face an increased risk of developing SpA compared to someone who is HLA-B27 negative and contracted the same infection (Reveille & Alkassab 2007). It is not impossible for HLA-B27 negative individuals to develop SpA, so it is important to note that HLA-B27 is not diagnostic of SpA; that is to say, it cannot prove that one has SpA. Nevertheless, HLA-B27 positivity does add a mark in favour of a SpA diagnosis in modern clinical patients (Reveille & Alkassab 2007). HLA-B27 positivity may also have bearing on the strength and timing of SpA expression in an individual. Someone testing positive is more likely to develop a chronic form of SpA and is also more likely to have an earlier age of onset and diagnosis than HLA-B27 negative individuals (see **Fig. 11**) (Feldtkeller *et al.* 2003; Reveille & Alkassab 2007; Queiro *et al.* 2002).

Figure 11: this diagram shows some of the key differences between HLA-B27 + and – cases of SpA. As discussed in-text, HLA-B27 + SpA is far more common, but HLA-B27 – cases do occur. The same bacterial infection can cause SpA in both + and – individuals, but the strength and timing of SpA development often vary. Sources: created by author; Colmegna *et al.* 2004;Feldtkeller *et al*. 2003; Reveille & Alkassab 2007; Skare *et al.* 2012; Queiro *et al.* 2002.



1.5 SpA as a Measure of 'Reactive Pathology' in Skeletal Material

It is quite evident that there is considerable overlap in the pathology, causative agents, and genetics of the SpAs, but there are some differences as well. Would any of these differences render SpA a poor measure of reactive arthropathy? In short, no. The current evidence supports that the SpAs are more similar than different in their pathological expression, with the most notable differences occurring in early disease expression (peripheral or axial) and medical history (identification of the bacterium involved) (Asquith *et al.* 2014; Carter 2010;). Further demonstration of the similarities between these conditions is reflected in the clinical debate over how much ‘lumping’ and ‘splitting’ is truly necessary for SpA classification (Garg *et al.* 2014, 670; Nash *et al.* 2005). All of the SpAs match the definition for 'reactive arthropathy' described in **Table 1** and produce notable skeletal changes. This in combination with their overall similarity in expression makes skeletal changes common to SpA (review **Table 3** and the “Spondyloarthropathy” operational definition in Appendix A) a good measure of ‘reactive pathology.’ Details of how SpA was utilized as a measure of reactive pathology is later described in Chapter 6.

1.6 Differential Diagnoses

Diagnosis of conditions in skeletal material is not a cut and dried situation. Unlike clinicians, bioarchaeologists infrequently have the advantage of case histories and soft tissue to evaluate as part of their final diagnosis. Furthermore, preservation of remains is a major problem, as the curse of missing skeletal elements is something that bioarchaeologist's must all too often grin and bear (Waldron 2009). These issues are further complicated by conditions which cause similar pathology and/or affect the same locations as SpA. If SpA is to stand as the measure of reactive pathology in skeletal material, we must also know how the pathology of SpA compares with conditions of potential confusion, as this is necessary for accurate identification of pathology in skeletal material.

1.6.1 Differentiating SpA from Other EAs

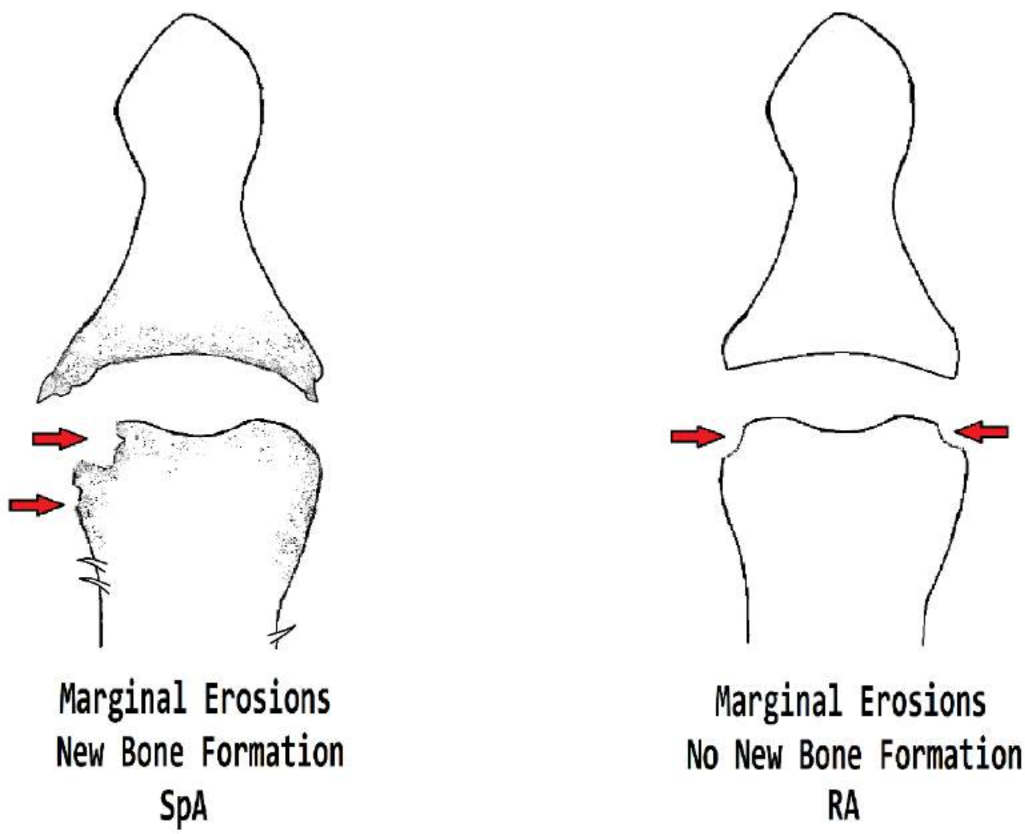
As discussed, erosive osteoarthritis is not expected to make an appearance in military assemblages, but this condition should still be understood for differential diagnosis. The presence of eburnation and other osteoarthritic changes are not associated with SpA, but it is not impossible for osteoarthritis and erosive lesions of other EA to occur in the same joint. The key for differential diagnosis is to determine if the erosions are primarily central or marginal and to consider what pathology is or is not present in the skeleton; for example, the changes of erosive osteoarthritis only take place in the hands, so involvement of other locations, like the spine or pelvis, would not be diagnostic of erosive osteoarthritis (Rogers *et al.* 1991; Waldron 2007). Furthermore, though bone formation occurs in both erosive osteoarthritis and SpA, the type of formation is quite different. The bone proliferation in erosive osteoarthritis will be typical of osteoarthritis (marginal osteophytes and new bone on articular surfaces), but bone formation in SpA frequently comes in the form of enthesopathy and periostits, which are typically absent in erosive osteoarthritis (Ezzat *et al.* 2013; Waldron 2009). One can also look for characteristic changes to aid differentiation, for example, the 'gull-wing' deformity that was shown in **Figure 3** is pathognomonic of the central erosions of erosive osteoarthritis, but such changes are not the norm for the marginal erosions of SpA and RA (Rogers *et al.* 1991; Waldron 2009).

Since gout is a condition of great antiquity, one that largely affects men, and has many triggers, cases of gout could be encountered in military skeletal assemblages. The lesions of gout typically have an appearance and pattern of expression that allows it to be set apart from other erosive arthropathies. The erosions of gout are often para-articular or articular, rather than marginal as seen in SpA and RA (Waldron 2009). Gout erosions are usually monoarticular and occasionally polyarticular, whereas SpA and RA are quite commonly polyarticular (Ortner 2003; Rothschild & Heathcote 1995; Waldron 2009). The presence of a Martel hook is also a strong indication in favour of gout. The absence of spinal changes, SIJ changes, and bone formation at the entheses can help differentiate gout erosions from those of SpA (Doherty 2009; Waldron 2009). As for RA, gout erosions are often asymmetric, where those of RA are symmetric (Waldron 2009). RA erosions are also commonly associated with osteoporosis, which is not seen in gout (Waldron 2009).

In the case of differentiating RA from SpA, the pathology that is not present can be the most telling. RA has little to no bone proliferation, so spinal and SIJ fusion are absent (Aceves-Avila *et al.* 2001; Rothschild 2001; Waldron 2009). There may be some spinal involvement in the form of erosions in the cervical vertebrae, especially C1 and C2, but changes involving bone proliferation (like fusion or enthesopathy) are not a feature of RA. Cervical erosions are not diagnostic of RA, as they may also occur in SpA (especially PsA) (Jacobson *et al.* 2008; Lambert & Wright 1977; Rothschild *et al.* 1990; Salvarani *et al.* 1992; Waldron 2009). Erosions in RA often affect the hands and feet and are marginal, which is also true of erosions in cases of SpA, but there are a few distinctive differences. For one, reactive bone formation, in the form of enthesopathy and periostitis, is frequently observed in association with the prehipheral erosions of SpA; however, both features are rarely seen in RA (see **Fig. 12**) (Jacobson *et al.* 2008; Schoellnast *et al.* 2006; Waldron 2009).

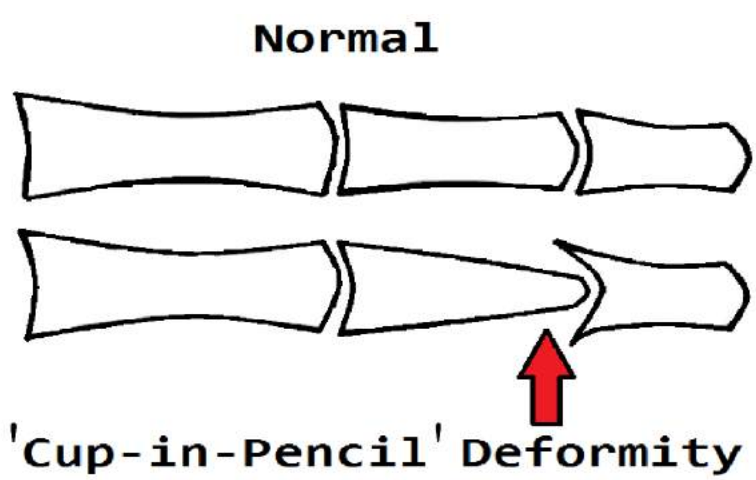
The pattern of RA and SpA expression is distinct as well. Where erosions in SpA are most frequently asymmetric, RA erosions are symmetric, often giving a mirror image appearance between the affected joints of both hands and/or feet (Jacobson *et al.* 2008; Resnick 1987). There is some need for caution when considering symmetry, as PsA has a variant which also causes symmetrical changes (Dhir & Aggarwal 2013; Kleinert *et al.* 2007; Waldron 2009).

Figure 12: erosions of SpA are often asymmetric and associated with bone proliferation, whereas RA erosions are symmetric and lack bone proliferation. Erosions marked by red arrows. Source: adapted from Zhang *et al.* 2009.



The symmetrical variant of PsA was originally thought to be uncommon, with asymmetric PsA occurring in about 60% of cases and the symmetrical in about 30% of cases (Moll & Write 1973). The symmetrical variant is now reported as being far more common by Helliwell *et al.* (1991 & 2000), who state the symmetrical variant has been reported in up to 70% of clinical cases. To further add to the confusion, both RA and PsA can cause the 'licked candy stick' deformity (though this is more pathognomonic of leprosy) and arthritis mutilans, which is associated with telescoping of digits (where collapse of tissues result in shortening of digits). Unlike these shared features, the 'cup-in-pencil' deformity is considered distinctly pathognomonic of PsA (see **Fig. 13**) (Hussain and Damegh 2007; Moll & Wright 1973; Zias & Mitchell 1996). There is also a tendency for both conditions to cause friability in skeletal material. RA erosions can cause osteoporosis and the erosions of PsA can be quite extensive, which gives a friable appearance (Waldron 2009

Figure 13: the 'cup-in-pencil' deformity is considered pathognomonic of PsA; where the distal end of one bone is sharpened by erosive changes and the proximal end of the articulating bone is affected by bone formation, which causes cupping. It is often observed in the distal interphalangeal joint(s). Source: adapted from Singh 2016.



Though RA and the symmetrical variant of PsA can be quite similar, there are notable differences. PsA only affects the axial skeleton in 20% to 40% of cases, but the presence of chunky paravertebral syndesmophytes in the spine and/or sacroiliitis can confirm a PsA diagnosis, as these are not features of RA (Jacobson *et al.* 2008). Erosions of PsA are also associated with bone proliferation in the forms of enthesopathy and periostitis, which is not typically observed in RA cases (Dhir & Aggarwal 2013; Helliwell *et al.* 1998; Jacobson *et al.* 2008; Kleinert *et al.* 2007; Schoellnast *et al.* 2006). The patterning of the two conditions can be somewhat different as well. RA most often affects the metacarpophalangeal, proximal interphalangeal, metatarsophalangeal, and wrist joints, but the distal interphalangeal joint is often spared from involvement or comes about later in very aggressive/advanced cases of RA (Helliwell *et al.* 1991; Kleinert *et al.* 2007; Rothschild 2001; Schoellnast *et al.* 2006). PsA can affect the same joints as RA, but demonstrates a preference for the distal interphalangeal joint, frequently affecting them first, followed by the proximal interphalangeal joints, and (in advanced cases) other joints of the hands and wrists; changes in the feet usually develop later than those of the hands, but this is not always the case (Gladman *et al.* 2007; Kleinert *et al.* 2007; Schoellnast *et al.* 2006).

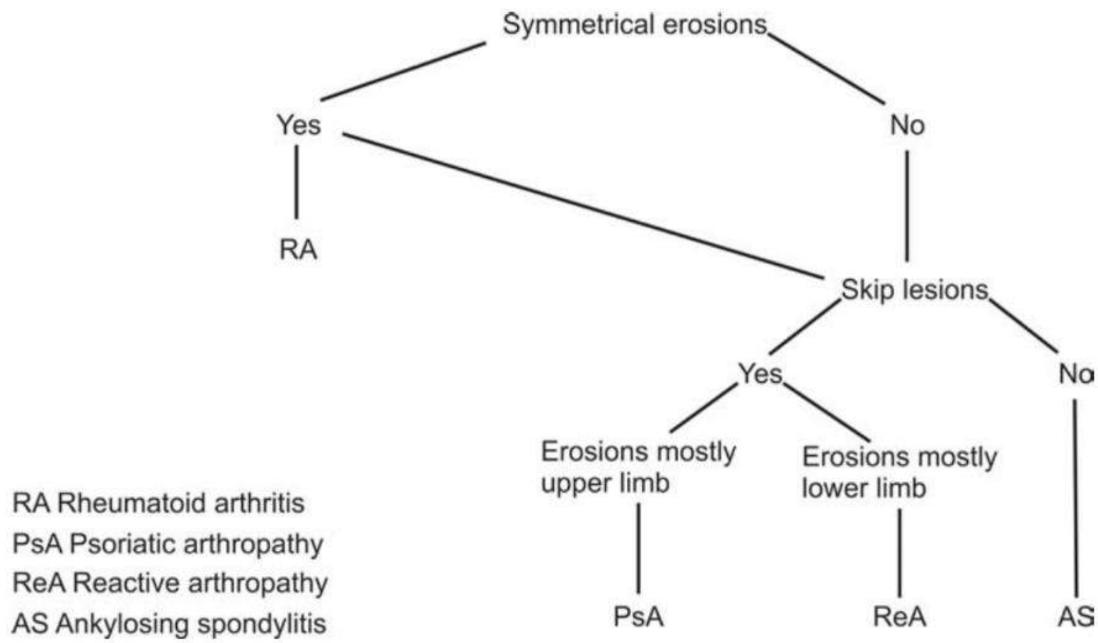
In early research, PsA was considered as the less aggressive of the two diseases, but it has now been proven that PsA can be quite aggressive, with 20% of cases causing disabling arthritis (Duarte *et al.* 2012; Gladman *et al.* 2007; Schett *et al.* 2011). Nonetheless, some research has shown there is a tendency for RA to involve more joints than cases of PsA (Helliwell *et al.* 2000; Schoellnast *et al.* 2006). Some of the discernible difference for RA and symmetrical PsA are impossible to assess in skeletal remains; for example, without a case history, the pattern of progression is unknown. Without this information, cases of symmetrical erosive pathology in skeletal material must show evidence of axial involvement (spinal fusion and/or sacroiliitis) to truly confirm a PsA diagnosis, in spite of the fact that axial involvement only occurs in 20 to 40% of cases (Jacobson *et al.* 2008; Kleinert *et al.* 2007).

Table 4 presents a rough summary of the differing features of the EAs and **Figure 14** show another diagram used for differentiation between RA and the SpAs.

Table 4: this table summarizes some of the key differences and similarities between the EAs. Source: created by author.

Summary of EA Characteristics						
	Erosive Osteoarthritis	**Gout**	**RA**	**PsA**	**ReA**	**AS**
Spinal Fusion	No	No	No	Yes, 20 to 40% of cases	Yes	Yes
SIJ Involvement	No	No	No	Yes	Yes	Yes
Enthesopathy	No	No	No	Yes	Yes	Yes
Marginal Erosions	Central	Para-articular or articular	Yes	Yes	Yes	Yes
Erosive Symmetry	Asymmetric	Asymmetric	Symmetric	Either	Asymmetric	Symmetric (mostly axial)
Periostitis	No	No	No	Yes	Yes	Yes

Figure 14: the diagram below indicates some of the distinguishing features that can be used to differentiate between cases of RA and the SpAs. Source: Waldron 2009, 70.



1.6.2 Differentiating SpA from Non-Erosive Conditions

In addition to the differentiation between the forms of EAs, there is also a need to understand how SpA differs from certain non-erosive conditions. For instance: Diffuse Idiopathic Skeletal Hyperostosis (DISH) causes spinal fusion and can produce SIJ fusion and enthesopathy, all of which are features of SpA. DISH is a condition more commonly found in males and is associated with age, with onset typically occurring after the age of 40 in clinical cases (Olivieri *et al.* 2009; Waldron 2007). The exact cause of the condition is not fully understood, but it does appear linked to dietary and metabolic associations, such as obesity, type II diabetes, high levels of serum uric acid, and abnormal vitamin A metabolism (Kiss *et al.* 2002; Waldron 2009).

The differential diagnosis between SpA and DISH comes down to the specifics of how spinal fusion and SIJ fusion occur. In ReA and PsA forms of SpA, fusion is not continuous (skip lesions as present) and occurs in the form of 'chunky' paravertebral syndesmophyte bridging on the right and/or left side of the vertebral column that, over time, may extend across the disk space (Helliwell *et al.* 1991; Helliwell *et al.* 1998; Jacobson *et al.* 2008; Toivanen 2007; Waldron 2009). Paravertebral bone formation does not typically start at the intervertebral margins, but away from the margins towards the mid-vertebral body. ReA and PsA also show a preference for the lumbar and lower thoracic spine, though occasionally cervical involvement is seen in PsA (Jacobson *et al.* 2008; Resnick 1987; Rothschild *et al.* 1990; Salvarani *et al.* 1992; Waldron 2009).

In AS, spinal fusion is continuous (skip lesions are absent) and proceeds from the lumbar or lower thoracic vertebrae up the spinal column (Waldron 2009). Fusion in AS also takes the form of syndesmophyte formation but has a different appearance from ReA and PsA. AS targets the annulus fibrosus, causing syndesmophyte formation to be smaller, smoother, and to originate closer to the intervertebral margins of the vertebral bodies (Helliwell *et al.* 1998; Madsen & Jurik 2010; Olivieri *et al.* 2009). Eventually in AS, the whole of the intervertebral disk spaces may be obscured by undulating smooth fusion, but in early AS, the primary locations targeted by syndesmophytes are the anterior and posterior corners of the vertebral bodies (Helliwell *et al.* 1998; Madsen & Jurik 2010; Olivieri *et al.* 2009). Spinal bone formation in AS is often extensive, causing the costovertebral joints in the thoracic spine and even the interspinous ligaments of the posterior spine to become involved (Madsen & Jurik 2010; Olivieri *et al.* 2009; Waldron 2009).

In DISH, spinal fusion is continuous (skip lesions are absent), with bone formation resembling that of dripped candle wax (Arriaza 1993; Hannallah *et al.* 2007; Mader *et al.* 2013; Rogers *et al.* 1985; Waldron 2009). The intervertebral disk space is preserved in DISH and fusion is normally confined to the anterior longitudinal ligament; the same is typically true of the anterior sacroiliac ligament of the SIJ if it is involved, meaning fusion is confined to the ligament and not associated with inflammatory changes like articular bone formation or erosions (Braun *et al.* 1998; Cammisa *et al.* 1998; Hannallah *et al.* 2007; Mader *et al.* 2013; Resnick *et al.* 1975; Waldron 2009; Waldron & Rogers 1990). The spinal fusion in DISH may be extensive, involving the whole spine, but the fusion is paravertebral and confined to the right side in the thoracic region (Hannallah *et al.* 2007; Mader *et al.* 2013; Resnick *et al.* 1975; Waldron 2009). The reason fusion is confined to the right side in DISH is most likely due to the presence of the descending aorta on the left side, a hypothesis that seems to be confirmed by the condition of situs inversus, which causes the aorta to descend on the right rather than the left. In cases of situs inversus, DISH spinal fusion in the thoracic region is observed on the left rather than the usual right (Hannallah *et al.* 2007; Mader *et al.* 2013; Resnick *et al.* 1975; Waldron 2009).

The confinement of thoracic changes to the right paravertebral position in DISH can be a distinguishing feature from cases of ReA and PsA, as spinal changes are not limited to just the right side in the thoracic region. Another feature that can be used for differentiation from AS is involvement of the costovertebral joints, a feature that is observed in AS, but is typically absent in DISH (Arriaza 1993). Finally, DISH can be differentiated by the lack of disk space involvement, which can be observed in SpA (Waldron 2009). **Figures 15** and **16** are diagrams showing the typical patterning of spinal involvement in these conditions.

Figure 15: Spinal Bone Formation in DISH & SpA (A)

In **PsA** and **ReA**, spinal bone growth: **1)** primarily takes the paravertebral position (right and/or left) **2)** often follows along the ligament, but may extend across the disk space **3)** in well-developed cases, skip lesions are present (shown by red arrow) **4)** syndesmophytes are often chunky. View: anterior.

In **AS**, spinal bone growth: **1)** involves the lateral and anterior aspects of the vertebrae, but bone formation is typically smoother/less bulky than seen in other conditions, especially the anterior formation **2)** it is not uncommon for the costovertebral joints or other spinal facets to ankylose, **3)** changes are continuous without skip lesions **4)** fusion expands upward from the lumbar or lower thoracic vertebrae (shown by red arrow). View: left lateral.

In **DISH**, spinal bone growth: **1)** occurs within the ligament and is limited to the ligament; it does not invade the disk space **2)** is confined to the right paravertebral position within the thoracic vertebrae **3)** is continuous without skip lesions **4)** has a flowing, dripped candle wax appearance. View: anterior.

Source: created by the author.

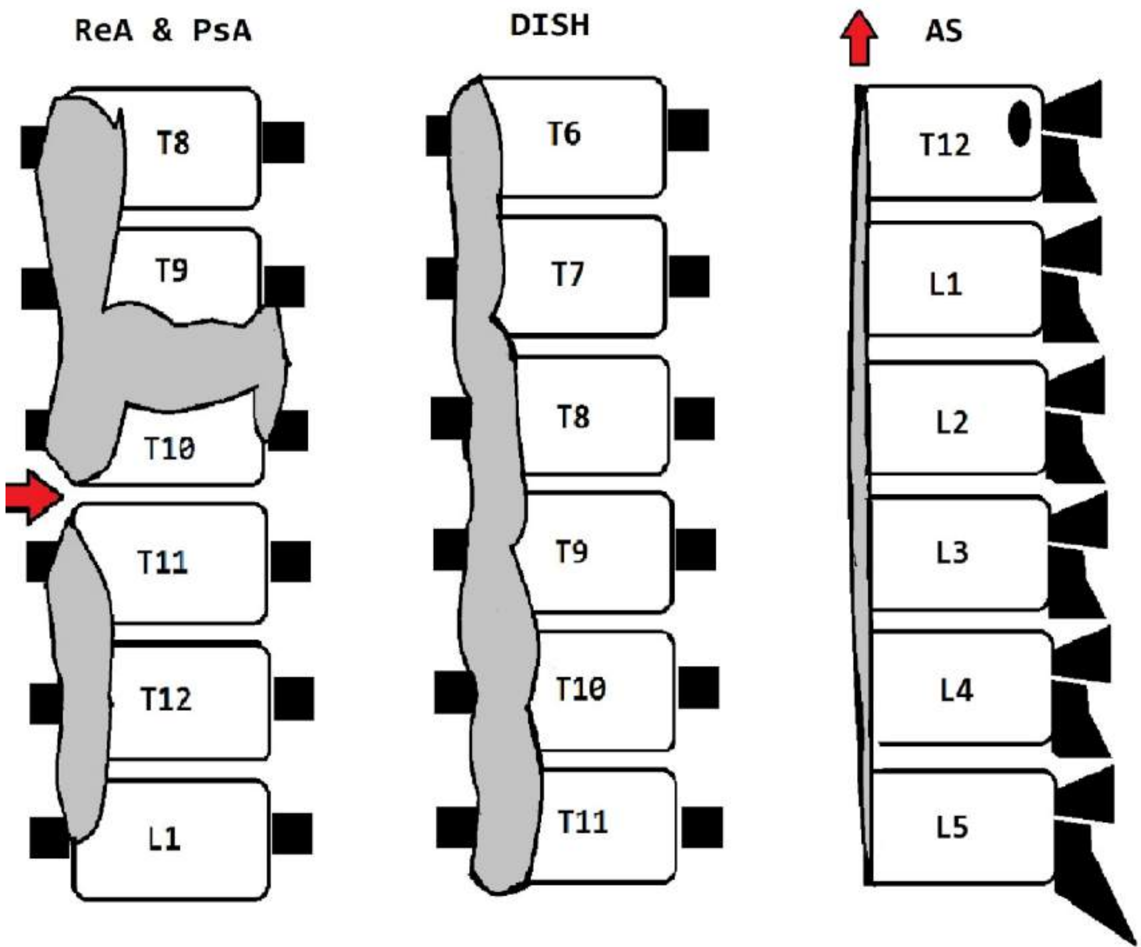


Figure 16: Spinal Bone Formation in DISH & SpA (B)

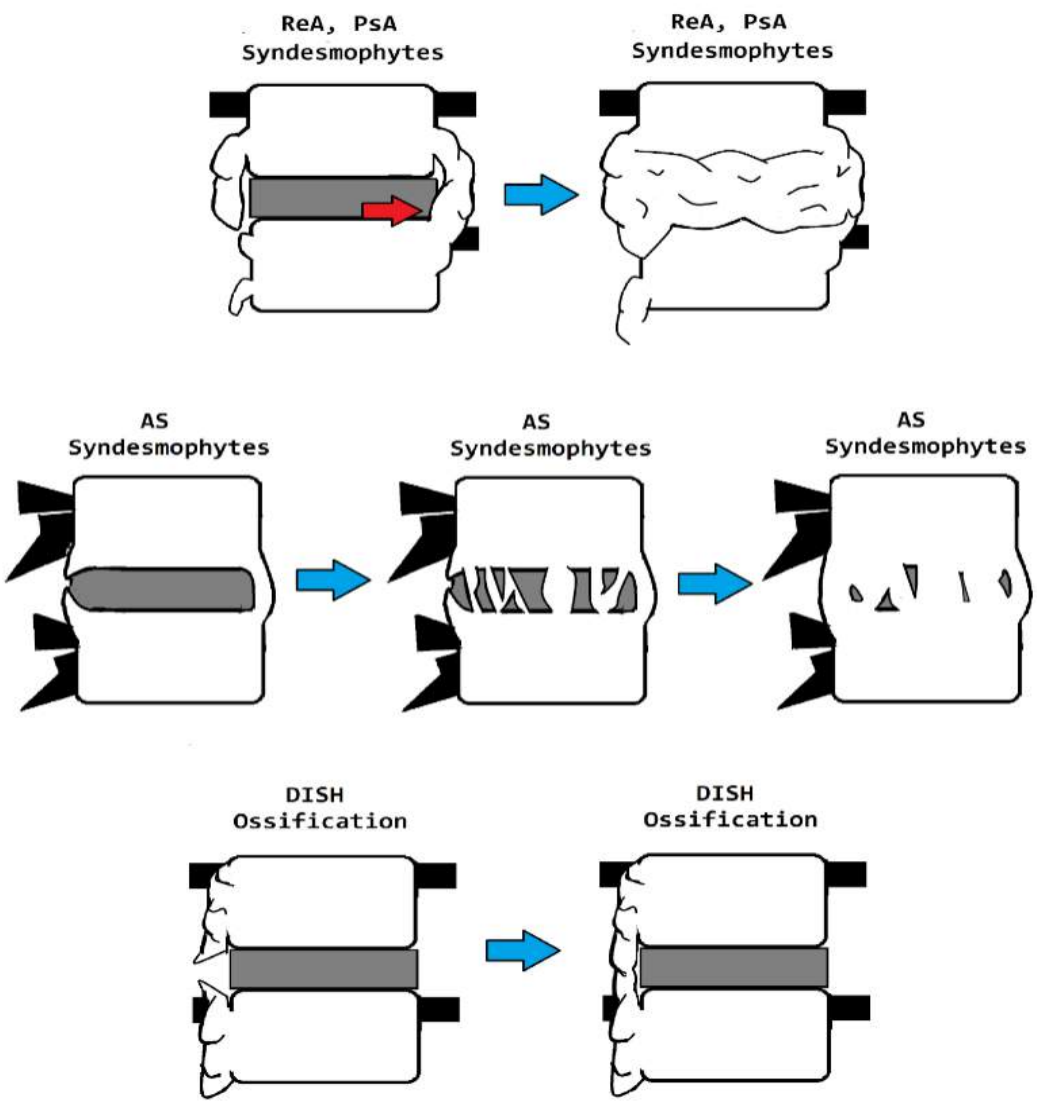
(blue arrows represent changes over time)

In **ReA and PsA** fusion is caused by ossification of the paravertebral connective tissues. Bone formation takes on the appearance of chunky, comma shaped syndesmophytes that bridge together in the paravertebral position(s). Bone formation does not generally start from the joint margin. Early in formation, there may be space preserved between the bridging bone and vertebral body, but this will disappear over time (shown by the red arrow). View: anterior.

AS targets the annulus fibrosus. Compared to ReA and PsA, syndesmophytes of AS occur close to the joint margins, are smoother, smaller, and less bulky. Eventually, fusion may involve all points of the vertebral body margin, but, in early development, the anterior and posterior corners of the vertebral body are favoured positions for syndesmophyte formation. View: lateral.

In **DISH**, fusion occurs as a result of ossification of the anterior longitudinal ligament. Bone formation is bulky, but flowing, frequently taking an undulating appearance of dripped candle wax. Unlike the SpAs, the disk space is spared and only the right side is involved in the thoracic region. View: anterior.

Source: created by the author.



Though DISH is certainly one of the primary conditions to be considered for differential diagnosis of SpA, other conditions should be mentioned as well. Tuberculosis (TB) for example, may cause lytic lesions resembling erosions. When TB spreads to bone, which is only in about 2% of cases, the most common site to be affected is the spine (half of the cases exhibiting skeletal changes); other locations affected in skeletal TB are the knee, hip, and wrist (Waldron 2009). Spinal erosions may occur in SpA but are often associated with notable bone proliferation, which is not typical of spinal TB where bone formation is minimal (Ortner 2003; Waldron 2009). Where erosions of EAs may be found in a number of locations, TB lytic lesions are often unifocal, though they may extend out from that location to become quite sizable (Ortner 2003; Waldron 2009). In some cases of spinal TB, the weakening of the spine becomes great enough to causes collapse, or Pott's disease; this level of concentrated destruction is not typical of SpA or RA spinal erosions (Ortner 2003; Waldron 2009). **Figure 17** is an example of a spinal TB lesion.

Lytic lesions also occur in metastatic cancer and mycotic infections. Though metastatic cancer may be encountered, mycotic infections are low on the list of differential diagnoses for destructive bone lesions in European assemblages, as they are quite rare (Hershkovitz *et al.* 1998; Kelley & Eisenberg 1987; Ortner 2003). As several conditions do cause lytic lesions, it is important to note how lytic bone destruction differs from that of erosive arthropathies. Lytic lesions are often surrounded by normal bone, but erosions of EAs are frequently (though not always) associated with some form of abnormal bone (osteoporotic or reactive bone formation) (Ortner 2003; Waldron 2009). Another important distinction is whether the observed lesion is found in association with a joint. Though it is possible for lytic lesions of TB, metastatic cancers, and mycotic infections to be associated with a joint, this is not a requirement. The same is not true of erosive arthropathies, as to be considered an 'arthropathy,' it must be associated with a joint. More information about lytic conditions can be found in Appendix A.

Figure 17: the inferior surface of this lumbar vertebrae exemplifies the typical appearance of a lytic lesion caused by spinal TB. It is a concentrated, but highly destructive lesion of the vertebral body with minimal new bone formation; the bone formation that is present is highly irregular. Source: photo taken by author, EA 845 from the Stray Park Cemetery in Plymouth, permitted by Bournemouth University.

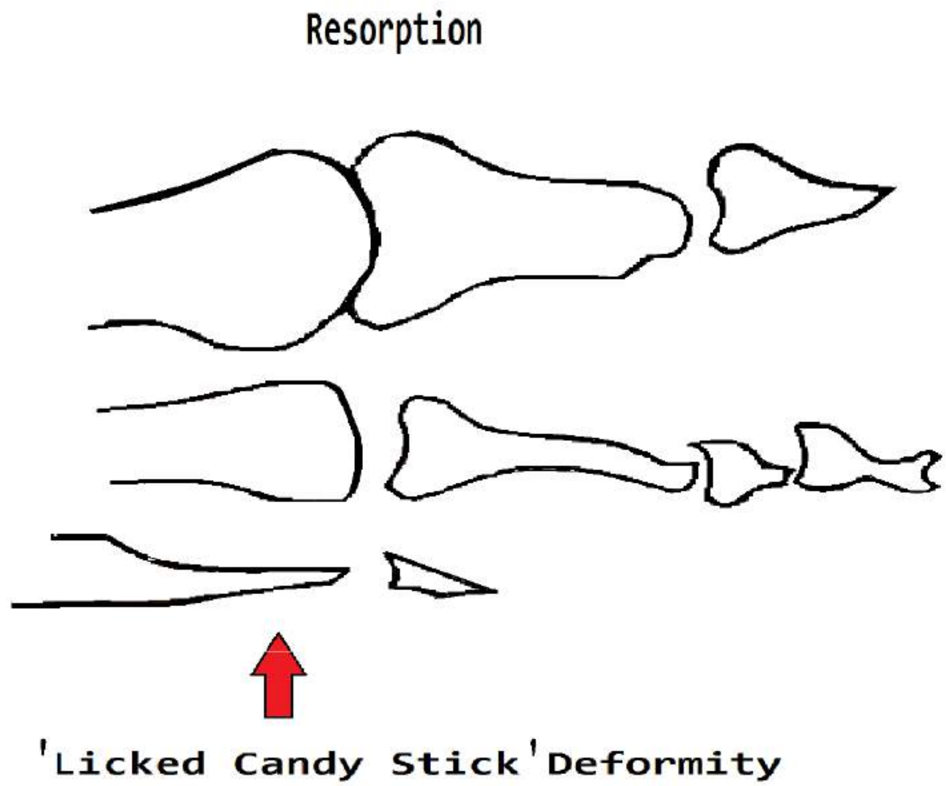
Infections like osteomyelitis may cause some confusion due to the formation of an opening called a cloaca, which allows pus to be expelled from the infected bone (Waldron 2009). The differential diagnosis for a cloaca and erosions is often simple, as the overall appearance of osteomyelitis is quite distinctive. For starters, cloacae are not directly associated with joints and are frequently large with smooth walls (see **Fig. 18**), meaning they lack the scalloped edges of true erosions. Secondly, the new bone formation associated with osteomyelitis is exceedingly irregular and not associated with the entheses or joints specifically. In cases of osteomyelitis, new bone formation occurs in the periosteum and creates a smooth but billowed appearance that, in advanced cases, may produce an outer shell of bone which surrounds the original; this is known as an involucrum (see **Fig. 19**) (Waldron 2009). The new bone formation may also cause disruption to the blood supply of underlying bone, making avascular necrosis another common feature of advanced bone infections, which can result in the creation of sequestra (see **Fig. 19**); these can sometimes be difficult to see, as they lie inside the medullary cavity (Waldron 2009). When changes like that of osteomyelitis are found in association with a joint, septic arthritis may be to blame (García-Arias *et al.* 2011; Ortner 2003). Septic arthritis can cause erosive changes and reactive bone formation in the joints, but like osteomyelitis, these changes are often highly irregular and disorganized compared to what is typically observed in EAs; septic arthritis can potentially affect any surface and frequently results in ankylosis (García-Arias *et al.* 2011; Ortner 2003; Waldron 2009). Ortner (2003) points out that, in dry bone, the changes of septic arthritis often resemble that of TB, but with less bone destruction. Also dissimilar from most EAs, septic arthritis is often monarticular (with the exception of gonococcal septic arthritis, which is frequently polyarticular) and tends to show a preference for larger joints like the knee; however, wrists and ankles are also noted with some frequency (García-Arias *et al.* 2011; Ortner 2003; Waldron 2009).

Figure 18: the image below shows a cloaca, as well as billowing periosteal bone formation. These changes are characteristic of osteomyelitis. Source: photo taken by author, KWK 3045 from the pensioner's cemetery for the Royal Hospital for Seamen in Greenwich, permitted by MOLA.

Figure 19: the image below displays a case of osteomyelitis, which occurred in the right femur and was likely caused by amputation of the lower leg. The red arrow indicates the sequestra and the blue arrow the involucrum. Source: photo taken by author, KWK 3045 from the pensioner's cemetery for the Royal Hospital for Seamen in Greenwich, permitted by MOLA.

Leprosy is a condition which causes neuropathy and is yet another condition that may produce lesions resembling erosions. The lesions of bone destruction in Leprosy usually lack the scalloped appearance and patterning of true erosions. The changes of leprosy are more to do with bone resorption (osteolysis), which can also be observed in some forms of EAs; for example, the 'licked candy stick' deformity (see **Fig. 20**) that may be observed in cases of PsA and RA is actually most pathognomonic with Leprosy (Hagihara *et al.* 2015; Waldron 2009). Such changes occur in the hands and feet, but are not necessarily joint associated, as the bone shaft eventually becomes involved as well. The osteolysis of leprosy causes concentric loss of cortical bone that works inward (from distal to proximal) (review **Fig. 20**) (Waldron 2009).

Figure 20: the figure below exemplifies the concentric pattern of osteolysis in leprosy, which works from distal to proximal. Such changes may result in the 'licked candy stick' deformity indicated by the red arrow. Source: adapted form Mann & Hunt 2005.



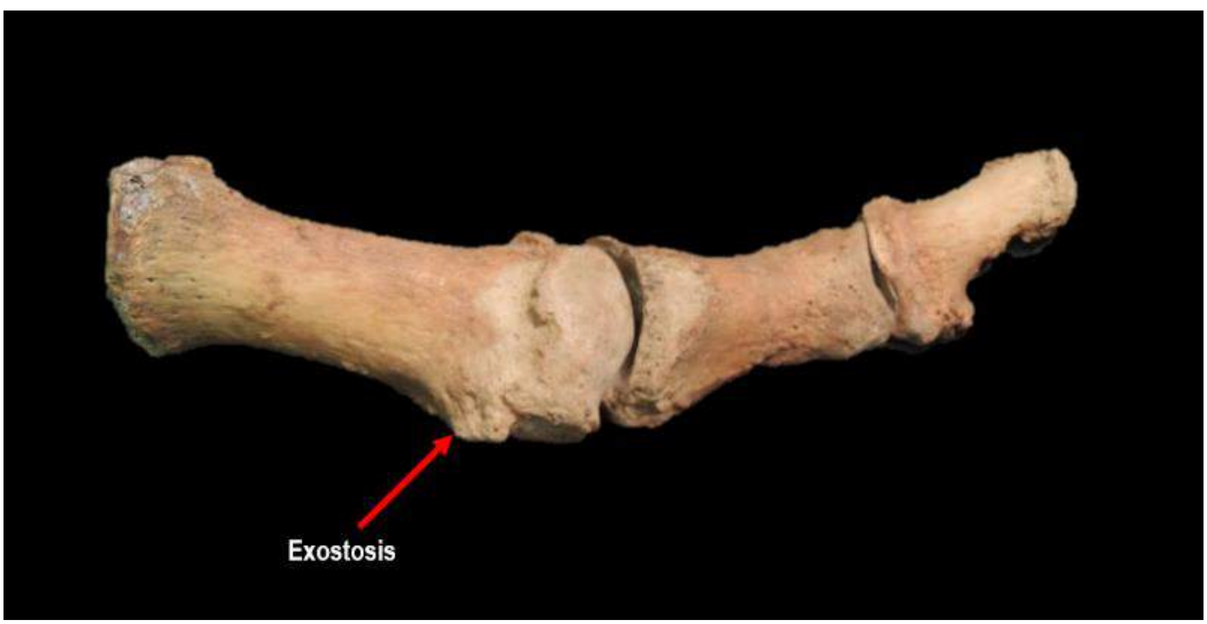
Though the 'licked candy stick' deformity may be observed in certain forms of EAs, more traditional erosions should also be present. A further distinction can be made by the presence or absence of secondary pathology. In cases of leprosy, secondary osteomyelitis (especially in the feet) is common, as the loss of sensation causes injuries to go unnoticed by the afflicted individual, leading to infection; Charcot's joints, especially in larger joints, occurs in leprosy for the same reason (Hagihara *et al.* 2015; Waldron 2009). While periostitis may be observed in certain EAs, osteomyelitis and Charcot's joints are not typical. Finally, the presence of rhinomaxillary syndrome (resorption of the maxillary areas of the face, especially the nasal area) would support a leprosy diagnosis, as this is not a feature of EAs (Andersen & Manchester 1992; Hagihara *et al.* 2015; Waldron 2009).

A final note on a condition of potential confusion with EAs is hallux valgus, which is abnormal lateral deviation of the great toe (Mays 2005). This condition may be congenital in some cases, but is primarily caused by biomechanical stress, which is most commonly attributed to wearing ill-fitting shoes (Mays 2005; Piqué-Vidal *et al.* 2007). Though not always the case, hallux valgus may cause destructive lesions on the mediodistal surface of the 1st metatarsal. When such lesions occur, they are para-articular and often cut deeply into the bone. Though the lesions may be round, they can also take the form of an elongated groove. The most telling feature is the lack of a scalloped and roughened appearance, as lesions of hallux valgus frequently have smooth walls of thickened trabecular bone (see **Fig. 21**). Exostosis of the medial epicondyle of the distal 1st metatarsal is commonly observed alongside lesions of hallux valgus and one may also observe evidence of lateral deviation in the joint (Mays 2005).

If changes are observed only in the greater toe(s), gout is the condition which may be confused with pressure lesions of hallux valgus. Neither gout nor hallux valgus are reactive arthropathies, so mistakes in identification should not cause distortion of figures for reactive pathology. Nevertheless, it is worth noting that the presence of hallux valgus does not mean erosive pathology cannot coexist. In fact, RA patients have been reported to exhibit a high prevalence of hallux valgus, between 55% and 76% (Matsumoto *et al.* 2015).

For more information on possible conditions for differential diagnosis with EAs, see Appendix A.

Figure 21: the top image shows pathology from EA 909 from the Stray Park Cemetery in Plymouth. The lesion on the disto-medial surface of the 1st metatarsal exhibited an elongated (groove-shaped) lesion with smooth walls. Such pathology is likely due to hallux valgus. The bottom image displays the greater toe of FAO90 2193 from St. Brides Lower. Exostosis and lateral deviation are evident. Source: photos taken by author, permitted by Bournemouth University and MOLA.



Chapter 1 has provided a detailed description of the aetiology and pathology of the primary conditions of interest to this research: SpAs. As mentioned at the start of the chapter, knowledge of the aetiology of reactive arthropathies is important, as this information contributes to the understanding of 'why' there is a reason to suspect reactive arthropathies were common among past military combatants. To further understand this connection, Chapter 2 will illustrate the strong association between the military lifestyle and infectious diseases, the bacterial agents of which are nearly identical to those previously described in section 1.4.2.

Review of Introduced Acronyms:

Erosive Arthropathy (EA) / Arthropathies (EAs)

Spondyloarthropathy (SpA) / Spondyloarthropathies (SpAs)

Reactive Arthritis (ReA)

Psoriatic Arthritis (PsA)

Ankylosing Spondylitis (AS)

Enteropathic Arthritis (EnA)

Rheumatoid Arthritis (RA)

Acute Rheumatic Fever (ARF)

Human Leukocyte Antigen (HLA)

CHAPTER 2:
The Military Lifestyle, Infectious Disease, & Rheumatism

This chapter provides a historical overview of the military connection to particular forms of infectious diseases, but more importantly, it seeks to provide an explanation of the living and behavioral circumstances that created a higher exposure and susceptibility to these infectious diseases in military groups. Military medicine has been practiced for thousands of years. Though the recording of their findings has not always been perfect or without bias, referral to primary documents produced by military physicians and surgeons provide valuable information about the commonality of particular ailments, medical treatments, and insight into the practitioner's understanding of these conditions. As such, historical military medical documents have been a primary source of information for this chapter, but these works are also accompanied by secondary resources of historians, historical geographers, sociologists, and medical researchers. The secondary resources used for this chapter have been selected from peer-reviewed periodicals, books from reputable publishers, and/or authors from reputable organizations. Book reviews by relevant (by discipline or topic) peers were used for heavily utilized texts to identify and avoid weak points; for example, Skinner (2015), Kirby (2008), Palkon (2008), Ellis (2002), Hawk (2002), Hawk (2015), Totelin (2013), and Ostwald (2009). When possible, statements from secondary resources have been cross referenced with evidence from primary resources.

This chapter provides a general overview describing military medical practice throughout history, with special emphasis being placed on military policies and practices that influenced military outbreaks of infectious diseases. When it comes to resources available on the history of military medicine, it is evident that the quality of information available is highly correlated with time, with discussion of ancient topics being especially problematic due to a lack of primary resources or limited knowledge of the quality and contexts of the primary resources that are available; matters of numerical figures are particularly worrisome (Totelin 2013). Nevertheless, rather than ignoring the topic of ancient military medicine, much of the information considered in relation to the ancient history of military medicine is kept to general conclusions. As one moves forward in time, more primary resources become available and there is more knowledge of the history of these documents, so one will note increasing specificity as the historiography section progresses. After the historiography section, there is more specific examination of how military combatants have faced increased susceptibility and exposure to infectious diseases, which partially depend on statistics and discussion from primary resources. As such, the historiography section concludes with consideration of biases that could influence the information provided in the remainder of the chapter. The closing of the chapter establishes how bacteria associated with particular military infectious diseases are linked to reactive arthropathies.

2.1 Historiography & Historical Context

2.1.1 Military Medicine & Disease

Military medical practitioners throughout history have played numerous roles. Primarily, their purpose is to reduce the loss of manpower; they ensure that as many combatants as possible live to fight another day (Gabriel 2012). Additionally, they have been responsible for the evaluation of conscripts, suggested and encouraged adoption of good hygienic/sanitation practices, served in logistical administrative roles, and (historically) provided medical care to animals accompanying military units (Gabriel 2012). Though the role of military medical practitioners has been vast, their ability to influence and create change has faced many challenges. For instance, issues such as quotas, low rank, and competing medical factions often made it difficult for military medical practitioners to generate change with any haste, which has majorly influenced how military history played out.

The history of military medicine is often studied by examining pioneering individuals and structural advancements in relation to the evolution of military technology (Hudson 2007 [a]). Indeed, advancement of weaponry over time has produced worse injuries that have required more efficient medical care, but war also produces another problem – disease. The connection between disease and militaries is largely due to issues of overcrowding and sanitation, which are further complicated by weakened immune systems. There are also social issues that contribute to the spread of disease in military groups. These factors are explained in detail in later sections of this chapter, but the present section is concerned with the history of military medical practice in relation to the progression of attitudes, actions, and ideas that would both contributed to and (eventually) reduced the occurrence of military epidemics.

Pre-Eighteenth Century

The history of violence and disease precedes the written record; for instance, skeletal remains demonstrating perimortem trauma in a 10,000-year-old assemblage of African hunter-gatherers is suggested to be the first known example of group conflict (war) (Lahr *et al.* 2016). Evidence of general violence and disease stretch even further back into the historical record (Han & Silva 2014; Odes *et al.* 2016; Sala *et al.* 2015). Attempts to treat injuries and disease likely have great antiquity as well, but, due to the lack of written records, the details of these early treatments are left largely to speculation based on fragments of physical evidence (McCallum 2008). The founding of the practice of 'medicine' is not a concept that can be attributed to any one culture, as it developed in the ancient world independently within the confines of different cultures (Gabriel 2012). Military medicine developed in a similar independent fashion. In the earliest armies (Sumerians, Egyptians, and Assyrians), it appears that military medicine was usually a reflection of the medical knowledge known in mainstream society, but this was not always the case in ancient cultures; for example, the military was a very influential part of Roman culture, so mainstream medical practices were largely a reflection of military medical customs and knowledge rather than the reverse (Gabriel 2012).

Military medical practice is usually more concerned with results than the advancement of theoretical insight; accept what works, abandon what does not (Gabriel 2012; Rostker 2013). This may lead to a conclusion that there was a lack of sophistication to its practice, but the lack of coherent medical theory did not hinder the development of pragmatic and effective means of treating conditions and injuries (Gabriel 2012, 43). For instance, evidence suggests that one of the earliest forms of surgery was trephining the skull (removing a section of the skull to expose the dura). This is a risky surgery and one requiring skill, but the practice appears to have been conducted with impressive success in ancient times; a study of remains from ancient Peru suggested that "trepanation survival rate reached 90% at one point and was accompanied by a low frequency of infection (4.5%)" (Andrushko & Verano 2008, 12).

Successful implementation of this procedure illustrates that empirical medical practice is possible without the aid of proven modern medical theory (such as germ theory and antisepsis). Just as in general medicine, empirical treatment of wounds also occurred in ancient armies; for instance, ancient Greek treatment of wounds were based on observation and trial and error (Gabriel 2012; McCallum 2008).

The success of ancient military medicine was a reflection of military organizational sophistication; this was also frequently true of later systems of military medicine. Rome and Assyria had large, well-organized militaries that established formal means of providing military medical care, but citizen armies with no permanent configuration (like those of ancient Greece) could not provide a strong structure capable of providing quality medical care to its combatants (Gabriel 2012; Rostker 2013). Though military medicine in Greece faced organizational challenges, they clearly realized the military provided great empirical advantage to the advancement of medical practice; Hippocrates stated that surgery and war were linked, advising "that anyone who would become a surgeon should find himself an army and follow it" (McCallum 2008, xv; Gabriel 2012).

While empiricism did have some influence on wound treatment, treatment of disease in ancient times was largely spiritual, as it was frequently believed deities or enemies created and cured disease magically (such as Apollo plaguing the Greeks invading Troy in Homer's *Iliad*) (Gabriel 2012; Longrigg 2013; McCallum 2008). Nevertheless, some ancient cultures did manage to take actions that reduced the occurrence of disease. For example:

> The rabbis of Israelite armies of the thirteenth century BCE served as a sanitary corps and were experts at the detection and prevention of disease and contagion. The Hebraic tradition of kashruth ensured an uncontaminated food and water supply, and the ritual butchering of animals by shochets (religiously trained slaughterers) made them experts at recognizing the clinical signs of human and animal sickness. The shochet originally was employed to ensure that an animal sacrifice was fit to offer the gods. Later, he extended his skills to examining the food supply for the army, a practice that reduced illness and disease considerably (Gabriel 2012, 46).

Non-deliberate factors may have also reduced the occurrence of disease in some ancient armies. The armies of ancient Greece infrequently spent extended periods of time afield, which is one of the most common seats of military diseases due to poor sanitation and overcrowding. Though disease was not unknown to ancient Greek militaries (during the Peloponnesian War, disease forced Hagnon to withdraw his fleet from Athens after losing 1,050 of a total 4,000 troops), the short duration of time afield in combination with some evidence of good field hygiene practices may explain why descriptions of diseases ravaging Greek armies are rather few; alternatively, it could also be a matter of historical recording or survival of documents discussing the topic of military disease in ancient Greece (Gabriel 2012; Longrigg 2013). The tragedy of these apparent ancient successes against disease is that the benefits of good sanitation was largely unrecognized or ignored, which allowed disease to remain a leading cause of military fatalities until the twentieth century when militaries widely enforced protocols related to field hygiene and sanitation (Gabriel 2013; McCallum 2008).

Rome was well known for its military, which was large, well organized, and heavily armed. The size and mobility of Roman armies brought on disease and traumatic war injuries. Roman generals and emperors realized that soldiers who knew they would be cared for if injured were more likely to fight, which made providing military medical care a matter of state obligation (McCallum 2008; Rostker 2013). Julius Caesar offered citizenship as a means of gaining military surgeons and Germanicus would pay for their services (McCallum 2008). Eventually, every legion and naval vessel had its own surgeon assigned and a network of *valetudinaria* (military hospitals) were founded (McCallum 2008; Rostker 2013).

The focus of early Roman military medicine was largely on surgery. The sick were largely self-treated with herbal remedies or by physicians, who were widely considered untrustworthy (Gabriel 2012; McCallum 2008). Early Roman conflicts struggled greatly with disease as a result; one epidemic during the siege of Syracuse was described by Titus Livius as being so frightening that men threw themselves at enemy lines, preferring to die by the sword than by disease (McCallum 2008). Roman distrust of physicians would eventually change: "the standing of Greco-Roman physicians improved dramatically in 91 B.C. when Asclepiades of Prusa came to the city. His use of diet, baths, exercise, and massage and his avoidance of surgery and poisonous medicines enhanced both his personal reputation and that of his profession" (McCallum 2008, 270). With the acceptance of physicians came improved military field hygiene. Medical officers were assigned the task of ensuring the health of Roman legions, a position that was taken very seriously after disease became a major issue during the Roman Civil War (40s B.C.) (Gabriel 2012). With the help of medical officers, Roman forts became outstanding examples of good military hygiene by enforcing proper waste disposal and standards of cleanliness in addition to providing washing facilities for men and clothing (Gabriel 2012; Rostker 2013). Based on analysis conducted by military medical historian Richard Gabriel (2007), 6% of Roman soldiers would die in battle, 8 to 10% from wounds and infections, and 35% to general health issues (including disease). The 35% general health issue fatalities of Roman soldiers is lower than the estimate calculated for other ancient armies (such as the Egyptians), which fell between 40 and 45% (Gabriel 2007). This difference in percentages may have been due to Roman efforts placed towards maintaining good sanitation (Gabriel 2007). Ultimately, Roman military hygiene, ambulance services, hospitals, and development of an extensive array of surgical equipment made their military medical practices quite advanced, but the likes of it would not be seen again until the 19th century (Gabriel 2013; McCallum 2008; Rostker 2013).

Though organization of Roman military medicine was quite good, medical practices remained largely the same to that of the classical Greeks. Even Greco-Roman military surgeon and physician Galen of Pergamon (see **Fig. 22**) (who published 500 books about anatomy, physiology, pathology, therapeutics, and pharmaceuticals) largely relied on Greek medical principals (McCallum 2008). Galen was an experimenter who combined his findings with those of Hippocrates and Pythagoras. Though certainly the scholar of his day, Galen's focus on animal dissections and reliance on ancient Greek philosophy to rationalize his findings caused him to record many errors that would persist until the sixteenth century (McCallum 2008).

Figure 22: Greco-Roman physician Galen of Pergamon (also known as Aelius Galenus or Claudius Galenus). His medical works on anatomy greatly influence the practice of medicine until the sixteenth century. Lithograph by P. R. Vignéron. Source: Wellcome Library n.d.

With the fall of the Roman Empire and entrance into the Middle Ages, militaries became more disorganized than those of Roman armies and organized military medicine fell out of use. Medical care, military or otherwise, was delegated to religious orders until the thirteenth century (McCallum 2008). Formal medical care for military combatant was rare in Europe, but barber surgeons (see **Fig. 23**) often followed armies; barber surgeons "were untrained practitioners of folk medicine and surgery whose status as medical practitioners lay in their old practice of cutting the tonsures of monks. They earned a living cutting hair, shaving beards, pulling teeth, dispensing folk remedies, and, later, bleeding and applying poultices to the sick" (Gabriel 2013, 46). These barber surgeons had no formal training, but did learn through experience. For instance, military barber surgeon Ambroise Paré (1510-1590) kept with the practice of using hot oil to cauterize wounds but, upon running out of oil, he realized men left without this treatment healed better, causing him to dispense of this practice and reintroduce the Roman technique of tying off veins and arteries; unfortunately, the practice of ligature would not be widely and efficiently practiced until the nineteenth century (Gabriel 2013; Showalter & Astore 2007). Though occasionally hired by commanders or ruling leaders to provide their services, most barber surgeons chose to follow armies and were paid by the wounded soldiers (Gabriel 2013).

Galen's medicine dominated through the Middle Ages, but it was a bastardized version of the original. Until the fall of Constantinople in 1453:

> The manuscripts and translations of the works of Greek and Roman medicine were available in their original versions only in Byzantium. While some of this knowledge had reached the West during the Middle Ages, much of the original empirical medical knowledge of the Greek and Roman texts had been lost or distorted over the centuries by Arab and Christian scholars, physicians, and clerical authorities who, in translation after translation, had edited and reedited the texts and removed information considered dangerous to the faith (Gabriel 2013, 44).

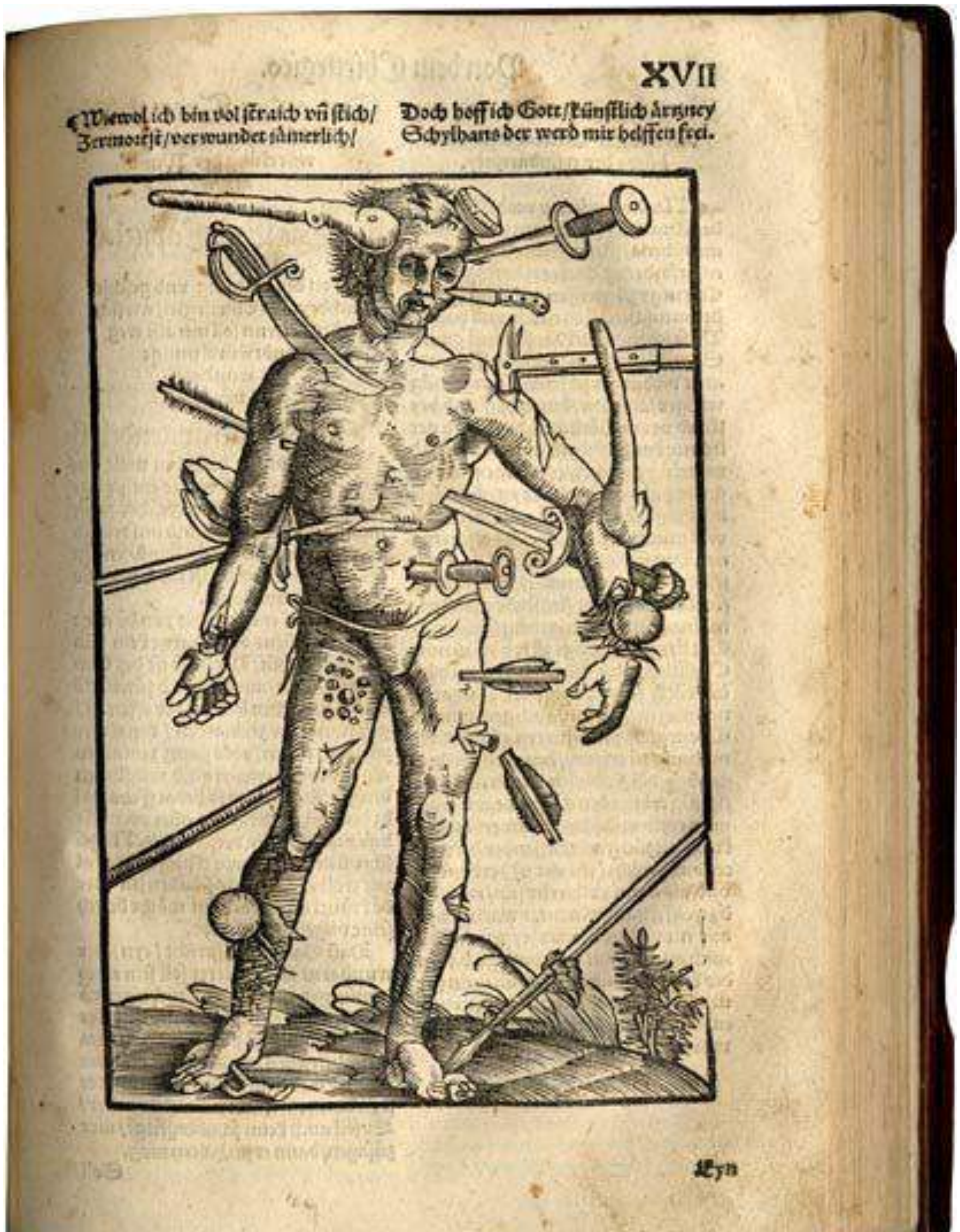
Galen's work was no exception to these circumstances. For example, it was widely accepted that Galen's work encouraged provocation of wound suppuration (puss production) as part of the healing process, but Galen's original work actually states the opposite (Gabriel 2013; Grant 1974).

Renewal of empirical based medicine occurred during the Renaissance. This change occurred for several reasons (Gabriel 2013). Foremost, the timing was right. The Middle Ages had been dominated by religious doctrine, but pandemics had greatly reduced the population, causing people to question their clerico-secular society. The devastation left by diseases like the plague illustrated the failures of clerical medical doctrine – "that god visited death and disease as punishments for sin was hardly credible in an age when disease seemed to strike at random, when saint and sinner alike perished, and when large numbers of priests, monks, and even popes died" (Gabriel 2013, 42; Grigsby 2004). The decrease in population also left a young generation without the traditional guidance of elders to indoctrinate them, leaving them more freedom to explore and establish their own moral and intellectual parameters (Gabriel 2013).

In addition to timing, the fall of Constantinople in 1453 allowed the original classical works of Greek and Roman medicine to spread throughout Europe, reintroducing Europeans to empirical research and encouraged the development of new methods of scientific inquiry (Gabriel 2013; Kyle 2017). Also aiding the spread of information and ideas was the invention of the printing press. Wide use of the printing press by the 1460's had a major impact on medicine, as it allowed information and ideas to become more accessible and easily communicated between practitioners (Eisenstein 1980; Gabriel 2013).

In the sphere of military barber surgeons, there was an issue with many of these early medical transcripts; they were large, which was not conducive to traveling with an army. This would change in the later 1500's with cheap pocket compendiums that could be easily carried, allowing military barber surgeons to benefit from the spread of medical knowledge through books. Ambroise Paré (a French military barber surgeon) published one of these early pocket compendiums, *Anatomie Universelle,* in 1561 and Joseph Schmidt (a German military surgeon) published the pocket compendium *Mirror of Anatomy* in 1601 (Gabriel 2013; Showalter & Astore 2007).

Figure 23: the diagram, the "Wounded Man," was first published in Hans von Gersdorff's *Feldtbuch der Wundartzney* (1517). It depicts human-inflicted wounds barber surgeons regularly encounter, including injuries from military weapons. Source: Hagströmer Medico-Historical Library n.d.



In addition to having more accessible texts, Andreas Vesalius, who was a military surgeon for Charles V, helped break away from the traditional Galen ideas of medicine. Where Galen had based his works on animal dissections, Vesalius' work had been produced from human dissections. Vesalius' publication *De humani corporis fabrica* (1543) described the mistakes he discovered in Galen's version of anatomy; for instance, Vesalius proved the mandible was one bone rather than two (Gabriel 2013; McCallum 2008; Saunders & O'Malley 2013).

To accompany new means of scientific inquiry, frequent warfare and changes to military tactics in the fourteenth century would stimulate the renewal of formal military medicine (examples: the Swiss had begun using the Roman phalanx along with instituting the use of pikes and the British began to emphasize the use of bowmen to combat armored knights) (McCallum 2008; Rogers 1999). In the fourteenth century, the Swiss became the first nation-state since Rome to provide medical care to their armies (Gabriel 2013; Garrison 1922; McCallum 2008). The Swiss viewed their people as being free citizens with rights and functioned under a system of reciprocal obligation (citizens would serve the state and the state would serve its citizen); this meant the government had an obligation to care for the men in their military, which included the hiring of barber-surgeons to care for the sick and wounded (Gabriel 2013; Garrison 1922). The renewal of military medicine in the rest of Europe was slower due to reliance on mercenaries for combat rather than recruits from the nation's own populous, but as nationalistic armies began to become more common in the late fifteenth and early sixteenth century, it was "expected that they would develop the outlines of a military medical service to treat the common soldier" (Gabriel 2013, 56).

The standard use of gunpowder by the 15th century contributed to the demand for military medicine (Keen 1999; McCallum 2008; Rogers 1999). Bladed weapons did not break bones in the same explosive and shattering manner of gunpowder, which meant wounds were more difficult to treat. Furthermore, projectiles often introduced foreign material into the wounds that would cause infections (Gabriel 2013; McCallum 2008). Indeed, infection was so common some were convinced that gunpowder was poisonous, which lead to practices of ‘detoxifying’ wounds, which only succeeded in making infections worse (McCallum 2008). Ultimately, failure to treat such wounds lead military surgeons to conclude that the best course of action was to remove (amputate) the affected extremity, a practice that would persist into the 19^{th} century (McCallum 2008).

In the sixteenth century, standing armies became increasingly common in Europe and were well established by the seventeenth century. Standing armies allowed warfare to occur on a larger scale (Keen 1999; McCallum 2008; Showalter & Astore 2007). Siege warfare also became more common. Though disease had always been a problem for militaries, siege warfare had massive armies congregated into small areas for extended periods of time, which was less than ideal for sanitation and ideal for contagion (McCallum 2008). The tragedy of military epidemics was the attitudes toward them. Epidemics were considered inevitable and were accepted as a normal cost of war; however, one sixteenth century example clearly illustrates how military commanders could have reduced infectious disease had more attention been given to military sanitation.

During the siege of Metz in 1552 (part of the Italian War of 1551–1559), Charles V brought almost 220,000 men to besiege the city, while his opposition, the Duke of Guise, commanded a mere 6,000 troops housed inside the city walls (Gabriel 2013). Charles V’s army went about business as usual – by giving little consideration for matters of sanitation or provisioning of quality supplies (Heizmann 1917). As often was the case in such situations, this resulted in Charles V’s forces becoming ill with crowd diseases like typhus and dysentery, along with nutritional diseases like scurvy. After losing 20,000 men, Charles V was forced to abandon his siege of Metz (Gabriel 2013). Meanwhile, inside the city walls, the Duke of Guise applied basic rules of field sanitation with outstanding results. He increased expenditure to ensure troops were provided ample and quality rations; water sources were checked for purity and placed under guard to pervent purposeful contamination; ill soldiers were quarantined away from the garrison in hospitals located in remote locations; streets were ordered to be kept clean and waste (human or animal) was thrown over the city walls for disposal (Gabriel 2013; Heizmann 1917). Barber surgeons were also hired to aid the sick (Gabriel 2013; Heizmann 1917). Through these efforts, “not a single serious outbreak of disease occurred during the sixty-five-day siege” (Gabriel 2013, 59; Heizmann 1917). Unfortunately, such practices were not widely practiced after the Siege of Metz. Understanding of the positive effects of military sanitation would continue to accumulate, but major enforcement of military sanitation did not occur until the late nineteenth century (Gabriel 2013; McCallum 2008).

Though the Renaissance had brought empirical evidence and experimentation back into fashion, military medicine in the seventeenth century did not undergo any momentous developments (Gabriel 2013; Heizmann 1917). Use of dissection and clinical amphitheaters were a nuance of the period, but despite the new anatomical knowledge these practices provided, successful integration of this information into practice was limited (Gabriel 2013). Military medicine was still very much in the hands of barber surgeons, who frequently lacked proper training or competence. Nor had military hygiene improved (Gabriel 2013; Heizmann 1917).

In the seventeenth century, basic military hygiene ordinances were often in place for European armies, but these ordinances were rarely enforced or implemented, so military camps remained unsanitary and diseased (Gabriel 2013; Showalter & Astore 2007). Nevertheless, some important scientific discoveries were made in this century, such as the discovery of micro-organisms. In 1677, Antoni van Leeuwenhoek found small organisms (‘animalcules’) in droplets of water examined under a microscope (Committee of Dutch Scientists 1996; Gabriel 2013). Unfortunately, these organisms’ connection to disease was not realized; these organisms were believed to be produced by disease through spontaneous generation, when, in actuality, they caused disease. The leading theory of disease before the acceptance of germ theory in the late nineteenth century was that of miasma, “a concept that originally related to ideas of pollution and referred to putrefaction of the air by decaying matter and the sick, and generally associated with bad smells”

(Charters 2014, 11). As a result of these misunderstandings about disease aetiology, dispassionate acceptance of disease as an unavoidable consequence of war continued; however, hope was not far off, as the eighteenth century would see these attitudes become increasingly unaccepted (Gabriel 2013).

Eighteenth Century

The focus on empirical evidence and experimentation, along with the focus on gaining anatomical knowledge, from the seventeenth century all coalesced in the eighteenth century. Dissection, teaching hospitals, private medical schools, and large scale medical publishing were now common, which produced more qualified medical professionals (Gabriel 2013). With this more official and scientific focus, the medical profession began to shake off many of its superstitious undertones (Gabriel 2013).

This increasingly scientific focus added legitimacy to the practice of medicine, which meant governments were forced to pay closer attention to the quality of the military medical care they provided. As a result, military medicine began to look more professional, which is illustrated by the founding of the first military medical school and journals in this century (Gabriel 2013). By the mid-eighteenth century, all major armies had institutionalized systems of medical care (Gabriel 2013). Establishment of professional military medical care was also due to the popularity of nationalistic movements; since militaries represented the power of the nation, governments were motivated to improve the quality and organization of their armies as a whole. Other military improvements included voluntary enlistment, daily food rations paid by governments, uniforms, and medical examination of recruits (Gabriel 2013; Heizmann 1917).

Militaries want to recruit healthy individuals, but historically, this was not easily done: "in times of social disruption or difficult economic times, recruits flooded the recruitment stations, and large numbers of marginally healthy adults with poor sanitary habits entered military service" (Gabriel 2013). This did not help prevent the spread of disease in military groups. Routine medical examinations were introduced as a means of eliminating the recruitment of individuals with poor health. In the early part of the eighteenth century, these examinations were not overly thorough, but, by the latter half of the century, mandatory checks with specific guidelines had been put into place (Gabriel 2013). Even into the nineteenth century, military examinations of recruits were taken seriously, as indicated by several publications, including: *Principals of Military Surgery* (Hennen 1820), *On the Enlisting, Discharging and Pensioning of Soldiers* (Marshall 1839), *Military Miscellany: Comprehending a History of the Recruiting of the Army…* (Marshall 1846), and *Hints to Young Medical Officers of the Army on the Examination of Recruits* (Marshall 1828).

Medical examination of recruits should have been beneficial in reducing the occurrence of disease, but, in practice, other issues limited the effectiveness of these examinations. Though guidelines were in place (M'Grigor & Franklin 1828), following these guidelines was another matter. There was a double-edged sword for military medical examiners. They were expected to provide rigorous inspection of recruits to only allow those of good health into the service, but they were also expected to fill military quotas (Willey 2015). With service being voluntary, the lower and middling class volunteers did not always provide the healthiest of individuals to choose from (Gabriel 2013).

Though military medical examination practices were established in the late eighteenth century, publications of the nineteenth century reveal enduring issues. For example, Marshall (1839) reports there were "certain differences of opinion, on the eligibility and ineligibility of recruits" and lists conditions such as gonorrhoea and slight deformities from fractures as examples where medical officers are "often at a loss to determine to what extent he should permit the above consideration to have weight in making up his opinion" (x). Hennen (1820) notes that such "dubious cases" are often left to the surgeon's "own discretion" (449). Naval recruitment practices of the eighteenth century were worse than those of the armies. Though the volunteer naval recruits would have been screened and (in theory) healthy, impressed sailors were not subjected to any medical examinations or were not quarantined before being placed onto vessels for service (Gabriel 2013). Due to the extremely close quarters inhabited on ships, the introduction of one ill impressed sailor could easily result in a ship full of sick sailors. These issues with medical recruitment policies make it unsurprising that men with various diseases and poor sanitation habits continued to enter the army in spite of inspections (Gabriel 2013). Recruitment practices in eighteenth century America were worse, as there were no medical examinations (Gabriel 2013). With no scrutiny over the health of individuals, disease rapidly became a problem for the Continental Army during the Revolutionary War (1775-1783); epidemics became so feared that the Continental Army struggled to obtain sufficient numbers using voluntary recruitment (Gabriel 2013).

With the move towards creating more professional armies, improvements were made to food rations by increasing their quality and quantity. This should have reduced both gastrointestinal and nutritional diseases among combatants, but, while the rules were in the books, implementation was difficult and often failed (Gabriel 2013). All European militaries relied on contracted commissary officers to meet their supply needs by hiring provisioners and organizing transport for supplies, but "this arrangement led to common abuses of fraud and theft, and the pressure to keep expenditures down often reduced food for the troops to less than sufficient quantities or quality" (Gabriel 2013, 92). Indeed, during the Seven Years War (1756 – 1763), a British Commissariat of Accounts who traveled to Germany in 1761, "reported that he found various problems and abuses upon his arrival; not only disorder, but even 'collusions and frauds,' which caused shortages of provisions and, consequently, pillaging" (Charters 2014, 90). Apart from corruption, logistical issues, such as understaffing and poor administrative structure, made proper provisioning difficult as well (Charters 2014).

Though the battle against military diseases in the eighteenth century cannot be considered a successful venture, there was marked difference in the attitude towards military disease. The organization of eighteenth century militaries relied on voluntary service and aid from public financing, which lead to increased care for the well-being of troops (Charters 2014). For example, British expansion of power in the eighteenth century was viewed as being a paternalistic act rather than one of ambition, but to be considered creditable, this ideal had to be applied to its military: "the successful fiscal-military state was a caring fiscal-military state, one that paid attention to and invested in the welfare of its armed forces" (Charters 2014, 4). Disease during this time period was viewed as being the result of disorder in an individual's constitution and environment (Charters 2014). Though disease was not understood in terms of contagious pathogens, this thinking was not fully incorrect, as military environments and provisioning do influence the outbreak and scale of disease. This thinking ultimately meant, "troops remained healthy when commanders paid close attention to the physical and moral state of their men, and provided them regular supplies of fresh provisions and salubrious accommodation. An outbreak of disease among the troops, therefore, pointed to a failure of leadership" (Charters 2014, 4). Such thinking meant reports of disease among military combatants were viewed by the public as being a failure of military officials (administrative failure) and politicians (political weakness) to properly care and provide for their troops (Charters 2014).

Ultimately, the welfare of military combatants took on a wider meaning in the eighteenth century for various reasons. Disease depleted manpower, which could influence success or failure in military campaigns. Additionally, disease was viewed as being the result of disorder, so death of military combatants due to disease was seen as being "inglorious and objectionable," (Charters 2014, 4). Furthermore, reports of military disease "led to recruitment problems, caused friction among colonial and allied civilian populations, engendered doubt in the minds of allied governments and commanders, and were a powerful weapon in the hands of opposition politicians on the home front" (Charters 2014, 4).

For these reasons, the eighteenth century was a time when governments began to pay more attention to the wellbeing of combatants. As previously discussed, some of these attempts, such as increasing and improving rations and provisions, failed due to issues of implementation and corruption; however, some efforts did lead to marginal success. For instance, this century would see wider practice of inoculation. Variolation involves immunizing an individual against smallpox by introducing matter produced by the virus (such as pus) into the individual's body, which then develops immunity after this small exposure. Though the practice had been used for centuries, it gained popularity in Europe during the eighteenth century after Lady Mary Wortley Montague had her daughter inoculated in the presence of the British royal court (Gabriel 2013; McCallum 2008; Riedel 2005). By 1775, Dutch and Prussian armies had voluntary programs for smallpox variolation (McCallum 2008). At the same time, during the American Revolutionary War, General George Washington got approval from the Continental Congress to enact a mandatory program to inoculate new recruits for smallpox (Gabriel 2013; McCallum 2008). Britain did not allow variolation until 1798, but, when made available, the practice was voluntary rather than mandatory (Gabriel 2013).

Naval medicine would also see improvements. Naval military medicine had not become a matter of importance until the fifteenth century, as before this point, most ships stayed close to land and could access aid ashore, but as ships ventured out into open waters for extended periods of time, onboard care became a necessity (Gabriel 2013). The quality of care was rather poor even into the eighteenth century. Due to the rather bleak standards of living aboard ships, the surgeons attracted to the navy were frequently of low quality and had little official training (Gabriel 2013, 101). They were also ill-equipped, as surgeons had to buy their own instruments (Gabriel 2013).

In the eighteenth century, James Lind published several works detailing improvements that could be made to improve the health of seamen: *A Treatise of the Scurvy* (1754), *An Essay on the Most Effectual Means of Preserving the Health of Seamen in the Royal Navy* (1757), and *An Essay on Diseases Incidental to Europeans in Hot Climates* (1768) (Brown 2011; Gabriel 2013). Lind's recommendation for a program of examination and quarantine for impressed sailors was adopted in the

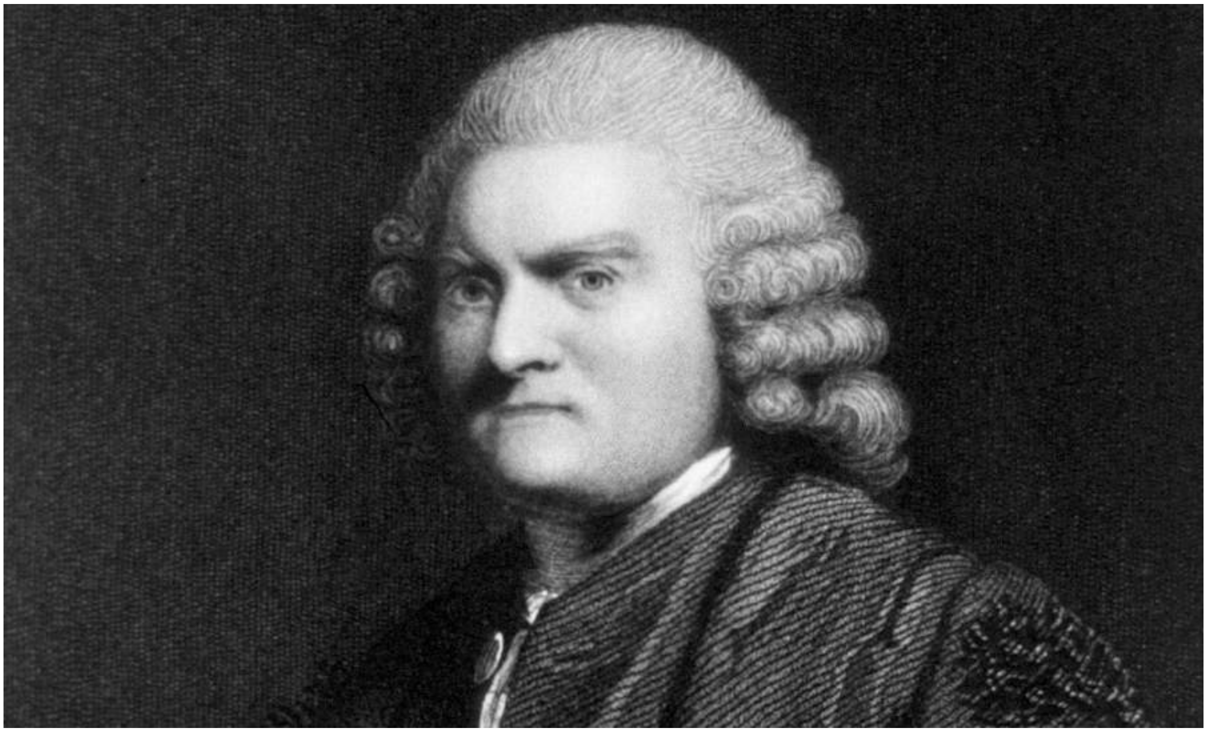
British Royal Navy in 1781, but his other recommendations (such as use of lime juice to prevent scurvy, avocation for better diets, and regular issue of soap to sailors) were largely ignored (Brown 2011; Gabriel 2013; Lind 1754). Though Lind was ignored, Gilbert Blane, Commissioner on the Sick and Wounded Board of the Admiralty for the British Royal Navy, had more political influence and advocated for many of the same recommendations in his book *Observations on the Diseases of Seamen* (1785); Blane's work saw that lime juice and soap were provided and that areas aboard ships were set aside for use as sick bays (Blane 1785; Gabriel 2013).

On land, Sir John Pringle's (see **Fig. 24**) work *Observations on the Diseases of the Army* (1753) encouraged that military facilities focus more on sanitation as a means of reducing disease (Gabriel 2013; McCallum 2008). For example, Sir John Pringle suggested that better ventilation be provided in barracks, naval vessels, and hospitals (McCallum 2008). Several others in the eighteenth century made similar suggestions to improve military hygiene: Richard Brocklesby's *Economical and Medical Observations* (1764), Hughes Ravaton's *Chirurgie d'armée* (1768), and Jean Colombier's *Code de médecine militaire* (1772) (Gabriel 2013). Once again, despite being pointed out on a number of occasions, these suggestions were largely ignored (Gabriel 2013). As a result, disease remained the number one killer of military combatants by the end of the eighteenth century.

Poor sanitation and hygienic practices for surgery commonly killed combatants as well, as wounds frequently became infected. Pringle coined the term 'antiseptic' in the 1750s. Antisepsis is now understood as the use of chemicals to stop the growth of bacteria to reduce the risk of wound infection (McCallum 2008). Before germ theory, it was the use of chemicals to reduce infection, though the cause of the infection was not yet understood. Antisepsis practices are ancient, as oils, wines, and honey have been used to reduce infection in wounds by the Greeks, Romans, and ancient Egyptians, but Pringle's coining of the term 'antiseptic' was accompanied by experiments on decomposition that ultimately proved its value (Gabriel 2013;

McCallum 2008). Despite this evidence, general use of antiseptic practices did not occur until the latter nineteenth century.

Figure 24: Sir John Pringle, author of *Observations on the Diseases of the Army* (1753). Source: Royal College of Physicians of Edinburgh n.d.



The eighteenth century "laid the methodological groundwork for the progress in medical knowledge and clinical technique that was to follow in the next two centuries" (Gabriel 2013, 88). This century saw increased governmental concerns over the prevention of military epidemics that translated into changes in policy, though these policies were often ignored or poorly enforced and, as such, did not reduce the occurrence of military epidemics. By the end of the eighteenth century, medical practice had been firmly established as a scientific discipline, which would further increase the importance of military medicine leading into the nineteenth century.

Nineteenth & Early Twentieth Century

Though it took the entirety of the century to achieve, the nineteenth century would produce professional and efficient systems of military medicine (Gabriel 2013; McCallum 2008). Motivating this change were tactics and technological advancements that produce high fatality rates. In spite of increasingly lethal weaponry, disease remained the predominant killer of military combatants (see **Table 5**) (Gabriel 2013; McCallum 2008).

Table 5: Until the twentieth century, disease killed more combatants than battle wounds. Exceptions to this pattern have been highlighted in **bold**. Source: adapted from Smallman-Raynor & Cliff (2004, 34 [a]).

Disease & Battle Fatalities from Nineteenth Century Conflicts					
WAR	FORCE	MAJOR DISEASES	NUMBER OF DEATHS (000's)		
			Battle Wounds (a)	Disease (b)	Ratio (b) : (a)
French Revolution and Napoleonic Wars (1792-1815)	British Army	Typhus, dysentery, fevers	25.6	192.9	7.6:1
Mexican War (1846-1848)	US Army	Dysentery	1.5	11.0	7.3:1
Crimean War (1853-1856)	Allied Army	Dysentery, cholera, typhus, fevers, scurvy	24.9	95.1	3.8:1
	Russian Army		35.7	37.1	1.0:1
Italian War (1859)	French Army	Typhoid, dysentery, malaria	**5.5**	**2.0**	**0.4:1**
American Civil War	Union Army	Typhoid, malaria, typhus, dysentery, measles, smallpox	91.0-110.0	184.0-224.6	1.7-2.5:1
	Confederate Army		72.3	120.0	1.7:1
Austro-Prussian War (1866)	Prussian Army	Cholera, typhoid fever	4.5	6.4	1.4:1
	Austrian Army		8.9	19.0	2.1:1
Franco-Prussian War (1870-1871)	German Armies	Smallpox, dysentery, typhoid, typhus	**26.5**	**14.6**	**0.5:1**
Russo-Turkish War (1877-1878)	Russian Army	Typhus, typhoid fever	34.7	81.1	2.3:1
Cuban and Spanish-American Wars (1895-1898)	Cuban Forces	Smallpox, yellow fever, typhoid	**5.2**	**3.4**	**0.7:1**
	Spanish Forces		9.4	53.4	5.7:1
	US Forces		0.7	5.5	7.9:1
Great Boer War (1899-1902)	British Army	Typhoid	7.5	14.4	1.9:1

War was frequent in the nineteenth century. The French Revolution, War of 1812, Napoleonic Wars, Crimean War, Mexican War, American Civil War (which is often considered the first truly modern war), and Franco-Prussian War were some of the larger conflicts of the century, but they were far from the only conflicts (Gabriel 2013; McCallum 2008; Smallman-Raynor & Cliff 2004 [a]). The frequency of war provided the stimulus, as well as the knowledge (opportunity to practice and experiment), needed for military medical practice to flourish.

Though the eighteenth century had seen the creation of military medical systems of some proficiency, nineteenth century systems would evolve to be highly efficient. At the beginning of the nineteenth century, surgeons, physicians, and barber surgeons all remained separate and competing professions, which lead to a lack of cohesion in the provided care to military combatants. Leading up to this century, surgeons were often looked upon with suspicion and viewed as being less reliable than physicians; though physicians had some rather dangerous treatment methods for disease, they were favored over surgeons, who were perceived as being eager to hack away at one's body (Gabriel 2013; Hudson 2007 [a]). Such thoughts would disappear by the end of the nineteenth century; barber surgeons would disappear, replaced by properly trained surgeons, who were now considered respectable members of the medical profession (Gabriel 2013). This professionalization of medical professions was reflected in the elevated status of military medical practitioners. Where military surgeons and physicians previously had some influence in military administration, their rank was often low, but their status would be elevated in the nineteenth century.

Early in the century, suppuration of wounds was accepted as being inevitable, some even considered it to be beneficial to the healing process (Gabriel 2013; Manring *et al.* 2009). New discoveries and realizations about bacteriology in the nineteenth century would change these ideas and lead to full enforcement of antiseptic (actions used to kill bacteria already present in a wound to prevent infection) and aseptic (actions used to prevent bacteria from ever entering a surgical wound) practices (Gabriel 2013; Manring *et al.* 2009; McCallum 2008). At the beginning of the century, the miasmas theory of disease was still widely accepted (Gabriel 2013). While Antoni van Leeuwenhoek's discovery of small organisms ('animalcules') had occurred in the seventeenth century, convincing evidence that these organisms produced and contributed to the spread of disease was not accepted until the late nineteenth century.

In the 1860's, Lord Lister conducted studies on British hospital mortality rates due to infections, finding "infection carried off 80 percent of the patients who underwent amputation of the femur and 50 percent who underwent amputation of the tibia in the Male Accident Ward at London Hospital" (Gabriel 2013, 137; McCallum 2008). Just preceding this time (between1857 and 1863), Pasteur had conducted experiments that proved fermentation and putrefaction were caused by microorganisms; later, in 1878, Pasteur would use his findings to support germ theory (the theory that disease is caused by microorganisms) (Gabriel 2013; McCallum 2008). Lord Lister, who accepted Pasteur's evidence for germ theory, set out to discover means of killing bacteria to prevent infection of wounds (Gabriel 2013; McCallum 2008). In 1865, Lord Lister covered compound fracture wounds in cloths soaked in carbolic acid, which successfully prevented infection; he presented his finding at University College London in 1866 and in the 1867 publication *On the Antiseptic Principle in the Practice of Surgery* (Gabriel 2013; Lister 1867; McCallum 2008). Lord Lister's findings illustrated the positive results of antiseptic and aseptic practices and, upon enforcing these practices at his hospital, surgical mortality rates from infection were reduced from 45% to less than 1.5%; however, wider acceptance took time, as acknowledgement of Lister's findings would mean one would also have to accept Pasteur's support of germ theory, which was not seen as being fully supported (Gabriel 2013; McCallum 2008).

Findings by Pasteur that supported germ theory were further validated by Robert Koch's 1880 publication *Investigations into the Etiology of Traumatic Infective Diseases*. Koch's research on anthrax bacillus was able to clearly demonstrate that microorganisms caused specific diseases and established a methodology for testing the causative nature of disease-specific agents (Gabriel 2013; Koch 1880). Though germ theory had originally been suggested by Girolamo Fracastoro in 1546, acceptance of germ theory did not occur until the findings of Lord Lister, Pasteur, and Koch had been cumulated (Gabriel 2013; Garrison 1922; Gerstman 2003; Manring *et al.* 2009). In the military medical profession, germ theory, along with antiseptic and aseptic practices, did not begin to gain firm acceptance until the 1870s. Implementation of antiseptic and aseptic practices in Germany occurred during the Franco-Prussian War (1870 – 1871) with great results. Despite German success, the U.S. Army did not accept antiseptic surgery as an official practice until 1877, but even with acceptance it took time to gain momentum (Gabriel 2013; Rostker 2013). In 1884, only 5 of 179 of U.S. Army surgical procedures employed antiseptic surgery and, in 1886, 60 out of 168 surgical procedures employed antiseptic surgery; even by the Spanish American War (1898), there were some issues providing the equipment and laboratories needed to properly train military surgeons in this technique (Rostker 2013). By the 1880's, antiseptic surgery had also gained firm acceptance in the British military (Goodrich 1885). Acceptance of germ theory obviously had a great impact on the understanding of disease causality and transmission, so its late acceptance meant disease remained the primary cause of death in military conflicts of the nineteenth century.

Disease truly was an overwhelming problem for nineteenth century militaries. The problem was not wholly due to poor understanding of bacteriology and disease aetiology. Disorganized military medical systems also contributed to disease lethality. France serves as a rather apt example of poor beginnings. Toward the end of the eighteenth century, the French Revolution would see the medical service influenced by differing political fractions, producing near-constant disruption to its organization, which resulted in a rather disorganized system run by fewer surgeons for larger armies leading into the nineteenth century (Gabriel 2013). Napoleon did little to help the situation, as he did not believe a permanent military medical service was necessary (Rostker 2013). The constant assembly and dismantling of medical services made it impossible to establish a stable system of military medicine. The quality of surgeons also suffered under Napoleon's chaotic medical administration; Napoleon's chief surgeon Baron Percy called the military surgeons *chirurgiens de pacotille* ("slop-shop surgeons") (Brice & Bottet 1907; Gabriel 2013). The result of this disorganization is evident in the horrendous figures for hospital deaths for wounds and disease during the Napoleonic Wars: "of the 4.5 million soldiers who served in the revolutionary and Napoleonic armies, 2.5 million died in hospitals from wounds and disease…When the sick and wounded were transported home, the mortality rate in transit reached 41 percent" (Gabriel 2013, 141). During his 1812 campaign, Napoleon's force began with 533,000 men, but the toll of disease and cold would see only 40,000 return after the retreat from Moscow, which included high fatalities of military medical officers; 63% of medical officers were lost due to battle, disease, cold, and capture (Gabriel 2013, 141). One exception to the *chirurgiens de pacotille* was Dominique-Jean Larrey, who was Napoleon's medical director and chief surgeon. Like Percy, Larrey attempted to convince Napoleon of the necessity of a permanent military medical service (arguments which failed), but he was also an extremely influential, active, and interesting military surgeon; he was wounded three times during his participation in 26 campaigns (60 battles, 400 engagements) and wrote of his experience in *Memoires de Chirurgie Militaire et Campagnes* (1812) (Gabriel 2013; Larrey 1814). Larrey realized the poor quality of recruited medics and went about establishing training sessions in anatomy and surgery to provide education to medical recruits (Gabriel 2013; Larrey 1814). He also issued instructions for sanitation and would help establish an ambulance corps (Gabriel 2013).

British medical services during the Napoleonic wars were no better. The Army Medical Board (a small administration of surgeons and physicians) was responsible for administrating military hospitals and were expected to provide a surgeon and surgeon's mate to each regiment. Regimental officers had ultimate command of medical resources (doctors, materials, hospitals, transport, etc.) and would frequently order that medical supplies/personnel be kept to a minimum during peace time; this meant the military was ill prepared when conflicts occurred (Gabriel 2013). Training of military surgeons was limited and they were still viewed as inferior to physicians at this early stage of the nineteenth century (Shepherd 1991). The British also had issues providing a sufficient number of medical practitioners. When the French had trouble supplying medical practitioners to their regiments, they turned to impressment, but England merely lowered its standards for admitting people into military medical service, meaning young and largely inexperienced medical men were admitted (Gabriel 2013).

The British military did not have official sanitary codes, so regulation of field hygiene practices was left to the unit commander (Gabriel 2013). As medical practitioners usually occupied lower military rank, it was not uncommon for their suggestions to go unheeded by military commanders, causing hygienic practices to be haphazardly conducted; unsurprisingly, disease in British military camps thrived. For instance, in April 1809, 40,000 British troops were sent to Walcheren, Holland to attack Napoleon's naval base at Antwerp, but troops were forced to reside in swamps. In just a few weeks, half of the army was ill and 4,000 were dead from disease (Gabriel 2013; Shepherd 1991). This campaign resulted in some reform. The members of the Army Medical Board were replaced, as the failure at Walcheren was viewed as being the result of their poor planning and ability to adapt (Gabriel 2013; Shepherd 1991). One of the new members was James McGrigor, who was assigned to Maj. Gen. Arthur Wellesley, Duke of Wellington during the Peninsular War (Gabriel 2013). When McGrigor arrived, he quickly set about making changes; he "overhauled the medical supply system and standardized the flow of medical supplies to the front. He also instituted regular procedures at the hospitals, appointing inspection teams to enforce hygiene measures to reduce disease. He introduced weekly medical inspections for the rank and file and a sanitary code for the regiments" (Gabriel 2013, 149; McGrigor 1861; Shepherd 1991). Though his changes were sound, they did not expand outside of the Peninsular War. McGrigor again made medical reforms at Waterloo, but, once again, demobilization would see many of these reforms fall apart. McGrigor did succeed in establishing a military medical school and, along with Henry Marshall (who was considered a 'soldier's friend' for his special attention towards the care of common soldiers), "attempted to institutionalize the practice of regular medical reports on the health status of the army, but this reform came to fruition only after the Crimean War [1853 -1856] had proven yet another medical disaster for the British" (Gabriel 2013,151; Shepherd 1991).

During the Crimean War (1853 – 1856), the British had 2,255 killed in action and 12,225 dead as a result of disease (Gabriel 2013). The close quarters of trench warfare and long sieges, in addition to system failures, contribute to the high disease fatalities (Gabriel 2013). At the start of the war, Andrew Smith had only recently taken over as the Medical Department's Director General after McGrigor retired in 1853 (Shepherd 1991). When war broke out, the Medical Department was very small, consisting of 225 medical officers, of which, only 52 had medical degrees (Gabriel 2013; Shepherd 1991). Smith had been watching events carefully and, anticipating war, had begun to plan accordingly (Shepherd 1991). Smith was able to make a report of his inventory and needs to the War Office within 24 hours of being told to prepare for a campaign (Shepherd 1991). Though carrying out his duties to the best of ability, Smith had little executive power, which meant he was not privy to information about future movements, which forced him to make arbitrary and retroactive plans throughout the war (Shepherd 1991). Eventually, the British military had 1,000 medical physicians, but this was not sufficient (Gabriel 2013). Further adding to disease troubles were poor hygiene and improper provisioning, but the War Office often failed to meet requests for improvement in these areas; for example, requests to address the overcrowded conditions of hospitals and to provide practical clothing to troops were denied (Nightingale 1863; Shepherd 1991).

Feeling ignored by the War Office, medical officers presented their problems to the public through publications like *The Lancet* (see **Fig. 25**) and *Medical Times and Gazette*, which lead to public outcry and successfully caused parliament to make reforms; unfortunately, these reforms were too late to make any major impact during the Crimean War (Gabriel 2013; Shepherd 1991). The most significant reform ordered that, be it a time of peace or conflict, a regular strength medical corps of 280 individuals for every division of 10,000 men be established (Gabriel 2013). Furthermore, in 1878, more rank privileges were provided to army medical officers, but obtainment of medical resources still relied upon permission of military field commanders (Gabriel 2013).

Figure 25: This excerpt from the 21 October 1854 issue of *The Lancet* critiques the actions of the British Army Medical Service. Source: Anon 1854, 338.

> "It has become painfully evident that the medical arrangements for the army of the East have been most inadequate, both as regards the provision against cholera and epidemic disease, and the attendance upon the wounded in battle. We quite agree with Mr. GUTHRIE…that the care of the sick and wounded of our fleets and armies, ought not, in any degree, to be left to the spontaneous philanthropy of the public. These things should be matters of foresight and previous arrangement, or our sick must suffer from graver horrors than even those necessarily incident to war and slaughter… the ridiculous regulations of the Army Medical Service have rendered it impossible to send out the full complement of medical officers with the troops engaged in the East. Our men have died in numbers of their wounds on the field of battle, or crowded, without attendance, in transport ships and hospitals, because a sufficient number of qualified medical men could not be found … We consider that a Commission of Inquiry ought to be issued forthwith, to ascertain with whom rests the real responsibility of the grave mistakes which have been committed."

Across the Atlantic Ocean, American conflicts faced many of the same problems with disease due to poor sanitation practices, limited medical training on part of medical servicemen, and systemic issues. When the War of 1812 began, the U.S. Army was very short on medical staff and did not have a centralized authority to oversee the handling of medical assets (Gabriel 2013). In 1818, congress created an official medical corps and appointed Dr. Joseph Lovell as the first Surgeon General, who served until 1836 (Gabriel 2013; Pilcher 1905). By the Mexican-American War (1846 – 1848), there were 7,000 men serving in the medical corps, which included 71 medical officers (including one Surgeon General), but this increased to 115 officers during the war, though this was still insufficient for the 100,182 man army (Arnold 2015; Gabriel 2013 161). Disease was rampant during this conflict, with approximately 10,790 deaths due to disease and 1,458 killed in action (Arnold 2015; Gabriel 2013; McCallum 2008). Not long after this conflict, the American Civil War (1861-1865) occurred.

As had been the case in Europe and the Mexican-American War, disease was the number one killer, "the chance of a Civil War combatant not surviving the war was 1 in 4 compared to 1 in 126 for the Korean War. Of the Union dead, 3 of every 5 died of disease; in the Confederacy, 2 of every 3" (Gabriel 2013, 163). Both armies in the Civil War relied on volunteer recruitment in the early war, but medical examinations were not carried out with much thoroughness, so many recruits were not physically fit for duty (Bollet 2002; Gabriel 2013). The indiscriminate admission of men early in the war was due to quotas and the belief that war would be over quickly, meaning men only needed to be capable of marching and carrying a gun (Bollet 2002). The war was not short; it would last four years and, to date, remains one of history's bloodiest wars. As time progressed, both Union and Confederate armies developed more strenuous systems of medical examination for recruits. Even so, there were other issues noted with recruitment.

Combatants were either from urban or rural areas and were generally of lower socioeconomic status. It is often assumed that men from urban backgrounds would be less fit for duty, as they were frequently exposed to disease in crowded city environments and were less physically active than 'farm-boys' (Bollet 2002; Hart 1913). The American Civil War illustrated that this assumption is not necessarily true, as many military surgeons, like Dr. Albert Gaillard Hart (Surgeon of the 41st Regiment Ohio Volunteer Infantry), noted that rural recruits were worse off than their urban comrades. In part, this was due to immunity. To be considered 'urban,' one came from a community of 2,500 or more people, so rural recruits truly came from *very* secluded areas (Bollet 2002). As such, rural recruits were often unexposed to childhood diseases common to urban recruits, causing them to quickly contract conditions such as measles upon entering the military; on the other hand, their urban counterparts had been exposed and become immune to these conditions as children, which resulted in a more robust immune system (Bollet 2002; Smallman-Raynor & Cliff 2004 [a]). In addition to immunity, the urban recruits seemed to be less affected by the challenges presented by the military lifestyle, as the challenges did not greatly differ from those faced periodically in their pre-war lives. Dr. Hart writes:

> It was at first supposed that men from the rural districts, with their regular habits and well-developed muscles, would prove enduring soldiers, while the city recruits of less robust build, and with more or less irregular habits, would fare ill. The recruits were a great surprise; it proved that steady farm work had not developed good legs for drilling and marching. On the other hand, the man from the city was less affected by irregular meals, labor, and sleep. He was better prepared to look out for his own comfort on the field, and proved to have more adaptation to the exigencies of the service. My regiment was made up chiefly of young men from farming communities, whose most arduous night work had consisted in coon hunting (Hart 1913, 239).

In addition to poor recruitment habits in the early war, the Union Medical Department was ill prepared for war; in 1860, there were 30 surgeons and 38 assistant surgeons, of which, more than 20 surgeons and assistant surgeons resigned to join the Confederacy (Bollet 2002; Gabriel 2013; McCallum 2008). Additionally, the Union Surgeon General's Office was under weak leadership. Eighty-year-old Thomas Lawson was the Union Surgeon General at the beginning of the American Civil War (Bollet 2002; Gabriel 2013; McCallum 2008). He was a man of poor health and was fixated on frugality; for example, he considered the purchase of medical texts for field surgeons an unneeded extravagance (Bollet 2002; Gabriel 2013). When he died May 15, 1861, his replacement, Clement Finley was also fixated on frugality and was only accustomed to meeting the demands of small frontier army posts, "his lack of vision is illustrated by his decision to wait for a battle before ordering necessary medical supplies and dressings" (Bollet 2002, 14).

Much as had occurred in the U.K. during the Crimean War, public outrage over the state of poor military treatment of combatants would lead to reforms. The U.S.

Sanitary Commission was founded in response to public outrage and became a fierce and successful advocate for reform of the Union Surgeon's General Office, but their efforts were originally met with much resistance (Bollet 2002; Gabriel 2013). In December 1861, the editor of the popular *New York Tribune*, Horace Greeley, wrote of Finley's incompetence, citing his refusal to establish military hospitals in South Carolina on the grounds that the warmer climate made them unnecessary and also challenged that the Medical Bureau was wasting its time fighting the Sanitary Commission when it should be battling its "official enemies typhus, malaria, and smallpox, defective ventilation of tents, imperfect drainage of camps, and lazy regimental surgeons" (Bollet 2002, 14; Schroeder-Lein 2008). Such editorials led Finley to allow the Sanitary Commission to assist, but he would only allow them leeway in aiding volunteer regiments, leaving regular army troops strictly under the care of the Union Surgeon's General Office. Nevertheless, the Sanitary Commission made beneficial medical changes that would result in an ambulance service and hospital improvements (Bollet 2002; Gabriel 2013).

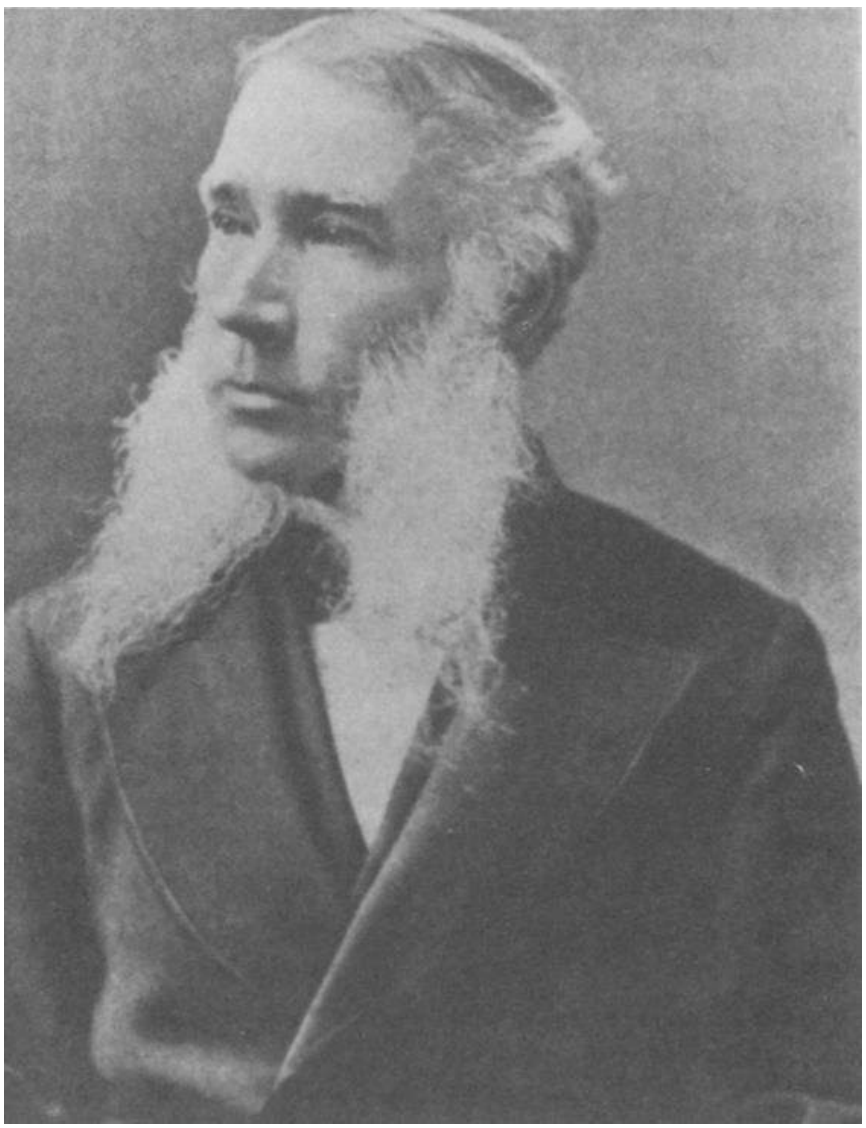
Finley was eventually dismissed based on pressure from the Sanitary Commission and was replaced in April 1862 with William Hammond, who improved the system for reporting medical data. Due to personal conflicts with government superiors, Hammond was also replaced in 1863 by Joseph Barnes. Joseph Barnes would ultimately sort out the remainder of the administrative issues with the Medical Bureau. Though the Union Medical Department had a rough start, by the end of the war an efficient medical system capable of handling mass casualties, setting sanitation standards, and regulating hospitals was founded (Bollet 2002; Gabriel 2013). In addition to an efficient medical system, the records kept by the Union Army were excellent, resulting in the publication of a post-war six-volume U.S. government publication *The Medical and Surgical History of the War of the Rebellion* (1870-1888); with its detailed figures, descriptions, photography, drawings, and detailed literature review, Europeans considered this publication to be America's first major contribution to academic medicine (Bollet 2002; Gabriel 2013).

Meanwhile, the Confederate Surgeon General's Office had brief troubles with poor leadership until former U.S. Army physician, Samuel Preston Moore (see **Fig. 26**), was appointed to the office July 30, 1861 (Bollet 2002; McCallum 2008). Moore would serve throughout the war. He was a stickler for paperwork and adherence to protocol, but was also known for listening and acting accordingly to complaints and concerns (Bollet 2002; Cunningham 2014). Overall, Moore was an efficient leader, especially in light of challenges such as the Union Blockade, which limited access to supplies; Moore "directed a successful effort to develop substitutes for scarce pharmaceuticals from the indigenous flora of the South" (Purcell & Hummel 1992, 361; Bollet 2002; Gabriel 2013; McCallum 2008). As with the Union Army, the Confederate Army kept thorough medical records during the war, but these records were lost due to the burning of the Confederate capitol of Richmond, Virginia; what little data survived was included in the *Medical and Surgical History of the War of the Rebellion* (Bollet 2002).

Sanitation was a concern during the American Civil War, but, similar to Europe, the power of medical officers to enforce good practices was limited. Army medical practitioners were ultimately under the rule of commanding officers, who often viewed sanitary regulations as being unnecessary, leading them to ignore or improperly implement suggested procedures (Bollet 2002). As the war went on and disease flourished, commanders began to take sanitation more seriously, but even so, troops did not always adhered to regulations (Bollet 2002).

While the U.S. established a rather efficient medical system by the end of the Civil War, European systems still left much to be desired. France, Britain, and the U.S. would dedicate the first quarter of the nineteenth century to establishing surgery as a legitimate discipline, but Russia and Germany lagged behind in this development until the middle of the century (Gabriel 2013). The low status of surgeons in mainstream Germany did not apply to universities, who first explored the field with academic rather than practical interest (Gabriel 2013). This order had a distinct advantage, as university surgeons and physicians largely focused on empirical evidence and experimentation, making German medical practitioners more willing to accept and act upon new scientific discoveries. The best example of this attitude was Germany's ready acceptance of Lister's evidence favoring antiseptic and aseptic practices; they were the first country to implement use of steam sterilization, surgical face masks, gowns, and sterile operating rooms (Gabriel 2013).

Figure 26: Samuel Preston Moore left his position as a U.S. Army physician to join the Confederacy. He became the Confederate Surgeon General and served the duration of the American Civil War. He kept meticulous records and founded the *Confederate States Medical and Surgical Journal*. Source: Purcell & Hummel 1992, 362.



Movement out of universities into the military occurred after Otto von Bismarck unified Germany. Previously, the fragmented state made it difficult to establish a professional national army, but unification made this type of army possible (Gabriel 2013). More organized militaries equated to better military medical services, which, in addition to nationalistic pride, encouraged medical practitioners to leave universities in favor of practicing their profession in the military (Gabriel 2013). In addition to quality medical practitioners, by the Austro-Prussian War (1866), Germany had founded an efficient and adequately staffed army corps, which was likely inspired by the military medical system established during the American Civil War (Gabriel 2013). Though the organization of the medical system remained much the same, tweaks to surgical and field hygiene/sanitation were made in light of Lister's and Koch's findings during the Franco-Prussian War (1870-1871); systematic vaccination for smallpox was also employed (Gabriel 2013; McCallum 2008). The Franco-Prussian War was one of the few wars pre-twentieth century to have fewer fatalities due to disease than combat. Though this success may have been due to the quality of their military medical system and appreciation for bacteriology, success likely had more to do with the short duration of the Franco-Prussian War; army camps have long been a location where infectious diseases have thrived, but during the Franco-Prussian War, German troops were not afield for extended periods of time and were frequently stationed near well-established hospitals where quality care could be provided (Harvard 1914; McCallum 2008; Seaman 1904).

The nineteenth century illustrates that successful care of military combatants is largely reliant on quality medical knowledge being used in tandem with a well-organized and efficient system of military medicine; failure on either part can produce poor results (Gabriel 2013). During the Franco-Prussian War, Germans provided Europe a template for a successful military medical system, which was emulated by most European nations by the end of the century; however, improper implementation of these sophisticated systems continue to be a hindrance. The Boer War (1899-1902) made it evident that disease remained undefeated as the primary killer of military combatants. As was evident in **Table 5**, disease outnumbered combat fatalities among British troops, with typhoid and dysentery (traditional 'crowd' diseases associated with unsanitary environments) being of prominent concern (Gabriel 2013; Smallman-Raynor & Cliff 2004 [a]). At the start of the Boer War, the British Army Medical Corps was new (a year old), understaffed, and unprepared; they spend much of the first year attempting to sufficiently augment their staff (Gabriel 2013). Making matters worse, when established, the British Army Medical Corps included sanitary officers, but their role was seen as unnecessary by everyone *except* members of the medical service. Despite their protest, the post was abolished prior to the Boer War (Gabriel 2013). Sanitation regulations remained in place, but without officers to enforce their usage, field sanitation was left to unit commanders who (as in previous conflicts) ignored regulations; for instance, water barrel carts and individual water bottles were to be routinely cleaned in addition to water supplies being boiled before use, failure to carry out these tasks was common, leading to rampant bowel infections during the Boer War (Gabriel 2013; McCallum 2008). Vaccinations for typhoid fever were provided, but participation was not mandatory, so most went unvaccinated due to fear caused by unfounded rumors that the vaccination caused reduced virility (Gabriel 2013). The unprepared medical service working in tandem with poorly implemented measures for disease prevention resulted in approximately 14,000 disease fatalities to 6,000 killed in action during the Boer War (Gabriel 2013; McCallum 2008). This was certainly a poor start to the twentieth century.

Their poor performance finally brought about successful reforms. Training standards for the British Army Medical Corps were increased and special focus was placed on teaching the importance of field sanitation procedures to officers. Officials took action to ensure their medical officers would no longer ignore military sanitation policies by requiring them to pass regular examinations in sanitation before being eligible for promotion (Gabriel 2013; McCallum 2008). Increased focus and serious enforcement of military sanitation policies became the norm throughout Europe and the U.S. in the early twentieth century.

Early twentieth century medical advancements, in addition to increasingly lethal weapons, would ensure that disease fatalities no longer outnumbered those of combat (see **Table 6**). By World War I (1914-1918), rates for many of the usual diseases (enteric fevers, cholera, typhus, and smallpox) had been greatly reduced and, on the whole, disease fatalities were far lower (Gabriel 2013; McCallum 2008). Though disease fatalities were lower overall, dysentery and malaria continued to be an issue and new diseases, like trench foot, became problematic (Gabriel 2013; McCallum 2008).

Table 6: By World War I, it was no longer typical for disease fatalities to exceed those caused by combat. Source: adapted from Smallman-Raynor & Cliff (2004, 34 [a]).

Disease & Battle Fatalities from Early Twentieth Century Conflicts					
WAR	FORCE	MAJOR DISEASES	NUMBER OF DEATHS (000's)		
			Battle Wounds (a)	Disease (b)	Ratio (b) : (a)
World War I (1914-1918)	All Forces	Various: Typhus, typhoid, dysentery, malarial, influenza, cholera, fevers	8,000.0	3,115.0	0.4:1
World War II (1939-1945)	All Forces	Various: Typhus, typhoid, dysentery, malarial, influenza, cholera, fevers	16,933.0	2,363.0	0.1:1
Vietnam War (1956-1975)	U.S. Forces	Malaria	45.9	10.0	0.2:1

Nonlethal diseases, such as venereal diseases, continue to be periodically common even in present day militaries (Gabriel 2013; Gaydos *et al.* 2015; Thompson *et al.* 2005). Traditionally lethal diseases, such as dysenteric diseases, also continue to affect military combatants in the twenty-first century, but attention toward prevention and advancement in treatment options (including antibiotics and vaccines) from the late nineteenth century onward reduced their overall occurrence and mitigated their lethality (Connor & Farthing 1999; Connor & Gutierrez 2013; Connor *et al.* 2013; Engen & English 2016; Gabriel 2013; Porter *et al.* 2015; Porter *et al.* 2011; Putnam *et al.* 2006; Sanders *et al.* 2004). Despite modern efforts to alleviate or eliminate infectious disease, the nature of the military lifestyle (discussed later in this chapter) means disease will remain an issue into the future. This is illustrated by Sgt. Michael Volkin, author of *The Ultimate Basic Training Guidebook*, who wrote an online article titled 'The Top 10 Things to Expect When Preparing for Boot Camp,' that lists number ten as, "expect to get sick…basic training is too crowded and too fast paced for your body to get enough rest. Your body will be stressed for a long period of time, thus causing your immune system to break down." Indeed, if one dares to bring up the unseemly topic of disease in relation to deployments with a modern day military combatant (as the current researcher has done on numerous occasions), one should be aware that 'getting sick' is exceedingly common and one will be regaled with exemplary (but not wholly pleasant) tales about said topic. Though outbreaks of infectious disease remain a problem in modern military groups, effective medical treatment is readily available, so these events are rarely deadly; however, as the historiography section has made clear, the same cannot be said for historical combatants (Cook 2001). While it can be said that the connection between the military lifestyle and infectious disease continues in spite of modern medical knowledge, the scale and the mortal impact were far greater among past combatants.

2.1.2 Consideration of Bias

The historiography section provides context for the information provided in the remainder of this chapter. The following sections explain the specific circumstances that make certain infectious diseases common among military combatants. This discussion includes consideration of statistical figures and living circumstance described in historical documentation. Though these documents can provide valuable insight, there are some biases and limitations that must be considered.

Military medicine has been practiced for thousands of years, but it was not always a formal venture with detailed recording. For example, in the United Kingdom, "the most notable statement to be made about British naval and imperial medicine prior to the 1680s is that it scarcely existed in print. There were numerous practitioners - sea surgeons, army surgeons and physicians, and colonial 'doctors' - but strikingly little publication" (Alsop 2007, 24). This has already been alluded to in the historiography section, as military medicine did not gain momentum as a proper discipline until the eighteenth century.

Time and changing perspectives can also be an issue. Older documents do not always survive into the present, reducing the number of resources available. For instance, there are far more military medical texts from the seventeenth century onward than there are from the ancient Greeks and Romans. Of the surviving documents, some can be difficult to interpret due to differing perspectives between the historical author and the modern reader; older documents are often missing contextual information and occasionally use terminology that has either lost its meaning or has developed new meaning over time (Mitchell 2011). Furthermore, older documents must often be translated, meaning information can literally be lost in translation; this concept is illustrated by the misinterpretation of Galen's ideas in relation to encouragement/determent of wound suppuration between the Roman Empire and the Middle Ages (Gabriel 2013; Mitchell 2011).

Though this sounds rather bleak, reliable resources do exist, especially from conflicts of the eighteenth century onwards. As discussed in the historiography section, this point in history marks the time in which medical practice began to develop its footing as a scientific field; regular publication of medical documentation specific to military medicine began in the late seventeenth century and the first military medical schools and periodical journals were founded in the eighteenth century. This scientific understanding and approach to medicine mark the beginning of modern medical practice, so the context of these works can be reasonably well understood by modern readers. As such, the problems previously mentioned primarily pertain to documents older than those considered for this project, but there are other biases worth considering in the documents used for this research.

It has largely been accepted that disease rates have been high in historical military groups, with much of the evidence coming from military medical text describing outbreaks; however, the statistics reported in many of these texts may not be an accurate reflection of true figures. In the case of military medical reports made to governments by military medical officials, such as the *Medical and Surgical History of the British Army which Served in Turkey and the Crimea…* and the *Medical and Surgical History of the War of Rebellion,* the statistics are noted by the authors to be as accurate as possible, but even they admit that certain diseases, like dysentery, were probably more common than their reports suggest. One reason conditions may have been underestimated is due to issues of recording. For instance, during the American Civil War, some conditions would have been handled informally during "sick call/surgeon's call" or have been self-treated (Bollet 2002). In these situations, cases went unrecorded because only those who were admitted to the hospital or were relieved from duty were recorded in the medical statistics, which would have led to underestimated figures in documents like *The Medical and Surgical History of the War of the Rebellion* (Bollet 2002). Historical methods of diagnosing disease would have also attributed to underestimation. Before medical imagery and genetic/microbial/biochemical testing, medical diagnoses were largely based on pattern recognition. Undoubtedly, poorly expressed or atypical cases would have gone unrecorded, been misdiagnosed, or been refered to with exceedingly general (meaningless) terms like 'remittent fever' (Bollet 2002).

In addition to technical biases, some conditions (like gonorrhoea) may have been underestimated in official documents for political and social reasons. Historically, the negative stigma associated with venereal diseases was quite strong, as sufferers were assumed to have participated in immoral behaviour of a sexual nature (Levine 2003). In the eighteenth century British military, individuals who were found to be infected with venereal diseases were punished via fines in order to 'repress immorality' (Marshall 1846, 61). A combatant could be fined anywhere from 5 to 10s depending on the grade of disease (Marshall 1846). This was a rather large sum for a soldier that only earned 3 to 4s per week, so "soldiers, as might be expected, did everything in their power to evade the summary jurisdiction of the Surgeon, whose fine or punishment was a much-dreaded penalty" (Marshall 1846, 61). If individuals did not seek treatment as a means of avoiding punishment or stigma, cases would have gone unrecorded, again contributing to underestimation in figures.

Despite the limitations of documents like *The Medical and Surgical History of the British Army which Served in Turkey and the Crimea* and *The Medical and Surgical History of the War of the Rebellion*, the effort placed into collecting and compiling accurate data for these publications can be considered nothing but impressive. The faults of these official documents often lean towards issues of underestimation rather than overestimation of figures. As such, these documents can be viewed as providing a modest picture of military diseases.

Less formal reports of disease, such as those written in letters to/from politicians, must be considered with more care. As discussed in the historiography section, disease was associated with disorder, which reflected poorly on the imperial state's paternalistic persona, which means politicians and military commanders had incentive to censor reports (Charters 2014, 115). The degree in which this censorship occurred is unknown, but evidence suggests it did occur; Admiral Byng was courtmartialled in 1756/57 and later executed, with one of his accusations being the modification and censorship of his dispatches in relation to sickness among his crew (Charters 2014, 115). Alternatively, there may have been instances where figures were overstated to illustrate a particular point. For example, the 1867 *Report of the Committee Appointed to Enquire into the Pathology and Treatment of the Venereal Disease* states that the report's purpose is to diminish the injurious effects of venereal diseases on the men of the Army and Navy (Her Majesty's Stationery Office 1867). In this publication it was estimated that venereal diseases in the British Royal Naval Service cost the government a total of £32,296 in the year of 1862; this was 32.5% of 1862's total hospital expenses. These figures may or may not have been accurate, but it cannot be denied that the document had bias motives that could have encouraged exaggeration; the document was written in support of the Contagious Disease Acts, which regulated prostitution as a means of reducing venereal diseases among military men. Nevertheless, as Levine (2003) points out, "the figures are horrifying even taking into account a degree of clinical unreliability and the inevitable political doctoring they underwent" (233).

While figures from historical texts must be viewed with some caution, they do indicate that certain infections were especially worrisome to historical combatants. The remainder of this chapter considers military problems surrounding dysenteric, venereal, and streptococcal infections. This includes specific address as to 'why' historical military combatants faced increased exposure and susceptibility to these infectious diseases.

2.2 Military Susceptibility to Infectious Diseases

There are many forms of stress (physical, environmental, and psychological) that are all too familiar to combatants. At minimum, some form of training (which could be both mentally and physically taxing) would be experienced by military men. This training was often in the form of 'drill,' where men were taught and repeatedly practiced in formations, technique, and operation of weaponry (McCaffrey 2006; Showalter & Astore 2007). Military leaders conducting these drills were not known for sensitivity, as strong structure and discipline had been the norm for militaries since the Roman Empire (Showalter & Astore 2007). Soldiers would have been pushed to their limits to achieve ultimate efficiency. Infantrymen, who were often the most 'common' of recruits, would have been pushed especially hard: "an important aspect of infantry training was the assimilation and acculturation of conscripts, volunteers, and impressed men into a thoroughly masculine world…most men welcomed, or at least tolerated, harsh training as a price of unit cohesiveness and effectiveness" (Showalter & Astore 2007, 66).

Weaponry was often heavy and difficult to maneuver, which required a certain fitness level be maintained by combatants assigned particular tasks; for instance, the operation of a pike, which could be 12 to 15 feet long, could not be performed without training and physical strength (Showalter & Astore 2007). Long marches were another normal activity that could be quite taxing; marches were undertaken while carrying heavy supplies and weaponry (example: on average, an American Civil War soldier carried a load of forty-five pounds) (Hagerman 1992). In addition to weight, military combatants were not guaranteed to be marching on good roads/terrain or in good weather (Showalter & Astore 2007; Winters *et al.* 1998). Since combatants are frequently deployed to various parts of the world, they often encounter a wide range of environmental conditions that may be far from familiar; for instance, Napoleon's Grand Army in Russia faced challenges of extreme cold, but in Egypt, Napoleon's men faced challenges of extreme heat (Cole 2007; Winters *et al.* 1998). Militaries often had trouble providing appropriate shelter and clothing befitting of these new environments (Cole 2007; Winters *et al.* 1998; Shepherd 1991). Furthermore, for much of history, logistical issues made providing militaries with sufficient food and supplies very difficult, which meant foraging expeditions were a necessary act to supplement their provided provisions (Gabriel 2013; Showalter & Astore 2007).

Though military life could be physically exhausting with drills, foraging, and marches, it could also be quite boring (Maeland & Brundstand 2009; Showalter & Astore 2007). Repetitive and structured living in military camps or aboard ships was tedious, but commonly endured, as regiments frequently went weeks, even months, without combat; as Maeland and Brundstand (2009) describe it, “a standard formula says that wars consist of ‘5% horror and 95% boredom’ (or waiting)” (2). The horrors of combat are obviously capable of causing psychological trauma, but boredom is psychologically taxing as well, often leading to homesickness and nostalgia as a “dissociative reaction to finding oneself completely isolated or removed from an entire environment supportive and reassuring by its familiarity” (Showalter & Astore 2007, 120). Historically, these psychological issues were self-treated with copious amounts of alcohol, which ultimately created other issues, such as memory loss, sleep disturbance, and speech impairment; until the Enlightenment, commanders did very little to curb alcoholism among military combatants (Gabriel 2013; McCallum 2008; Showalter & Astore 2007). Nevertheless, whether facing physical or psychological stress (or both), combatants were often fatigued as a result.

In short, the lives of military combatants were far from easy, but many of these military commonalities would have also suppressed the immune system’s ability to ward off infectious organisms, which would have increased the likelihood of developing disease symptoms when exposed to pathogens (Dohms & Metz 1991; Ekblom *et al.* 2011; Everson & Toth 2000; Gleeson & Bishop 2000). This suggestion of suppressed immune function is supported by modern clinical research, including some research focused specifically on modern military combatants, who face many of the same challenges as historical combatants (fatigue, physical and psychological stress, exposure to extreme environments, and inadequate rations). Moderate exercise does not have any major impact on immunity, but intense and prolonged exercise can reduce secretory immunoglobulin A, which serves as the first line of defence against pathogens (Korzeniewski *et al.* 2013 [a]; Walsh *et al.* 2011). Natural killer cells, neutrophils, and macrophages are also affected by acute exertion (Korzeniewski *et al.* 2013 [a]). Strenuous exercise has been shown to induce a psychological stress response (increased production of stress hormones), which affects the number and proportion of leukocytes in the blood (Dhabhar 1996; Ekblom *et al.* 2011; Hackney 2006; Korzeniewski *et al.* 2013 [a]). Shift work/duty and other forms of sleep disruption have been shown to decrease the activity of natural killer cells and concanavalin-stimulated interlukin-2 production (Cohen *et al.* 2009; Irwin *et al.* 1996; Korzeniewski *et al.* 2013 [a]). Food restriction reduces T lymphocyte response in addition to causing hormonal changes, fatigue, and feelings of confusion (see **Fig. 27**) (Booth *et al.* 2003; Korzeniewski *et al.* 2013 [a]). Climate (cold, heat, and high altitudes) can influence the immune system by modifying T cell counts, natural killer cell counts, and immunoglobulin levels (Korzeniewski *et al.* 2013 [a]). Problems with alcoholism likely contributed to immune system suppression among historical combatants, as modern research has demonstrated the immunomodulatory properties of ethanol (Goral *et al.* 2008; Pan *et al.* 2006).

In addition to immune suppression, wartime causes a number of other unhealthful circumstances that affect military populations and the civilians they encounter, including overcrowding, the collapse of social infrastructure (such as healthcare facilities or public amenities), and a breakdown (or amendment) of the normal rules of social behaviour (Burkle & Greenough 2006; Smallman-Raynor & Cliff 2004 [a]; Toole). Making matters worse, the various epidemiological backgrounds within a military group create the perfect scenario for epidemic disaster (Smallman-Raynor & Cliff 2004 [b]). Combatants are recruited and deployed into various geographical locations with differing disease environments, but the immune system does not always have a means of defending its host against these new pathogenic exposures, making the combatant more susceptible to their harmful effects (Smallman-Raynor & Cliff 2004 [b]). Even hygienic practices of individuals can influence the overall health of a military assembly; some decisions/habits, such as defecating in unregulated areas or lack of handwashing, can contaminate water and food sources that are consumed by entire regiments.

Figure 27: U.S. Military MRE (Meals Ready to Eat). MRE's are commonly consumed for extended periods of time afield and during early deployments when kitchens are being established. Though designed to be nutritionally adequate, their ability to sustain combatants for extended periods of time is debated: "this assumption implies that a soldier will eat the entire CRP [another name for an MRE, Combat Ration Pack] under favorable and unfavorable conditions and does not account for the increased metabolic demands associated with extreme environmental conditions and psychological activity" Booth *et al.* 2003, 62). Source: Rupp 2015.

2.3 Military Lifestyle & Bacterial Diseases

The previous section established ‘why’ military combatants were susceptible to disease-causing pathogens, but what were the circumstances that allowed particular pathogens to thrive? The diseases commonly found among historical combatants, be they deadly or merely unpleasant, have been successful for various reasons. The historiography section hinted at some of these reasons – overcrowding, poor sanitation, mixing populations with differing immune backgrounds, and recruitment of individuals with poor constitutions. Many of these reasons will be explained in further detail in the following sections, along with other factors.

2.3.1 Diseases of Environment: Gastrointestinal & Pharyngeal Infections

Military Environment: Overcrowded & Unsanitary

The benefits of good hygienic and sanitation practices cannot be understated when it comes to preventing disease. Though historical examples like Roman forts and the Siege of Metz in 1552 clearly illustrated this point, enforcement of military sanitation policies was not taken seriously until the early twentieth century. Tragically, many of the deaths caused by diseases common to unsanitary environments could have been avoided if not for a mixture of ignorance, blatant disregard for beneficial policies, and poorly implemented military medical system.

Disregard for sanitary measures often made matters truly deplorable, as good sanitation is difficult to uphold even when given due consideration. For instance, overcrowding (congregating of large numbers of people and animals into small areas) is a nearly unavoidable issue in many military environments that makes proper waste disposal and delivery of clean water sources difficult. Doctor Joseph Woodward discussed overcrowding and its negative effects in his *Outline of the Chief Camp Diseases of the United States Army* (1863):

> Crowding is a condition present in all great encampments. Thousands of men are frequently, from military necessity, aggregated together in a comparatively limited space… Under such circumstances the immense population, resembling that of a great city, congregated upon an area even less than that which a city of equal population would occupy, is deprived of all those advantages of drainage and sewerage which great cities usually enjoy in civilized countries. But not only is the actual population per acre too great for health, the men are crowded together in their tents in a most unhealthy fashion (45). (see **Fig. 28**)

As this quote makes evident, overcrowding, as well as the resulting unsanitary conditions, was the natural state of past military encampments, but such conditions were not limited to this setting. Sickness also spread rapidly in military hospitals due to overcrowding. This is just one of the topics Florence Nightingale wrote about in relation to medical reform. In her work, *Notes on Hospitals,* she states that, "in civic hospitals the amount of cubic space varies between 600 and 2,000 cubic feet per bed. In some military hospitals it is under 300, and from 700 to 800 appear to be considered a somewhat extravagant allowance. The army regulation as to cubic space in hospitals is overcrowding" (Nightingale 1863, 13-14). Overcrowding in camps and hospitals was common, but crowding on naval vessels was even worse. The Royal Navy designed its ships for endurance, which allowed their ships to stay at sea for longer periods of time (Cook 2001). Though Navy ships could hold a considerable amount of supplies, the crew was forced to occupy extremely close quarters; for example, the average space allowance for seamen to hang their hammock was 14 inches apart (Cook 2001; Lavery 2011).

Woodward (1863) compared the overcrowded military environments to urban cities, but notes that the situation is worse, as the crowding often occurs in less space than is found in cities. He also mentions that military encampments are frequently "depraved" of city solutions to sanitation problems, such as proper water drainage and waste disposal. Militaries had a difficult time accessing quality water sources, as water used by men for drinking and cooking was often the same water used for bathing, washing clothes and eating utensils, and flushing away excrement (Bollet 2002). For instance, a Confederate American Civil War soldier wrote:

> on the bank of the Chickahominy we have to drink the most miserable swamp water…the other day I went to the river to bathe, and found the river so filthy with a greasy scum on it from the mass of human bodies bathing that I was disgusted and went back. My clothes were so dirty that to get rid of the vermin I took them off and boiled them, while I went without any. This is the most terrible ordeal in a soldier's life (Toalson 2006, 166).

Matters were no better for European combatants of the late eighteenth and early nineteenth century. A Napoleonic foot soldier, Jacob Walter, wrote that many had died while marching due to dehydration, as "in most districts there was no water fit for drinking, so that the men had to drink out of ditches in which were lying dead horses and dead men" (Walter 1991, 76).

Figure 28: to exemplify the imagery described by Woodward, this photo shows a Union Army encampment (1862) on the Pamunkey River in Virginia. The image illustrates some of the features that commonly contribute to disease in military camps; there is standing water indicating poor drainage, people and animals (horses) living in close quarters, and boredom (men with nothing to do). Source: Gibson 1862, from the Library of Congress.

Though the ancient Romans had enforced good hygienic practices among their soldiers, Walter's Napoleonic War writings make it clear hygiene of later combatants was quite poor. For instance, his account of his first bath make it clear it had been quite some time since his last:

> It was just Christmas Eve, a date I would not have known if I had not learned it from the landlord. Here I also washed myself for the first time, but I could not rid myself of the lice, or rather of my "sovereigns," because if I had murdered as many as a thousand then the many other thousands would have taken revenge on me. For this reason, I did not undertake an attack on them.… The washing of my hands and face proceeded very slowly because the crusts on my hands, ears, and nose had grown like fir-bark, with cracks and coal black scales (Walter 1991,138).

As previously stated, soap was not provided to British naval combatants until Gilbert Blane's *Observations on the Diseases of Seamen* (1785) advocated for such measures. For camp soldiers, handwashing in clean water was likely an infrequent occurrence and, during the winter months, bathing was very rare due to the lack of warm water (Bollet 2002).

Removal of faecal waste was another sanitation issue commonly faced in military camps. McCallum (2008) states that a 1,000 man battalion produce more than 600 pounds of faeces a day (206). Horses were also common in camps. For an American Civil War cavalry regiment, Armistead (2013) states a minimum number of 1,200 horses were needed, but a single healthy horse can produces approximately 31 pound of faecal matter per day (Pavia & Gentry-Running 2011). Obviously, there was a lot of faecal matter to dispose of and keep away from food and water resources. This task was not always successful for various reasons. There were commonly regulations stating where and how latrines were to be established, but these regulations were infrequently followed in regards to depth and how much/how often dirt was to be used to cover waste (Bollet 2002; McCallum 2008). Improper coverage is problematic due to flies, which land on the fecal matter, pick up bacteria with their feet, and then spread it to the next thing they land on; anyone who has ever been camping in the summer months knows the annoyance of keeping flies away from food, the situation would have been no different for military encampments. Further complicating matters, one should not assume men made use of the designated latrines, which, due to limited privacy and smell, were not the most inviting of places.

Many bacterial diseases thrive in overcrowded and unsanitary environments, as they rely on contagion via a person-to-person or a faecal-oral (faecal contaminants entering the body by way of mouth) route. Crowding increases the opportunity for person-to-person spread, as close proximity means respiratory droplets are easily inhaled by others; alternatively, respiratory droplet may also enter through breaks in the skin after being picked up from other surfaces (Kumar 2012). Upper respiratory infections, which include streptococcal tonsillitis, are spread in this manner; even in the present day "acute respiratory diseases are the principle reason for out-patient treatment and hospitalization among military personnel, with an incidence exceeding that of the adult civilian population by up to three-fold" (Korzeniewski *et al.* 2013 [a], 118).

Due to hygienic (example: lack or improper handwashing) and sanitation (example: fly-improper waste disposal contamination) issues frequently found in military camps and aboard naval ships, it is unsurprising that food and other substances with faecal contaminants found their way into people's mouths. Many gastrointestinal infections spread via the faecal-oral route, as bacterial pathogens frequently reside in faecal-urinary matter. These conditions are difficult to stop without good sanitary and hygienic practices, as the pathogens produce symptoms that help rapidly spread the condition in overcrowded populations:

> because of the symptoms of diarrhea and vomiting, one infected individual can easily contaminate his or her surroundings, and especially a camp's water supply, thereby quickly spreading the disease. As a result, a clean water supply, sewage removal, and general sanitation measures are the best preventatives against such outbreaks, not only by separating refuse from food and water, but also by preventing flies from multiplying (Charters 2014, 93).

Put in more graphic terms, the liquid nature of the stools and vomit produced by these gastrointestinal infections provide bacteria the opportunity to coat many surfaces when expelled. In an environment where little effort is placed on cleanliness, the bacteria spreads easily and rapidly.

Dysenteric Diseases in Militaries

Diarrhoea, dysentery, and typhoid fever (along with typhus) have all been considered brothers and sisters because they share an affinity for a particular type of environment - unsanitary and overcrowded; these conditions are among those considered to be ‘crowd diseases’ (Charters 2014; Zinsser 1935). Diarrhoea and dysentery are commonly encountered even among modern combatants (Lim *et al.* 2005; Riddle *et al.* 2006; Riddle *et al.* 2008). Today, there is a clear medical distinction between the two conditions, but the key differences come down to the location affected (diarrhoea targets the small intestines and dysentery the colon) and the symptoms (diarrhoea is often watery and dysentery bloody). Though defined separately in modern medicine, historically the terms were largely indistinct and used interchangeably by many physicians (Bollet 1991). For the sake of this research, both diarrhoea and dysentery have been considered as blanket terms concerning ailments of the intestines leading to abnormal bowel movements.

Though diarrhoea and dysentery can be caused by viral and amoebic vectors, they are primarily caused by bacterial pathogens; the most common species include: *Salmonella enteritidis, Campylobactera jejuni, Yersinia enterocolitica, Shigella dysenteriae, Shigella flexneri, Escherichia coli* and *Clostridium difficile* (Kumar 2012; Lim *et al.* 2005; Riddle *et al.* 2008; Smallman-Raynor & Cliff 2004 [a]). Typhoid fever was also common to historical combatants and is caused by *Salmonella typhi.* Typhoid’s symptoms include diarrhoea and high fever. These symptoms alone can potentially be fatal, but if left untreated, Typhoid can also cause intestinal rupture and subsequent infection. All dysenteric conditions listed, including typhoid, are spread through ingestion of food or fluids contaminated with faeces or urine (Kumar 2012; Smallman-Raynor & Cliff 2001).

Diarrhoeal diseases can become epidemic and cause substantial damage in isolation, but diarrhoea is also a frequent symptom in other forms of infectious disease. For this reason, early examples of diarrhoeal diseases among combatants can rarely be distinguished from other forms of infectious diseases with much confidence. For example, Zinsser (1935) suggested that plague or dysentery are reasonable explanations for the epidemic described by Herodotus as bringing about Xerxes' withdraw from Greece during the Persian Invasion (480-479 B.C.), but neither assertion can be proven to be more or less likely than the other (151-152).

Though early examples often prove to be difficult, more scientific understanding of diarrhoeal diseases from the late seventeenth century onward provide more useful documents recording these conditions among military combatants. Dysentery was a major killer in many European conflicts, including the Irish Wars (1689-1691), the Ottoman War (1716-1718), The War of Austrian Succession (1739-1748), and The Russo-Swedish War (1740-1743) (Smallman-Raynor & Cliff 2004 [a]). Eighteenth century America also had troubles with dysentery. During the American Revolution, Benedict Arnold's troops marching to Canada were weakened by starvation, exposure, exhaustion, and diseases largely consisting of dysentery, diarrhoea, and 'rheumatism' (the historical term used to refer to arthritic aches and pains); in addition to this, they were further decimated by smallpox upon entering Quebec City in late 1775 (Desjardin 2007; Gabriel 2013; Smallman-Raynor & Cliff 2004 [a]).

The nineteenth century proved no better. As mentioned in the historiography section, the medical services offered to armies involved in the Napoleonic Wars were far from perfect and disease fatalities were high as a result. These fatalities included deaths due to dysenteric diseases. For instance, when Napoleon's Great Army reached Lithuania during its retreat from Moscow in 1812, the Russian Army had burned many of the towns and destroyed bridges at river crossings (see **Fig 29**), leaving troops temporarily stranded with little shelter, bad water, and a scarce supply of food. This ultimately resulted in over 80,000 men sick with dysentery, enteric fevers (typhoid), and typhus (Smallman-Raynor & Cliff 2004 [a], 107; Zinsser 1935, 161). Dysentery was also among the conditions that attributed to the 3:1 disease to combat fatality ratio during the Crimean War (Cook 2001; Shepherd 1991; Smallman-Raynor & Cliff 2004 [a]). In the American Civil War, diarrhoea and dysentery were the number one cause of death and discharge, with a total of 37,794 reported deaths in the Union Army alone, though the true mortality was suspected to be "considerably greater," (U.S. Army Surgeon General's Office 1888, 2).

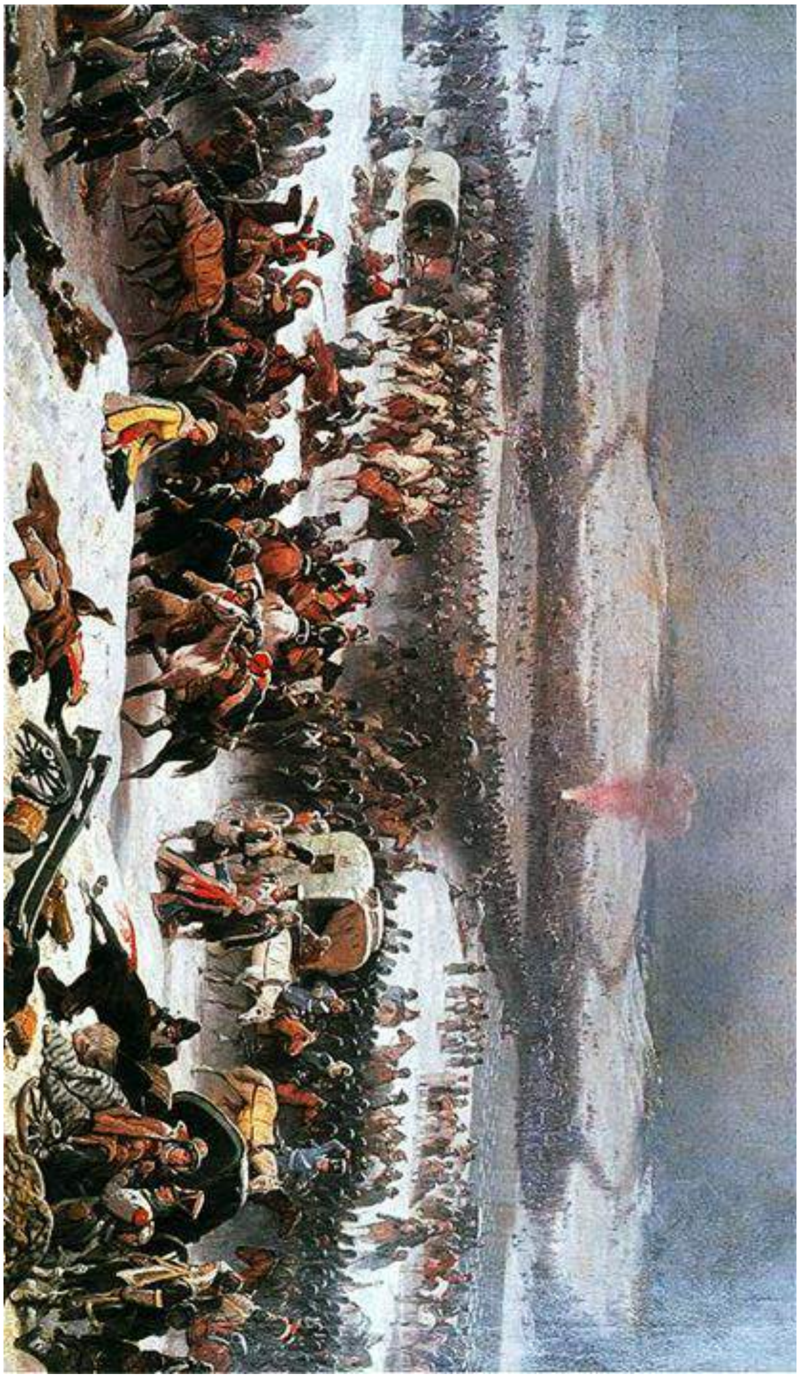


Figure 29: this painting by January Suchodolski is called Napoleon's Crossing of the Berezina. It depicts Napoleon's Grand Army crossing the Berezina River. They were forced to wade across a river ford, as all bridges had been destroyed. Source: Šliūpas 2016 from VilNews.

‘Fluxes’ were commonly reported aboard naval ships (see **Table 7**). Historically, naval outbreaks of gastrointestinal diseases have affected tactical decisions made in combat and were known to cause anxiety among commanding officers. Such was the case when the Royal Navy of Her Majesty, Queen Elizabeth I, awaited the potential attack of the Spanish Armada in 1588. The English, “suffered so severely from dysentery that Howard was to write to Francis Walsingham his fears and hopes that ‘God of his mercy keep us from the sickness, for we fear that more than any hurt that the Spaniards will do.’... When the Armada was sighted off the Lizard on 30 July 1588, the English decided to force the enemy out to sea before disease and hunger lessened the English powers of attack” (Brown 2011, 29). This was not the end of Queen Elizabeth I’s problems with dysentery in her Navy. In 1595, a voyage to the West Indies left one-fifth of her 2,500 seamen dead (Fury 2012, 210). Though navies slowly made improvements to sanitation, hygiene, and diets of marines and sailors due to the efforts of medical officers like Lind and Blane, navies of the eighteenth and nineteenth century continued to have issues with dysentery and other diseases (Brown 2011; Blane 1780; Gabriel 2013; Lind 1762). Ultimately, by land or by sea, gastrointestinal infections were exceedingly common among historical combatants.

Table 7: This table is adapted from work published by Doctor Gilbert Blane, who was appointed as the physician of Lord Rodney’s Fleet in 1780. Blane used the opportunity to observe the afflictions of sailors and recorded his findings in Observations on the Diseases Incident to Seamen (1785). This table shows the number of cases and deaths due to flux (diarrhoeal disease) between the months of February and June of 1781. Blane’s data makes it apparent that ‘the flux’ was far from uncommon aboard naval vessels. Source: created by the author, information from Blane 1785.

Flux Reported on 24 Royal Navy Ships, February to June 1781			
Month	Total Number of Cases		
	On Board Ship	Sent to Hospital	Dead
February	158	7	21
March	238	67	18
April	317	49	9
May	166	39	7
June	149	57	5

Streptococcal Infections in Militaries

In the modern military, upper respiratory infections, which include tonsillitis, are common and were likely no less common among historical combatants (Korzeniewski *et al.* 2013 [a]; Korzeniewski *et al.* 2013 [b]). The bacterial species *Streptococcus pyogenes* causes tonsillitis and pharyngitis (which often occur together as tonsillopharyngitis) (Chakravarty *et al.* 2014; Cunningham 2014; Denny 1994; Gray *et al.* 1999; Gunzenhauser *et al.* 1995; Hilário & Terreri 2002; Thomas *et al.* 1988). This bacteria spreads from person-to-person through respiratory droplets in the form of oral and/or nasal secretions (coughing, sneezing, runny nose) (Centers for Disease Control [CDC] 2016). The best means of preventing the spread of this bacteria is through good respiratory hygiene (covering the mouth when coughing and handwashing) and general cleanliness to insure infected droplets are not picked up from other surfaces (CDC 2016). Furthermore, due to the manner in which this bacteria spreads, it thrives in overcrowded conditions where respiratory droplets easily spread from host to host (CDC 2016; Gray *et al.* 1999; Thomas *et al.* 1988). The less than ideal hygienic practices and overcrowded nature of many historical military environments implies that streptococcal tonsillitis or tonsillopharyngitis, along with other conditions caused by *S. pyogenes* (like scarlet fever), occured among historical combatants (Smallman-Raynor & Cliff 2004 [a]; U.S. Army Surgeon General's Office 1888).

World War II is especially noted for its problems with streptococcal infections, some reports state that the US Navy had as many as a million cases (Gray *et al.* 1999, 382; Thomas *et al.* 1988, 125). They were also common in World War I, as the US Navy in 1918 reported 1,214 cases of scarlet fever and 2,772 cases of ARF (which is almost exclusively caused by streptococcal tonsillitis and pharyngitis) (Thomas *et al.* 1988). During the American Civil War, 66,000 cases of tonsillitis and 696 cases of scarlet fever were reported (U.S. Army Surgeon General's Office 1888, 732). According to Collison (2015), research into the medical records available for

General George Custer's 7th Cavalry from 1866 to 1883 revealed 584 cases of tonsillitis, which was the equivalent of 7% of cases within the database.

Though tonsillitis certainly makes an appearance in historical medical texts, based on the commonality of streptococcal tonsillopharyngitis in modern day militaries and twentieth century conflicts, tonsillitis and pharyngitis are not always recorded with the frequency one would expect. This is possibly due to one of the biases mentioned in section 2.1.2. Bollet (2002) speculates the low figures for tonsillitis are due to lack of recording rather than lower numbers in historical military groups, as 'sore throats' would have most commonly been treated at sick-call (allotted times where men would report, one after the other, to the camp physician for treatment of their medical problems). Ailments addressed during these sessions went largely unrecorded (Bollet 2002, 312). Alternatively, Collison (2015) suggests that the lack of antibiotic use may have allowed a certain amount of immunity to develop. The discrepancy in numbers may involve a bit of both explanations, but streptococcal tonsillopharyngitis was most certainly present among historical combatants, as ARF cases were commonly recorded in late nineteenth century conflicts; epidemics of ARF occurred among British troops during the Crimean War and 155,049 cases were reported during the American Civil War (Bollet 2002; Collison 2015).

Solutions for Diseases of Environment

As already made clear in the historiography section, prevention of diseases caused by unsanitary and overcrowded environments is possible, but only if sanitation and hygienic policies are obeyed with great diligence. For instance, in the British Royal Navy, Lind gave sound advice in *An Essay on the Most Effectual Means of Preserving the Health of Seamen in the Royal Navy* (1762) that was largely ignored until Blane's work *Observations on the Diseases of Seamen* (1785) advocated for many of the same changes (Blane 1785; Lind 1762). Though disease remained a problem after these changes, the positive results were evident. Before reforms in

1782, the British 100,000 sailor navy had 1:3.3 ratio sick to fit personnel, but thirty-one years later, the ratio for a 140,000 sailor navy was 1:10.75 (Gabriel 2013,103). Armies were also given reason to pay more attention to sanitation after Pringle's work *Observations on the Diseases of the Army* (1753), Richard Brocklesby's *Economical and Medical Observations* (1764), Hughes Ravaton's *Chirurgie d'armée* (1768), and Jean Colombier's *Code de médecine militaire* (1772) (Gabriel 2013; McCallum 2008), but much of this work was either excluded from official policy or was not considered important enough by military commanders to be enforced. It was not until the late nineteenth and early twentieth century that military medical practitioners' pleas for improved military sanitation were heeded.

Serious enforcement of military sanitation policies following the Boer War did greatly reduce the occurrence and fatalities of many 'crowd diseases,' but the problem has never been fully eradicated for streptococcal and gastrointestinal infections. Though more attention is given to the matter of crowding, militaries still have large numbers of individuals living in close quarters, which means tonsillitis and other respiratory infections remain common (Korzeniewski *et al.* 2013 [a]; Korzeniewski *et al.* 2013 [b]). Nevertheless, antibiotics (which militaries largely began to utilize during World War II) have made it possible for combatants to recover from these infections with greater speed and success (secondary complications such as ARF can be avoided if medical treatment is given in a timely fashion) (Chakravarty *et al.* 2014; Gabriel 2013).

Though taken seriously in most modern militaries, sanitation remains an issue periodically; for instance, soldiers newly deployed (unaccustomed to food and disease environments) and men working in camps being newly established (before proper food, water, and waste facilities are established) are likely to experience dysenteric diseases (Connor & Gutierrez 2013; Porter *et al.* 2015; Porter *et al.* 2011; Riddle *et al.* 2006; Riddle *et al.* 2008; Riddle *et al.* 2015; Sanders *et al.* 2004). Use of antibiotics and vaccines reduce the risk of fatality and the amount of downtime produced by these illnesses, but the cause of these condition in military groups resonates through time.

In comparing gastric infections among U.S. troops in the Middle East during World War II, Operation Iraqi Freedom (OIF), and Operation Enduring Freedom (OEF), Riddle *et al.* (2015) states:

> it appears that despite improved sanitation, provision of safe food, and other public health interventions, there has been a minimal reduction in disease incidence in OIF/OEF as compared with WWII, with overall disease and non-battle injury rates of infectious GI visits (the given medical surveillance category for all acute diarrhea, dysentery, and vomiting illness) between March 2003 and June 2006 of approximately 146 cases per 1,000 person-years…there is no question that diarrhea, dysentery, and gastroenteritis were and are still all too frequent an occurrence (914).

In comparing some of the reasons gastric infections have remained an issue since World War II, Riddle *et al.* (2015) found there were several notable similarities between the initial phases of deployments, including logistical issues, shortages in environmental health technicians which prevented achievement of some goals, poor hygiene infrastructure, and eating unauthorized foods (local cuisine). Issues of logistics, medical staff shortages, and trouble enforcing good hygienic practices repeatedly appeared in the historiography section, so the past does not greatly differ from the present in this regard.

Captain Mark Riddle, who is the Director of the U.S. Military Diarrheal Diseases Vaccine Research Program, was introduced and interviewed by popular science writer Mary Roach for her publication *Grunts: the Curious Science of Humans at War.* In this publication, Captain Riddle reveals that, though there are effective treatments for gastrointestinal diseases, convincing combatants to use these treatments can be difficult due to common misconceptions. For instance, there is a common belief that diarrhoea or vomiting are the body's way of getting rid of bad food or water, so any treatment that "stops you up" must be bad for you (Roach 2016). Fear and reluctance to utilize medical treatments is not a new problem, as historical medical treatments were avoided by combatants for various reasons – stigma related to having a particular disease, the fact that treatments were often highly unpleasant, and (similar to the case described in Roach 2016) false beliefs (example: nineteenth century avoidance of typhoid vaccinations due to the incorrect belief it caused reduced virility)

(Gabriel 2013). All in all, the U.S. nineteenth century military assertion “that to be a good soldier here bowels are of more consequence than brains” rings true for both past and present military combatants (Bollet 2002; Gordon 1898, 141).

2.3.2 Diseases of Behavior: Venereal Diseases

Sex, Venereal Diseases, & Military Combatants

In times of war, people are forced to come to terms with their mortality, men are placed in male dominated social groups, and combatants are separated from the normal social contexts of their home societies. All of these factors do much to alter the social norms and behaviours of people. Furthermore, military populations predominantly consist of young single males of sexually active ages (Korzeniewski 2012). Across world populations and throughout time, it has been demonstrated that war coincides with increased opportunities for sexual encounters and changes in sexual behaviours, such as increases in aggression and promiscuity (Goldstein 2001; Roberts 2013; Zaleski & Majewski 2015). The reasons as to why sexual encounters are common for military combatants has often been researched from the perspective of connecting sex to violence, but sex in the military contexts is comprised of both consensual and nonconsensual encounters with many factors outside of violence being involved (examples: boredom, politics, and alcohol consumption) (Roberts 2013; Zaleski & Majewski 2015).

Sex and violence/war have a long history as illustrated by some of the earliest myths and epics; for instance, in Homer’s *Iliad*, the catalyst for the Trojan War was Pairs stealing Helen from her husband Menelaus. The connection between sex and violence has been studied extensively as a means of explaining and understanding conflict related sexual violence; according to Bastick *et al.* (2007), conflict-related sexual violence is common, being reported in fifty-one countries in the twenty years proceeding their publication. Sexual violence in conflict is often assumed to refer to rape alone, but many other sexually violent acts occur in war, including forced marriage, sexual slavery, trafficking, genital mutilation, and sterilization (Zaleski & Majewski 2015). Understanding why sexual violence occurs in war is a complicated subject spanning many disciplines with differing theories that each have their own strengths and weaknesses (Zaleski & Majewski 2015).

Biological theories view men as innately sexually aggressive, so sexual violence is explained through genetics and adaptation for species survival (Zaleski & Majewski 2015). This view is sometimes identified as the 'pressure-cooker' theory, "men possess instincts for sexual aggression that are restricted under normal conditions, but that, in the chaotic wartime milieu, spew forth like the vented gas of a pressure-cooker" (Gottschall 2004, 133). Purely feminist approaches view acts of sexual violence as expressions of patriarchal hierarchy that portray men as strong and women as passive, so sexual violence during war is an expression of men enacting their role as aggressor and establishing (or in some theories, reestablishing) dominance (Gottschall 2004; Zaleski & Majewski 2015). Structural theorists use a similar line of thinking to feminist, but broaden their view to include cultural factors. They do not agree that all women are victims, instead, they argue some women face more risk than others due to their cultural identities; they are targeted by men belonging to powerful groups because they are female embodiments of opposing socio-cultural identities (Zaleski & Majewski 2015).

Cultural theories frequently view acts of sexual violence as being the result of military culture, "as an institution, the military is hierarchal and dominated by males and often socializes its members to be 'masculine' (aggressive) and devalues what is 'feminine,' or weak. In addition, it is also a system that views violence as a legitimate means of resolving conflict" (Zaleski & Majewski 2015, 5). Cultural theorist point out that militaries dehumanize their enemies as a mean of justifying killing and expect their opponents to be equally aggressive towards them, so in a kill or be killed atmosphere, sexual violence taboos become less restricting (Baaz & Stern 2014; Zaleski & Majewski 2015).

Strategic rape theory argues rape is used as a tool or weapon to achieve goals (Bastick *et al.* 2007; Gottschall 2004; Trenholm *et al.* 2011; Zaleski & Majewski 2015). Rape can be used to: decrease resistance among civilians through fear, emasculate (and subsequently demoralize) enemies, motivate combatants to fight (sex is promised as a "reward for bravery"), and destabilize family and community structure (Bastick *et al.* 2007; Gottschall 2004; Trenholm *et al.* 2011; Zaleski & Majewski 2015). Ultimately, explanations for wartime sexual violence are diverse, but there are several common themes – strategic purpose paired with expression of masculinity/femininity, aggression, and power (Bastick *et al.* 2007; Gottschall 2004; Zaleski & Majewski 2015).

Common participation in sex (consensual and nonconsensual) among military combatants is related to other factors. For instance, mental health is sometime associates with the sexual behaviors of military combatants. Compulsive sexual behavior (CSB) is composed of two primary components, "a pattern of abnormally frequent paraphilic (e.g., fetishism, sadism, pedophilia) or normaphilic (e.g., sexual fantasies, sexual urges, intercourse, masturbation) thoughts and/or actions, and 2) significant distress and/or life problems associated with these thoughts/behaviors" (Smith *et al.* 2014, 214). CSB is associated with psychiatric disorders, which are known to be common to military combatants, leading Smith *et al.* (2014) to investigate the prevalence of CSB in military combatants. Smith *et al.* (2014) found CSB is prevalent among veterans returning from combat. CSB in the general U.S. population has an estimated prevalence of 3–6%, but CSB in U.S. veterans returning from Operation Iraqi Freedom, Operation Enduring Freedom, and Operation New Dawn was 16.7% upon return from service, 15.5% after 3 month, and 8.8% after 6 months (Smith *et al.* 2014). They also found a strong association between CSB, Posttraumatic Stress Disorder, and physical trauma. Though specific diagnosis and focus on psychological issues in military combatants was largely a product of the twentieth century, historical documentation does suggest that historical combatants experienced psychological trauma as well. For example, in 1871 Dr. Jacob Da Costa published an article on 'soldiers heart' or 'irritable heart,' a condition causing rapid heartbeat and lightheadedness that appeared to be related to mental and emotional stress (Da Costa 1951).

Today, much is done in western culture to prevent and understand wartime sexual violence, but wartime rape was quite common historically and was even considered an entitled part of the victor's 'spoils of war' (Ailes 2012; Bastick *et al.* 2007; Boesten 2014; Donagan 1994; Gedney *et al.* 2015; Stiehm 2012; Zaleski & Majewski 2015). In other cases, sex (both consensual and nonconsensual) was a means of keeping spirits high. Wartime causes resources and services to be reduced or done away with, which makes new opportunities and hardships (Smallman-Raynor & Cliff 2004 [a]). Such changes alter not only the behaviours of men but also women; for instance, without men at home to provide the normal means of monetary support, war has often moved women from their social confinement to domestic home-life to working occupations. One occupation commonly adopted by women in wartime was camp following. Camp followers were women (and some children) who accompanied military armies to carry out necessary domestic tasks like cooking, laundry, and basic nursing (Ailes 2012). Another occupation often adopted by women was prostitution (Karras 1996). Sex with prostitutes can usually be considered consensual and was common among historical combatants. The reaction of commanders to prostitution has differed, but many accepted the practice or openly encouraged it due to the belief that fraternizing with prostitutes boosted troop morale (Ailes 2012; Bollet 2002).

Morale can become low among combatants in light of defeat or harsh conditions, but sex was viewed as a means of allowing men to reestablish their masculinity and providing them a reason to fight another day (Roberts 2013; Levine 2003). For example, during World War II, sexualized propaganda was used to motivate soldiers; pin-up girls were utilized as means of inspiring soldiers and propaganda frequently romanticized campaigns (see **Fig. 30**) (Roberts 2013). Another cause for low morale in militaries is boredom (Maeland & Brundstand 2009; Showalter & Astore 2007). In the time spent waiting for conflict, commanders employed drill and other structural activities as a means of keeping combatants occupied, but combatants have always found other means of keeping themselves entertained, which has historically included sex, drinking, gambling, creation of art, and writing (Bollet 2002; Gabriel 2013; Maeland & Brundstand 2009; McCallum 2008; Showalter & Astore 2007). Beyond sex being a form of entertainment, alcohol use among historical combatants may have also contributed to participation in sexual behaviors, as ethanol consumption has been linked to increased participation in high-risk sexual behavior (behaviors more likely to result in venereal infections) which include having multiple sexual partners, reduction of social disinhibition, and interference with decision making (Thompson 2005).

Figure 30: French girls embrace Allied soldiers after the liberation of Paris in 1944. Such images presented a romantic quality to military campaigns, "disseminated in the military press, this photo portrayed the invasion in mystic terms as a mission to save French women from the evils of Nazism. Victory was defined as putting a smile on the face of *la française* who would duly reward the soldier with a kiss" (Roberts 2013, 16). Source: Roberts 2013, 16.

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Where sex abounds, especially sexual relationships involving multiple partners, venereal diseases will follow. For this reason, it is no surprise that the urogenital infections most commonly found among military combatants are venereal in nature. Historically, venereal diseases largely consisted of two main diagnoses: syphilis (*Treponema pallidum*) and gonorrhoea (*Neisseria gonorrhoeae*); however, this does not mean they were the only conditions present. Until the twentieth century, 'gonorrhoea' was a blanket term used to describe any condition with urethral discharge, its key distinction from the historical diagnosis of 'syphilis' which lacks urethral discharge (Bollet 2002). With this definition, chlamydia (*Chlamydia trachomatis*) is another urogenital infection that likely occurred among past combatants, as it too involves urethral discharge and behaves similarly to gonorrhoea (Zenilman 2011).

Venereal diseases have long been reported among military combatants. The first major outbreak of syphilis in Europe occurred during the French siege of Naples in 1494 (McGough 2010; Showalter & Astore 2007). It is suspected that Oliver Cromwell's Army in the English Civil War was responsible for bringing a venereal disease (most likely endemic syphilis) to Scotland, which caused an epidemic in 1649 (Clemow 1903; Hinrichsen & Chase 1944; Lancereaux 1869). In the American Civil War, 109,397 cases of gonorrhoea were reported in the Union Army (U.S. Army Surgeon General's Office 1888, 891). In World War I, approximately 400,000 cases of venereal disease were reported in the British Army and venereal disease was a dominant cause for military hospital admissions in the United Kingdom throughout the nineteenth and twentieth century (Macpherson *et al.* 1923, 118; Smallman-Raynor & Cliff 2004 [a]). During World War II, gonorrhoea ranked as the number one disease related to hospital admissions among U.S. troops in Europe (844,872) and the Mediterranean (93,424), but also held the third rank in Africa and the Middle-East (3,721) (Smallman-Raynor & Cliff 2004 [a], 540).

The close relationship between naval combatants and venereal disease is a topic that can be researched by reading journal entries made by Royal Navy physicians (National Archives n.d.; Goddard 2005). Around the time of the Napoleonic Wars, naval surgeons customarily provided medical journals describing their observations on each voyage to the Admiralty and the College of Surgeons in London (Goddard 2005). Goddard (2005) conducted a study of 39 such journals from 13 ships dating from 1796 to 1810. Goddard found 446 reported cases of genitourinary conditions and, of this number, the majority (76%) could be attributed to venereal diseases specifically (418). Of the 446 genitourinary cases, "284 involved ordinary or able seamen, 59 marines, 12 petty officers, 15 officers, and 30 idlers" (Goddard 2005, 414). This statement makes it apparent that these infections (with most being venereal) were experienced by all aboard ship in spite of rank or position. It also becomes apparent from Goddard's research that these infections would have been inconvenient, as the length of time spent on the sick list due to genitourinary conditions was anywhere from 1 to 172 days, with the average being 22 days (Goodard 2005, 414).

Though prevention and treatment methods for venereal diseases have improved since the first half of the twentieth century, venereal diseases still frequently occur in modern militaries. During the Korean War (1951-1955), venereal diseases in U.S. Forces had an estimated incidence of 184/1,000 soldiers, with three-fourths of these cases being due to gonorrhoea (Korzeniewski 2012). During the Vietnam War (1955-1975), venereal diseases were the number one diagnosis in the Army's monthly morbidity reports (Korzeniewski 2012). Contemporary conflicts in Iraq and Afghanistan frequently report chlamydia is the number one infectious disease encountered among military troops (Aldous *et al.* 2011; Jordan *et al.* 2011).

Venereal diseases are a serious issue, as they left large numbers of men out of commission. Indeed, as discussed in the next subsection, nineteenth century military troubles with venereal diseases in America and Britain were viewed by government and military officials as being a rampant problem that caused both practical and moral dilemmas that needed firm address, leading these nations to create new policies and programs in an attempt to prevent these infections among combatants. They would discover there were no easy solutions. It was in the midst of this issues in America that Surgeon Samuel D. Gross (1805-1884) would note in his 1861 publication *A Manual of Military Surgery: Or, Hints on the Emergencies of Field, Camp and Hospital Practice* that it was very difficult to regulate what soldiers did during their downtime and, thus, "…it is impossible, even under the most rigid discipline, to prevent gonorrhoea among soldiers. They will expose themselves, in spite of all that can be done to prevent it, and they often pay a heavy penalty for their indulgence" (Gross 1861, 129). In the years following, Gross' suggestion that any attempt to prevent venereal disease in military combatants would be doomed to failure was largely proven true.

Solutions for Diseases of Behavior

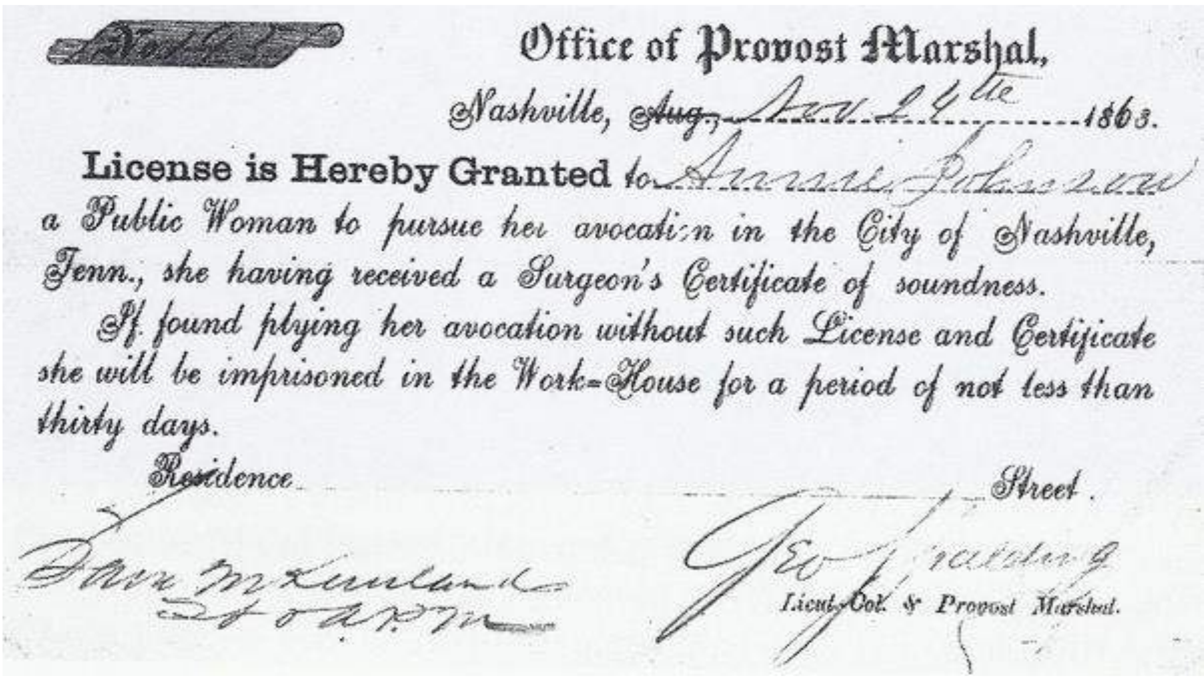
Military troubles with venereal diseases have often been attributed to the popularity of prostitution and wartime loosening of 'normal' moral conduct between the sexes. As such, many of the historical attempts to reduce the occurrence of venereal diseases in military combatants revolved around the regulation of prostitution; such attempts were commonly ineffective. One reason it is difficult to regulating prostitution comes down to commanders, as they frequently have the final say on the policies enforced upon their troops. The opinions and policies enacted by commanders in relation to prostitution have greatly varied, ranging from full-out encouragement, reluctant acceptance, and absolute vexation (Ailes 2012; Bollet 2002). Even highly religious wars, like the English Civil War, where some commanders were known for their harsh punishment of prostitutes, could not fully rid themselves of the practice; prostitutes frequently followed armies despite the threat of punishment, as armies were good business (Gaunt 2014). In 1802, Napoleon I called for prostitutes following his armies to be inspected for venereal diseases, a policy that was later accepted in other European countries like Belgium and Italy (Gibson 1986). When adopted by the Italian army and navy in the mid-nineteenth century, inspections occurred weekly, taking place every Sunday (Gibson 1986).

During the American Civil War, Brigadier General Robert Granger claimed he was, “daily and almost hourly beset” by his commanders and surgeons to find a solution to rid Nashville of the “diseased prostitutes infesting it” (U.S. Army Surgeon General's Office 1888, 893). The state in Nashville was certainly dire, as by 1862 there were an estimated 1,500 prostitutes working in the city, making the spread of venereal diseases a true problem among Union troops stationed in or near the city (Serratore 2013). As a solution to this problem, Lt. Col. Spalding decided to relocate Nashville’s prostitutes to other locations. The first and only attempt to enact this plan occurred in 1863, when 111 prostitutes were sent on the maiden voyage of the *Idahoe* to Louisville, Kentucky (Serratore 2013; U.S. Army Surgeon General's Office 1888). Upon learning the nature of the ship’s unique cargo, the *Idahoe* was denied entry into the city (Bollet 2002, 315; Serratore 2013; U.S. Army Surgeon General's Office 1888). The *Idahoe* also attempted to drop its cargo in Cincinnati, Ohio, but they too refused entry (Serratore 2013; U.S. Army Surgeon General's Office 1888). With no cities allowing the ship entry, the *Idahoe* was forced to return to Nashville with its prostitutes and an accrued $1,000 worth of damages to the new ship (Serratore 2013). This would not be the only time in history that officials have attempted to stop troubles with prostitutes during wartime via city expulsion. After the Normandy invasion of World War II, sex between American troops and prostitutes was rampant and indecent, leading Le Havre mayor Pierre Voisin to attempt to send arrested prostitutes to Paris by train, but this effort had no success, as the prostitutes would simply get off a the first top and take a taxi back (Roberts 2013).

Though Lt. Col. Spalding’s efforts to ship prostitute out of Nashville was a resounding failure, he went on to create a system of legalized prostitution, rationalizing that if he could not rid the city of prostitutes, they might as well employ a system which encouraged safe sex. Prostitutes registered themselves and obtained a $5 license (see **Fig. 31**) that allowed them to work (Serratore 2013; U.S. Army Surgeon General's Office 1888). Army doctors would then examine them weekly for 50¢ and, if found to have a venereal disease, would be provided treatment at a hospital that was partially paid for by the weekly fees (Serratore 2013; U.S. Army Surgeon General's Office

1888). Prostitutes discovered without a license or failing to attend scheduled exams could face up to thirty days in prison (Serratore 2013). The program was noted to have positive effects, but it was not long lived, ending at the American Civil War's conclusion in 1865 (Serratore 2013).

Figure 31: the image below is an example of the licenses provided to prostitutes in Tennessee during the American Civil War as part of the Union Army's attempts to reduce the occurrence of venereal disease. Source: Serratore 2013.



Office of Provost Marshal,

Nashville, ~~Aug.~~ Nov 24th 1863.

License is Hereby Granted to [illegible]

a Public Woman to pursue her avocation in the City of Nashville, Tenn., she having received a Surgeon's Certificate of soundness.

If found plying her avocation without such License and Certificate she will be imprisoned in the Work-House for a period of not less than thirty days.

Residence ____ Street.

Lieut. Col. & Provost Marshal.

The British would also turn to regulated prostitution as a means of controlling the rates of venereal disseises among military combatants. Between the 1850's and 1880's, legislation was placed on prostitutes through the Contagious Disease Acts as a means of reducing venereal disease and loss of man-power among military combatants (Jose & McLoughlin 2016; Levine 2003). Prostitutes within a five mile radius of military districts were required to register and undergo regular examinations (Levine 2003). If found to have a venereal infection, they would be admitted to specialized (lock) hospitals for treatment (Jose & McLoughlin 2016; Levine 2003). Originally, this was largely seen as an uncontroversial public health measure, but by the 1870's it became a major political and moral issues for its specific targeting of women, particularly women of lower socioeconomic status (Jose & McLoughlin 2016;

Levine 2003). The acts were repealed in 1886, but at their end, there was no statistics evidence the acts has significantly reduced rates of venereal disease (Metropolitan Female Reformatories 1873; Stansfeld 1877).

While attempts were made to reduce the occurrence of venereal diseases through regulation of prostitutes, some habits of commanders actually aided the spread of venereal diseases. For instance, the 1821 *Statement Respecting the Prevalence of Certain Immoral Practices in His Majesty's Navy* begins:

> it has become an established practice in the British Navy to admit, and even to invite, on board our ships of war, immediately on their arrival in port, as many prostitutes as the men, and, in many cases, the officers may choose to entertain, to the number, in the larger ships, of several hundred at a time; all of whom remain on board, domesticated with the ship's company, men and boys, until they again put to sea (Great Britain Royal Navy 1821, 1).

Navy officers often allowed prostitutes to board their ships in the fashion described above out of fear. Officers knew women were something their men wanted after being out at sea, but, as many sailors were impressed, they feared desertion if they were given the opportunity to disembark the ship (Pope 1996). To appease their sailors and eliminate the risk of desertion, officers would negotiate bringing prostitutes to their men aboard ship (see **Fig. 32**). Some Royal Navy officers did forbid the presence of women aboard ship, but this appears to have been a rather rare position to take (Boston *et al.* 2008; Pope 1996). No matter the rationale behind allowing men ready access to prostitutes when in port, such practices leave little doubt as to why the Royal Navy was well noted for its troubles with venereal diseases.

Figure 32: this 1810 engraving by Thomas Rowlandson depicts a naval officer (mid shipman) negotiating with prostitutes; the nearest prostitute has her hand out for payment and the mid shipman appears to be delving for money in his pocket. Source: Rowlandson 1810, from the National Maritime Museum.

Even today there are regulations in regards to appropriate/inappropriate sexual relations for military combatants, which includes regulation in regards to sex with or participation in prostitution (forbidden) and fraternization with fellow military members (Powers 2016). Though venereal diseases remain an issue for modern combatants in spite of these regulations, the means of preventing and treating these diseases greatly improved in the twentieth century, as prophylactic measures (use of condoms) and effective treatments (antibiotics) became widely available. Condoms have a long history, with the first known documented reference dating to 3,000 B.C.E. (Kahn *et al.* 2013). History has seen occasions where militaries have distributed condoms to combatants for use (for example, condoms of fish, cattle, and sheep intestine were provided to forces of Charles I during the English Civil War to reduce transmission of syphilis), but common regulation ensuring their dispersal didn't occur until the twentieth century; Germany provided condoms to its forces in World War I, but British and American militaries did not officially begin distributing condoms until World War II (Kahn *et al.* 2013). Propaganda was also used to warn combatants of the dangers of venereal diseases during World War II (see **Fig. 33**). Despite the dispersal of condoms and use of propaganda in World War II, there was no apparent reduction in the occurrence of venereal disease (rates remained high) (Kahn *et al.* 2013). Though prevention is difficult, wide military use of penicillin during World War II produced great results that were quickly noted: "U.S. Army investigators published the first large-scale trial of penicillin treatment for gonorrhea…the investigators studied 1,686 patients…they achieved a 92.5% cure rate using total penicillin doses of 160,000 units or less" (Rasnake *et al.* 2005; Kahn *et al.* 2013; Quinn 2013).

Figure 33: The following World War II propaganda posters were for venereal disease awareness among troops in the 1940s. They often warn military men against “good time girls” and “loose women,” but also employed emotions of guilt and regret in relation to venereal diseases. Source: LaMotte 2015.

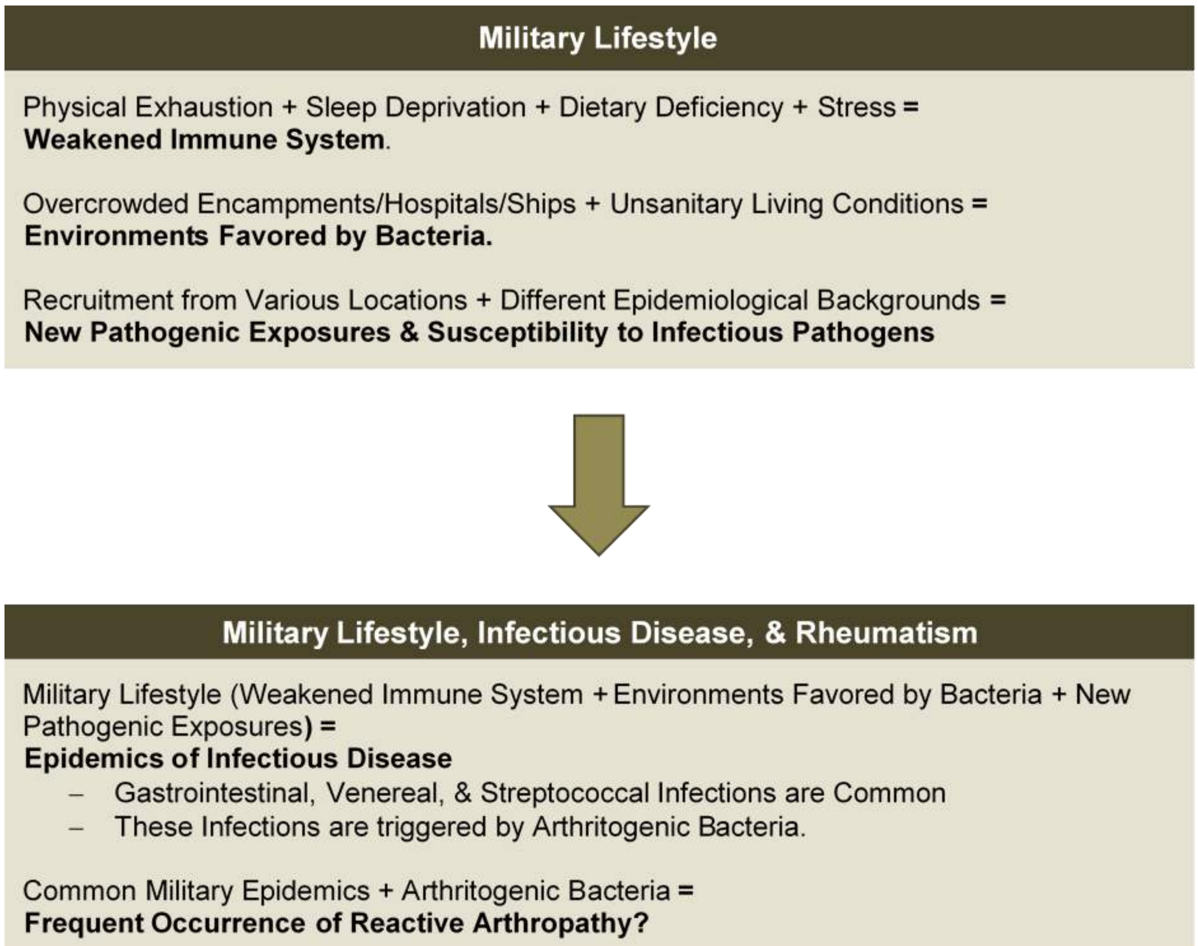
2.4 The Military and Rheumatism

The military lifestyle weakens the immune system and increases combatant's exposure to gastrointestinal, respiratory, and venereal diseases. In light of these circumstances, it is not difficult to see why military epidemics have been a major problem throughout history. Most research into this phenomenon has focused on the high fatalities or the resulting disruption to military efficiency and campaigns. For some combatants, there may have been far more enduring complications resulting from their exposure to military infectious diseases.

Many of the bacterial organisms associated with the diseases discussed in this chapter are known to be arthritogenic. As such, these bacteria are capable of triggering the development of reactive arthropathy. For example, the bacteria that trigger ReA cause the gastrointestinal and venereal infections common to military combatants: *Neisseria gonorrhoeae, Chlamydia trachomatis*, *Salmonella enteritidis, Campylobactera jejuni, Yersinia enterocolitica, Shigella dysenteriae, Shigella flexneri, Escherichia coli* and *Clostridium difficile* (Curry *et al.* 2010; Riddle *et al.* 2008). Another form of SpA that shares a connection to a bacterium associated with military epidemics is PsA, which is associated with tonsillopharyngitis infections triggered by *Streptococcus pyogenes* (Barton & Ritchlin 2005; Carter 2010; Chandran & Raychaudhuri 2010; Gercari & Ferizi 2011; Ritchlin & FitzGerald 2007; Wang *et al.* 1999). Furthermore, *Streptococcus pyogenes* infections are known to trigger ARF, which also qualifies as a reactive arthropathy based on the definition provided in chapter 1 (Bollet 2002; Denny 1994; Gray *et al.* 1999; Hilário & Terreri 2002).

Many of the historical medical practitioners and works discussed in this chapter (Pringle, Lovell, Woodward, *The Medical and Surgical History of the British Army which Served in Turkey and the Crimea During the War Against Russia in the Years 1854-55-56,* and *The Medical and Surgical History of the War of the Rebellion*), along with others, have mentioned cases of rheumatism. In fact, many described rheumatism as being common and a major contributor to medical discharges from service. Since the infectious diseases common to historical combatants are caused by the same bacterial organisms associated with reactive arthropathies like SpA and ARF, it is fair to assume these conditions were present in past military populations (see **Fig. 34**). Indeed, some scholars have previously suggested the possibility of certain reactive arthropathies having an affinity for soldiers (Bollet 2002; Collison 2015; Hodgetts & Espinosa 1990; McSherry 1982). Given the detail in which many historical medical texts describe cases of rheumatism, part of this research will involve identifying potential cases of reactive arthropathies described by historical medical practitioners; as such, many of the authors and works mentioned in this chapter will appear again in Chapter 7. This compilation of sources discussing historical cases of reactive arthropathy will focus on both qualitative data (sound historical descriptions) and quantitative data (number of military versus non-military references) as a means of validating suggestions of a military affinity between reactive arthropathies and military combatants. This data will be analysed and compared against the backdrop of the quantitative data produced in the skeletal investigation of this research.

Figure 34: the diagram below shows the relationships that suggest reactive arthropathies shared an affinity with past military populations. Source: created by the author.



CHAPTER 3:
Research Questions & Objectives

3.1 Primary Research Question & Hypotheses

One of the primary objectives of this research is to obtain quantitative data that can substantiate claims and suspicions that a historical affinity between reactive arthropathies and the military lifestyle are true. The present project seeks to fulfil this objective through the use of historical and bioarchaeological (palaeoepidemiological) research methods. Ultimately, the primary research question can be formally stated as …

PRIMARY RESEARCH QUESTION:
Using quantitative historical and bioarchaeological research methods, can a strong connection between reactive arthropathies and historical military combatants be established? Were reactive arthropathies an occupational hazard to historical military combatants?

For the literature investigation, it was hypothesized that…

Literature Investigation Hypothesis:
Examination of historical military documentation would provide numerous examples of reactive arthritis (ReA) indicating a military affinity for this condition.

ReA was retrospectively diagnosed when medical literature provided references to infectious diseases (dysentery, diarrhoea, and gonorrhoea in particular) being followed by rheumatism (the historical term for arthritis). The quality and quantity of described cases was then evaluated and compared to those of historical non-military references of ReA. This method was used to establishing a basic understanding of the level of affinity between the military lifestyle and ReA.

Upon finding satisfactory results from the literature investigation, the palaeopathological investigation was conducted. For this investigation, it was hypothesized that…

Bioarchaeological Investigation Hypotheses:

1. Examination and comparison of military related skeletal assemblages and control (non-military) skeletal assemblages would demonstrate a markedly higher prevalence of reactive pathology in the military assemblages.

2. A nested case control study would produce a significant odds ratio and Mantel-Haenszel X^2, indicating exposure to the military lifestyle is associated with increased odds for the occurrence of reactive pathology.

While the literature investigation is useful for establishing a baseline opinion on the matter of military affinity for reactive arthropathies, the statistical measures selected for the bioarchaeological investigation were chosen as the best possible means of obtaining definitive data to address the primary research question. If the statistical methods utilized for the bioarchaeological investigation illustrate a discernibly higher prevalence and increased odds for reactive pathology in military skeletal assemblages, then reactive arthropathies can be considered a distinct occupational hazard of historical military combatants. Even if the statistical results prove indiscriminate, reactive arthropathies would remain a hazard faced by historical combatants, but the relationship would not be specific to their occupation; in spite of differing lifestyles, both military and non-miltiary populations faced the same odds for developing reactive arthropathies.

3.2 Secondary Research Questions

If it can be concluded that reactive arthropathies were an occupation hazard to past combatants, this would indicate the relationship between the military lifestyle and infectious diseases had a larger impact than previously considered; an increased potential to develop reactive arthropathy. Assuming this is proven true, new questions become plainly evident in relation to the wider implications of this finding. These questions include…

SECONDARY RESEARCH QUESTIONS:

1. Were reactive arthropathies a hazard to all military groups?
2. What types of reactive arthropathies afflicted past military populations?
3. Does the presence of reactive arthropathy reflect on sanitation practices?
4. Could reactive arthropathies influence the outcome of military campaigns?
5. What medical treatments were available for these conditions?
6. If a military combatant developed a reactive arthropathy like SpA, how would this affect them?
7. If discharged for a rheumatic condition, what did life as a rheumatically 'disabled veteran' entail?

If negative results are obtained through the investigative methods employed, this would lead the investigation in the direction of addressing one main secondary research question: why were there negative results? Negative results could indicate that exposure to arthritogenic bacteria in military and non-military environments were not drastically different. Though historical urban areas were not known to be the most hygienic locations, this would contradict previous scholarly emphasis placed upon the relationship between the military lifestyle and infectious disease. Alternatively, negative results could indicate that intrinsic factors (genetics, age, sex) distorted the results. For example, would a low prevalence of reactive pathology indicate that the population was unaffected by the expected extrinsic factors or could this reflect a low prevalence of HLA-B27 in the historical population?

CHAPTER 4:
Palaeopathology & Previous Bioarchaeological Research

To understand this project's placement among previous palaeopathological and bioarchaeological research, Chapter 4 will evaluate present knowledge pertaining to erosive arthropathies (SpA in particular) and military assemblage research. The first two sections describe the history of erosive arthropathy (EA) research and the common narrative conveyed about the discovery of Reactive Arthritis (ReA). The final sections identify the areas of SpA and military assemblage research that have received the most and least attention in previous research.

4.1 Palaeopathology of EA Classification: Lumpers & Splitters

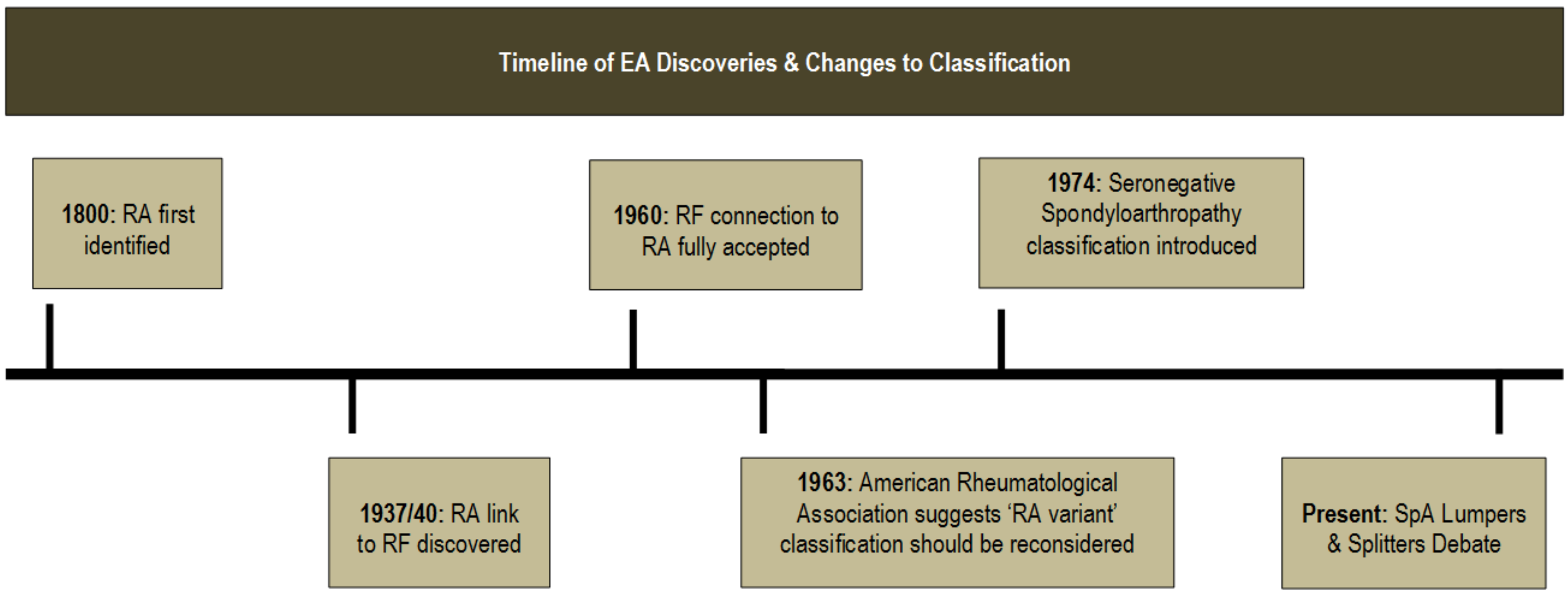
RA was first identified as a distinct condition in 1800 by French physician Augustin Jacob Landré-Beauvais (Waldron 2009). Though RA has been acknowledged as a specific condition since the beginning of the nineteenth century, it was not realized until much later that RA was a separate condition from the SpAs; SpAs were thought of as 'variants' of RA rather than conditions with differing aetiology and pathogenesis (Nash *et al.* 2005; Weissman 2009). RA is strongly linked to the presence of the autoantibody known as rheumatoid factor (RF). The discovery of RF's connection to RA was greatly important to the field of rheumatology, as it would ultimately lead to the separation of RA from the SpAs, but this process took time (Dörner 2004; Waldron 2009).

RF was discovered by Erik Waaler 1937 in an RA patient (Waaler 1940). After experimentation, Waaler published his findings in 1940, but RF's connection to RA remained largely unaccepted until the 1960's (Waldron 2009). As Waldron (2009) points out, one can see the early scepticism leading to slow acceptance by comparing different editions of rheumatology textbooks. For example, in Copeman's Rheumatology textbook, there is no mention of RF until the third edition (1964) and it is not until the fourth edition (1969) that he states the connection between RF and RA is undeniable (Waldron 2009, 48). Once this concept was accepted in the 1960s, clinicians discovered the RA ‘variants’ did not test positive for RF; they were seronegative. This would lead to a new system of classification.

Graham (1960) published the first article to suggest that AS was a separate entity from RA. Not long after, in 1963, the American Rheumatism Association presented the idea of splitting these conditions into separate entities rather than continuing to lump them together as ‘variants’ of RA (Moll *et al.* 1974). This, of course, raised the question of how the former ‘RA variants’ were going to be classified. In 1974, Moll *et al.* introduced the concept that rheumatoid factor negative conditions could be categorized together as Seronegative Spondyloarthropathies (Nash *et al.* 2005). As indicated in Chapter 1, the category of ‘Seronegative Spondyloarthropathies’ encompasses four conditions (AS, ReA, PsA, and EnA). Many clinicians now propose that less splitting and more lumping is necessary (Nash *et al.* 2005). This opinion ultimately results from evidence suggesting there is more similarity between the SpAs than differences (Asquith *et al.* 2014; Carter 2010; Nash *et al.* 2005; Rohekar & Pope 2010). Others continue to favour the traditional use of four specific conditions categorized under the overall heading of SpA, arguing there are enough aetiological differences (for example, the bacterial agents which trigger the conditions) to support this system (McKenna *et al.* 2004; Nash *et al.* 2005).

A timeline of EA discoveries and changes to classification is shown in **Figure 35**. Though the current categorical understanding of SpAs did not come about until the 1970’s, much was already known about these conditions. For instance, it had been realized in the early twentieth century that one of the ‘rheumatoid variants’ was connected to bacterial infections.

Figure 35: EA discoveries and changes to classification over time. Source: created by the author.



4.2 Palaeopathology of Reactive Arthropathies: The Common Rendition

ReA is the emblematic example of a reactive arthropathy. Acknowledgment of this condition's discovery is often noted to have occurred in 1916 (Berquist 2012; Bhan 2008; Elgazzar 2004; Gaston 2012; Hoch 2013; Jevtic & Pullicino 2005; Waldron 2009), but this is not the case. It has long been known that arthritis can follow certain infections, as historical medical documentation frequently mentions this. Though historical physicians wrote of this connection, they expressed great confusion in their discussions because there was no strong explanation as to how conditions of the bowels and genitals could result in rheumatism (Harty 1805; Huette 1869; Stillé 1864). As germ theory did not begin to gain acceptance until the late 1860s, their confusion is understandable. Despite the lack of satisfactory explanation for the dysenteric/venereal disease connection to rheumatism, many physicians accepted the relationship's validity and began noting its common features, which are quite clearly descriptions of ReA. There has been very little discussion of these pre-1916 references. This research will rectify this in Chapter 7, but the present section is focused on providing the common rendition presented in many rheumatology and palaeopathology texts.

It is interesting that wide medical recognition of ReA (and the concept of reactive arthropathies) occurred in 1916 in relation to cases observed in World War I military combatants. It is no secret that times of war frequently correlate with medical advancements. A large amount of sick and wounded generates urgency for successful and more efficient means of aiding the afflicted; there is also no shortage of subjects for medical experimentation and observation (Connolly & Heymann 2002; Kahn 2014). During World War I, rheumatology was one of many fields to make great medical advancements. Survivable wounds left behind horrendous injuries to bone, which encouraged the development and testing of new rehabilitative techniques (Kahn 2014). Physical activities of combatants frequently caused lower back pain, which lead to the discovery of disk impingement (Kahn 2014). By far the most notable advancement in rheumatology in World War I, was the scientific identification and description of the condition ReA (Kahn 2014; Pasero & Marson 2007).

This discovery was part of a great debate, as the same condition was discovered and almost simultaneously published by physicians on opposing sides of the war. Among the Axis powers, there was Hans Reiter (see **Fig. 36**) who served in the First Hungarian Army on the Balkans Front. With the Allied powers, there was the team of Nöel Fiessinger and Edgar Leroy, who were studying bacillary dysentery among French troops at the Somme (Hodgetts & Espinosa 1990; Iglesias-Gammara *et al.* 2005; Kahn 2014; Pasero & Marson 2007; Weinberger *et al.* 1962).

Figure 36: Hans Reiter (1881-1969). Source: Hodgetts & Espinosa 1990.

Reiter dominated the battle for priority, as what is now called ReA was once known as ‘Reiter’s Syndrome.’ In a cavalry lieutenant, Reiter described what would become known as the classic triad of symptoms for Reiter’s Syndrome/ReA: conjunctivitis, urethritis, and arthritis (Pasero & Marson 2007; Wu & Schwartz 2008). To later students studying the disease, it was the syndrome where one ‘‘can’t see, can’t pee, and can’t climb a tree’’ (Wu & Schwartz 2008, 113). Reiter's, findings were published on 14 October 1916 in the well-known publication *Deutsche Medizinische Wochenschrift* (Kahn 2014; Pasero & Marson 2007). Though realizing a bacterial agent was involved, Reiter mistakenly identifed the bacterium as a spirochete bacterium, which he called *Spirochaetosis arthritica* (Kahn 2014, 384; Hodgetts & Espinosa 1990). Despite this mistake, the name ‘Reiter’s Syndrome’ became popular for the triad (Kahn 2014). Reiter did much to push his own name forward as the first to describe this particular condition, with effective results; however, in reality, he was not the first (Kahn 2014; Pasero & Marson 2007).

Three days before Reiter’s work was published, another publication was made by Fiessinger and Leroy in *Société Médicale des Hopitaux de Paris*. They described the same triad of symptoms (conjunctivitis, urethritis, and arthritis) in two medical officers of the French Army, naming the condition “oculo-urethro-synovial syndrome” (Kahn 2014; Pasero & Marson 2007). Furthermore, unlike Reiter, they attributed the symptoms to the correct infectious agent, dysenteric bacteria (Kahn 2014). Though their priority and accuracy was pointed out by scholars, Reiter’s name remained predominantly associated with the condition, most likely due to his own assertions of seniority and the fact his article was printed in a more renowned publication (Kahn 2014; Pasero & Marson 2007).

Though the name Reiter’s Syndrome persisted for some time, it was later put aside in favour of ‘reactive arthritis’ (ReA). In part, this was late recognition that Reiter had not been the first to describe the ReA triad, but the change was primarily due to Reiter’s actions in World War II. Once again, Reiter stood with Germany when the world went to war, becoming a high ranking officer in the Nazi Party (Kahn 2014).

Reiter carried out criminal experiments on deportees and “was involved with or knowledgeable of involuntary sterilization and euthanasia undertaken by the Nazi regime. He also played an active role in the design of a study that inoculated concentration camp internees at Buchenwald with an experimental typhus vaccine, which resulted in hundreds of deaths” (Wallace & Weisman 2003, 208; Kahn 2014). Reiter was arrested in May 1945 and sent to Nuremberg where he was incarcerated for some time. Before going to trial, Reiter was released in 1947 for reasons restricted from records (Wallace & Weisman 2003). Reiter returned to the medical field, but, for his war crimes, his name was banned from the list of honorary members of the American College of Rheumatology and it has been generally agreed that the name ‘Reiter’s Syndrome’ should not be used in reference to ReA unless discussing or quoting earlier publications (Wallace & Weisman 2003; Kahn 2014).

Though other conditions later identified as SpAs (AS and PsA) were known in 1916, their connection to bacterial infections had not yet been realized. This makes ReA the first widely acknowledged reactive arthropathy. As stated in this common rendition, Reiter, Fiessinger, and Leroy are commonly given credit for the discovery of ReA; however, they were far from the first. Occasionally, publications attribute the discovery of ReA to another physician, Benjamin Brodie, who describe the ReA triad in 1818 (Edwards & Solomon 2010; Scott & Kingsley 2013; Waldron 2012). This less frequent rendition is closer to the truth, but it will later be shown that Brodie was preceded and followed by many others before Reiter, Fiessinger, and Leroy.

4.3 SpA Research in Bioarchaeology

To better understand the focus of past research in the fields of bioarchaeology and palaeopathology in relation to EAs, a literature review of key journal publications[2] was conducted. This review took place in the early stages of this project as a means of identifying topics most commonly discussed in relation to EAs. The present project's placement within the historiography of EA research in bioarchaeology and palaeopathology was then considered.

In the literature review, 29 articles were found to discuss EAs in skeletal material. Each article was classified using four descriptive labels: report on encountered cases, pathology study, antiquity debate, and prevalence study; some articles received more than one label. Articles labelled as 'reports on encountered cases' presented information about newly encountered skeletons exhibiting erosive pathology. This category had the highest count (13 articles). The next category, 'pathology study,' (11 articles) consists of articles that were primarily focused on describing, identifying, and recording particular types of erosive pathology; typically, these articles were aimed at easing differential diagnosis between EAs. Articles labelled as 'antiquity debate' (9 articles) deliberate the origin of RA, questioning if it is a new or old world disease. The final category, 'prevalence study,' was the least common (6 articles) and included articles that reported the statistical frequency of particular EAs in skeletal assemblages. The titles and labels of these publications can be found in **Table 8**.

[2] Specific searches were carried out on the following journal publications: *The International Journal of Palaeopathology; The International Journal of Osteoarchaeology; The American Journal of Physical Anthropology; The Journal of Rheumatology; Rheumatology International; Joint, Bone, Spine; Annals of the Rheumatic Diseases*. General searches of online scholarly databases were also conducted.

Table 8: This table shows 29 key articles that discuss EAs in skeletal material. The articles were categorized with the following labels: report on encountered cases (13), pathology study (11), antiquity debate (9), and prevalence study (6). It should be noted that some articles received more than one label. Source: created by the author.

Erosive Arthropathies in Bioarchaeological Literature		
Articles: Rheumatoid Arthritis		**Type of Study**
1	**Rothschild, 2001.** Rheumatoid Arthritis at a Time of Passage.	Antiquity Debate
2	**Aceves-Avila *et al.* 2001.** The Antiquity of Rheumatoid Arthritis: A Reappraisal.	Antiquity Debate
3	**Thould & Thould, 1983.** Arthritis In Roman Britain.	Report on Encountered Cases
4	**Mckinnon *et al.* 2013.** A Probable Case of Rheumatoid Arthritis from the Middle Anglo-Saxon...	Antiquity Debate Report on Encountered Cases
5	**Inoue *et al.*, 1999.** Erosive Peripheral Polyarthritis in Ancient Japanese Skeletons…	Antiquity Debate Prevalence Study
6	**Blondiaux *et al.*, 1997.** Two Roman and Medieval Cases of Symmetrical Erosive Polyarthropathy from Normandy…	Antiquity Debate Report on Encountered Cases
7	**Hacking *et al.*, 1994.** Rheumatoid arthritis in a medieval skeleton.	Report on Encountered Cases
8	**Rothschild *et al.*, 1997.** Identification of Childhood Arthritis in Archaeological Material …	Pathology Study
9	**Waldron *et al.*, 1994.** Rheumatoid Arthritis in an English Post-Medieval Skeleton.	Report on Encountered Cases
10	**Rothschild *et al.*, 1990.** Rheumatoid Arthritis "In The Buff"…	Pathology Study
11	**Kim *et al.* 2011.** Possible Rheumatoid Arthritis Found in the Human Skeleton Collected from the Tomb of Joseon Dynasty, Korea, Dating Back to the 1700s AD.	Antiquity Debate Report on Encountered Cases
Articles: Spondyloarthropathy		**Type of Study**
12	**Samsel *et al.* 2014.** Palaeopathological Diagnosis of Spondyloarthropathies…	Pathology Study
13	**Hagihara *et al.* 2015.** Severe Erosive Polyarthritis in a Human Skeleton Dated to the Early Modern Period of Japan.	Report on Encountered Cases
14	**Šlaus *et al.*, 2012**. Four Cases of Ankylosing Spondylitis in Medieval Skeletal Series from Croatia.	Prevalence Study
15	**Martin-Dupont *et al.*, 2006.** Spondylarthropathy Striking Prevalence in a 19th-20th Century Portuguese Collection.	Prevalence Study
16	**Waldron & Rogers, 1990**. An Epidemiologic Study of Sacroiliac Fusion in Some Human Skeletal Remains.	Pathology Study
17	**Arriaza, 1993.** Seronegative Spondyloarthropathies and Diffuse Idiopathic Skeletal Hyperostosis in Ancient Northern Chile.	Antiquity Debate Prevalence Study

18	**Inoue *et al*., 2005**. A Possible Case of Spondyloarthropathy in a Prehistoric Japanese Skeleton.	Report on Encountered Cases
19	**Zias & Mitchell, 1996.** Psoriatic Arthritis in a Fifth-Century Judean Desert Monastery.	Pathology Study Report on Encountered Cases
20	**Rothschild *et al*., 1999.** Spondyloarthropathy Identified as the Etiology of Nubian Erosive Arthritis.	Antiquity Debate Prevalence Study
21	**Rothschild & Woods, 1991.** Spondyloarthropathy: Erosive Arthritis in Representative Defleshed Bones.	Pathology Study
22	**Tersigni-Tarrant & Zachow, 2010.** Antemortem Pathological Changes Suggestive of Reactive and Degenerative Arthritic Disorders.	Report on Encountered Cases
23	**Rogers *et al.* 1985** Palaeopathology of Spinal Osteophytosis, Vertebral Ankylosis, Ankylosing Spondylitis, and Vertebral Hyperostosis.	Pathology Study
24	**Rothschild *et al.* 2004.** "Like a virgin"…	Antiquity Debate Pathology Study Prevalence Study
25	Cawley **& Paine 2015.** Skeletal Indicators of Reactive Arthritis…	Report on Encountered Cases Pathology Study
Articles: General EA Related		**Type of Study**
26	**Rogers *et al.* 1987.** Arthropathies in Palaeopathology…	Pathology Study
27	**Minozzi *et al.* 2013.** A Case of Gout from Imperial Rome.	Report on Encountered Cases
28	**Rogers *et al.* 1991.** Erosive Osteoarthritis in a Medieval Skeleton.	Report on Encountered Cases
29	**Rothschild & Heathcote, 1995**. Characterization of Gout in A Skeletal Population Sample…	Pathology Study

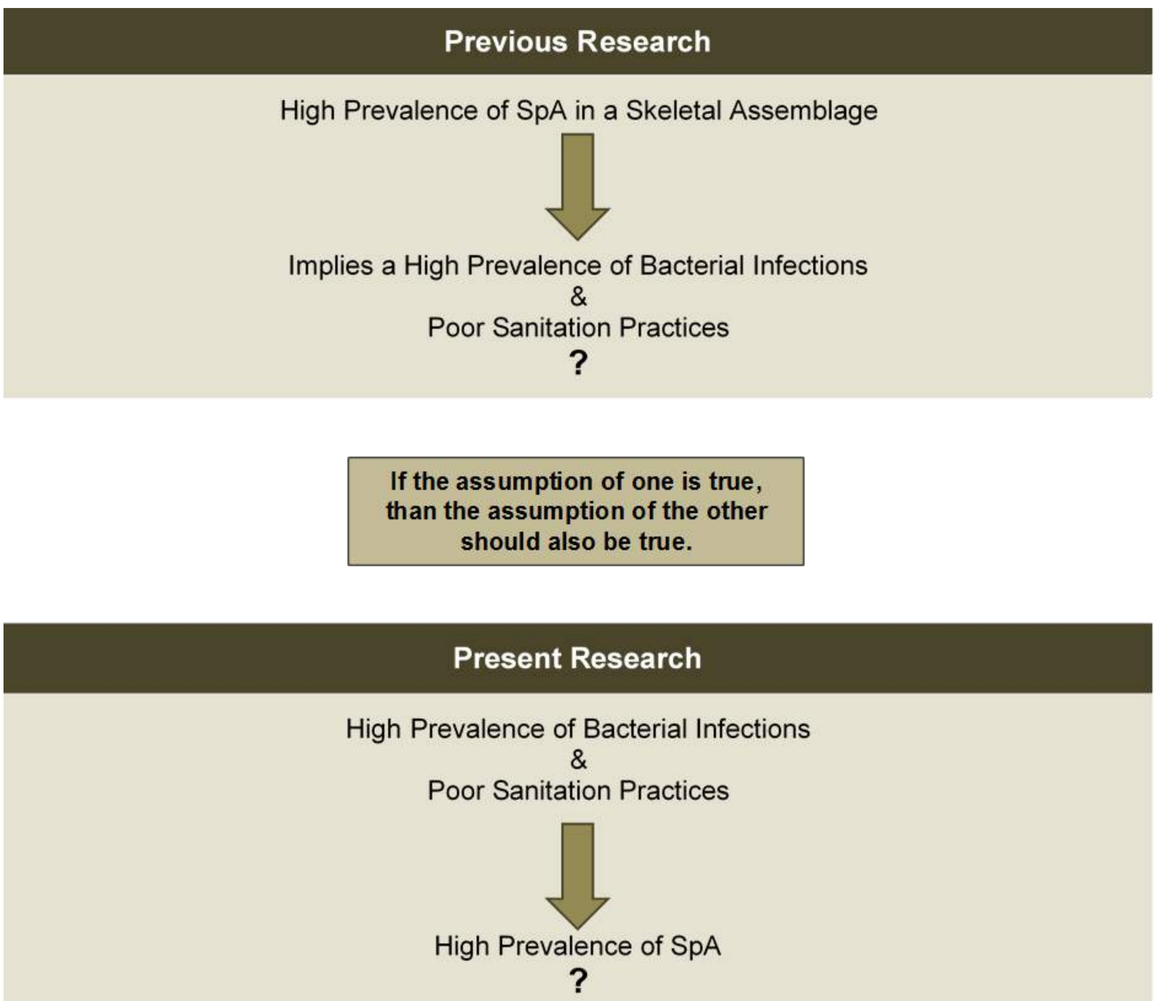
The present project certainly covers all of the descriptive categories of the literature review, with the exception of the antiquity debate, as RA is not a primary condition of interest outside of differential diagnosis. Much information has already been provided in relation to the pathology and pathogenesis of EAs (especially SpA) and newly encountered cases will later be reported. Though new reports on encountered cases and analysis of pathology are important, this project is primarily a prevalence study, which is the area of least focus in relation to past EA research.

Prevalence studies are of particular importance in palaeopathology. Their main goal is to identify the frequency of a given condition and look for trends that, ideally, allow for sound interpretations to be made about that condition in the past. Though the majority of the prevalence studies listed in **Table 8** pertained to SpA (5 out of 6), this can hardly be considered a large body of data. Furthermore, of the 5 articles mentioning SpA prevalence, this was only a major focus in 3 articles: Arriaza (1993), Martin-Dupont *et al.* (2006), and Rothschild *et al.* (2004).

Rothschild *et al.* (2004) investigated the prevalence of SpA to evaluate sanitation practices among ancient Italians. They did not find a significant prevalence of SpA, so Rothschild *et al.* (2004) concluded there were no major sanitary challenges in ancient Italy. Arriaza (1993) noted that there was a high occurrence of SpA cases in a prehistoric skeletal assemblage from northern Chile; 7.4%, with a minimum of 4.4% when only highly diagnostic cases were considered. Arriaza (1993) concluded the result likely indicated a high occurrence of infectious diseases in ancient northern Chilean societies. Similar to Arriaza (1993), Martin-Dupont *et al.* (2006) noted a high occurrence of SpA in a 19th–20th century Portuguese assemblage and decided to investigate this statistically, finding a prevalence of 6.7% for definitively diagnosed cases. They too concluded the results indicated the potential for "high exposure to infectious triggers" (Martin-Dupont *et al.* 2006, 309).

It is apparent that past bioarchaeological publications have used the reactive nature of SpA to interpret their results. Sanitation practices and rates of infectious diseases were unknown factors in past bioarchaeological investigations, but researchers made the prior assumption that the prevalence of SpA depends on these factors and can thus be used to interpret the historical state of infectious diseases (high or low) and sanitation practices (poor or sufficient) in past societies. The current project works in a slightly different manner, as the rate of infectious disease and state of sanitation practices are not unknown factors for military assemblages; infectious diseases were common and sanitation practices were generally poor. What is not known, is whether reactive arthropathies (like SpA) were more prevalent in historical military groups as a direct consequence of these exposures. In this sense, the present project is testing the rationale/prior assumptions made in previous research to interpret their findings relating to SpA prevalence. If the present research confirms reactive pathology is prevalent in historical groups known to inhabit unsanitary environments with a high occurence of infectious diseases, then the interpretations made by previous researchers should also be considered sound (see **Fig. 37**).

Figure 37: the diagram below shows the direction of prior assumptions made by past and present research relevant to SpA prevalence. The present project works in the opposite direction of past research. If the assumptions of previous research are true, then the assumptions of the present research should also prove true. In this sense, confirmation of the present research hypotheses will provide validation for the assumptions made by past researchers. Source: created by the author.



4.4 Military Assemblage Research in Bioarchaeology

Though past groups of people are referred to as a 'population' (as is occasionally done in this research), it is important to note that a skeletal assemblage is different from a true 'population' (Waldron 2007). A population is made up of living members of a particular group, but this is obviously not the case of skeletal remains found in burial contexts. In the case of bioarchaeological research, use of the term 'population' usually signifies a subset of non-living individuals that once belonged to a particular living population in the past. The problem with bioarchaeological subsets of populations is they are not truly representational of the living population in which they once belonged (Waldron 2007). For a skeletal population to be truly representational of its once living population, the dead would need to be *randomly* selected (killed) out of the living population, but there is very little random about death and burial. Death is not completely random, as some are at higher risk than others, a fact which is often expressed in the age distribution of skeletal assemblages. For instance, in archaeological skeletal assemblages, there is often a tendency for ages to be skewed towards having many young and old individuals, meaning the middle-aged individuals are underrepresented (Waldron 2007). Burial is even less random than death, as "there is little randomness about the place in which one is buried, this being determined by place of domicile, religious beliefs, and social mores, among other factors" (Waldron 2007, 28). Why is this relevant to the study of military skeletal assemblages? Military skeletal assemblages represent their living populations in a different manner than cemetery burial contexts.

Many military assemblages come from mass grave burial contexts, which are unique. As death due to battle or disease epidemics occur suddenly and kill many, rapid body disposal is necessary. In such instances, the death of individuals would be reasonably random. Burial is still not completely without bias, as high-ranking individuals are often provided separate burials from that of the common soldier. Even so, military mass graves are still a cross section of the largest portion of the living military group. Another unique feature of these contexts pertains to time. Individuals buried in mass graves allow precise points in history to be examined, as the individuals would have died at roughly the same time; this is opposed to normal cemetery assemblages where individuals are deposited into their burial context over long periods of time. Finally, military assemblages are male prominent, which could be useful for certain research projects. For these reasons, military mass graves offer unique potential for specifics relating to sex, time, and population representation. Despite these unique qualities, studies conducted on military assemblages are not overly diverse.

The traditional concentration on military assemblages has been on trauma and cause-of-death analysis (Jankauskas *et al*. 2011); some examples include: Constantinescu *et al.* 2015; Cunha and Silva 1997; Kępa *et al.* 2011; Kjellström 2005; Liston and Baker 1996; Mitchell *et al.* 2006; Meyer 2003; Novak 2007; Roksandic *et al.* 2007; Wescott *et al.* 2012; Willey and Scott 1996. The focus on trauma and cause-of-death analysis in military assemblages is important. Whenever possible, understanding the circumstances that surround death is of key concern and, in the case of military remains, violence is likely, so trauma analysis will always be of high priority.

Though trauma analysis is far from unimportant in military assemblages, there are other biological and pathological features of value (Jankauskas *et al.* 2011). Examination of trauma-focused articles (like those listed previously) indicate that common themes revolve around the type of weaponry used, styles of fighting, types of medical intervention used at particular periods of time/battles, and cause of death. Of the relatively few articles focused outside of trauma analysis in military assemblages, it is evident there is less emphasis on the circumstance of *death* and more focus on the manner in which they *lived*. For example, non-trauma related articles frequently focus on skeletal markers and what they may indicate in relation to military activities. Stirland and Waldron (1997) conclude that the level of degenerative changes in the spines of the relatively young individuals recovered from the *Mary Rose* were, “due to activities undertaken on board the ship” (335). This provided further reflection on recruitment habits of the sixteenth century Navy, as the age of the individuals and the amount of degeneration suggested that many, “must have been recruited as adolescents” (see **Fig. 38**) (Stirland & Waldron 1997, 335).

Figure 38: the photo below displays part of the thoracic and lumbar spine from an individual from the *Mary Rose*. This was a young individual as indicated by the unfused epiphyses (arrows). Despite the young age of the individual, several indications of degeneration are present, including: Schmorl’s nodes (arrow heads) and vertebral body compression. Source: Stirland & Waldron 1997, 331.

Non-trauma related research has also focused on evaluating biological features that could indicate military affiliations. For example, Steegmann (1986) discovered that the height of 14 soldiers discovered at Ft. William Henry (1755 – 1757) were taller than the average height recorded for provincial soldiers in 1760; their variation in height was also significantly lower than the provincial soldiers from 1760. Steegman (1986) suggests this cemetery was dedicated to a select, specialized group within the military. This conclusion is supported by the historical knowledge that armies, including those of the eighteenth century, had “grenadier companies,” which included members specifically selected for features such as height to produce “maximum intimidation” (Steegman 1986, 435).

Other researchers have used military assemblages to interpret enlistment strategies. Palubeckaitė *et al.* (2006) examined a mass grave in Vilnius, Lithuania from Napoleon's Grand Army and found the dentition of the Vilnius assemblage had a lower prevalence of linear enamel hypoplasia than other contemporary assemblages. One interpretation provided by Palubeckaitė *et al.* (2006) included the possibility that high standards for conscription were used for Napoleon's Grand Army, selecting "only the healthiest individuals without diseases and bodily deformities" (363).

Other studies have occasionally focused on infectious disease. It was mentioned in the Introduction that the bioarchaeological exploration of military infectious diseases has been limited. Since infectious diseases do not cause direct skeletal changes, it is not uncommon for bone reports of military assemblages to note very little about these conditions (Coughlan & Holst 2007; Jankauskas et al. 2011; Scott *et al.* 1998; Stirland 2013). Bioarchaeological contributions have been limited to the few infectious diseases that leave skeletal changes (such as Tuberculosis and Syphilis) or to providing secondary evidence suggestive of ideal environmental conditions for infectious disease. For instance, Palubeckaitė *et al.* (2006) states that dental status can be used as an indicator of diet and hygiene. They found the men of Napoleon's Grand Army had been recruited from 'good stock,' but the, "substantial amount of pulp caries and a high number of carious teeth in some individuals suggest increased vulnerability to disease" (Palubeckaitė *et al.* 2006, 316). They further state this supports historical accounts that the diet of these combatants was of poor quality and that, "individuals with a poor immune system and/or who are exposed to frequent stresses are more susceptible to caries and other oral diseases. Poor sanitation in camps, long marches with heavy loads, and the poor quality of diet could make individuals less resistant to oral disease and increase the rate of caries" (Palubeckaitė *et al.* 2006, 362). These conditions help explain the oral pathology they observed, but are also ideal conditions for the occurrence of infectious diseases.

It is rare for bioarchaeologists to be provided with direct evidence of conditions such as dysentery, diarrhoea, typhoid, and typhus, but Raoult *et al.* (2006) is one such example. They examined a mass grave in Vilnius, Lithuania from Napoleon's Grand Army. Some remains of clothing were recovered from the grave, along with segments of body lice. Through DNA testing of the lice, they identified the presence of *Borrelia recurrentis, Bartonella quintana,* and *Rickettsia prowazekii.* These bacteria all cause trench fever and typhus (see **Fig. 39**). This finding was used to support their conclusions that "louse-borne infectious diseases affected nearly one-third of Napoleon's soldiers buried in Vilnius and indicate that these diseases might have been a major factor in the French retreat from Russia" (Raoult *et al.* 2006, 112).

Figure 39: an example of lice recovered from the remnants of clothing discovered in the Vilnius mass grave assemblage. Source: Raoult *et al.* 2006, 116.

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Non-trauma related studies have demonstrated their potential value to understanding the lives of past military groups and should serve as encouragement for similar research. As previously discussed, the present project focuses on the military connection to infectious disease by questioning its potential consequence - the development of reactive arthropathy. With this objective, this project can be counted among the non-trauma related bioarchaeological research into military assemblages. As this approach has not been previously utilized, this research provides a new tactic in which military infectious disease can be explored through bioarchaeological means.

4.5 Summary on Project Placement

The palaeopathology of EA classification indicates early understanding of RA and SpA was complicated by basic similarities. This information will later prove important to a case study examined in Chapter 10. The background on the common narrative told about ReA's discovery is necessary information for Chapter 7, which reveals that the history of this condition is far older and more complex than is normally indicated. Finally, sections 4.3 and 4.4 demonstrate the bioarchaeological placement of this project in relation to SpA and military assemblage research.

CHAPTER 5:
Materials

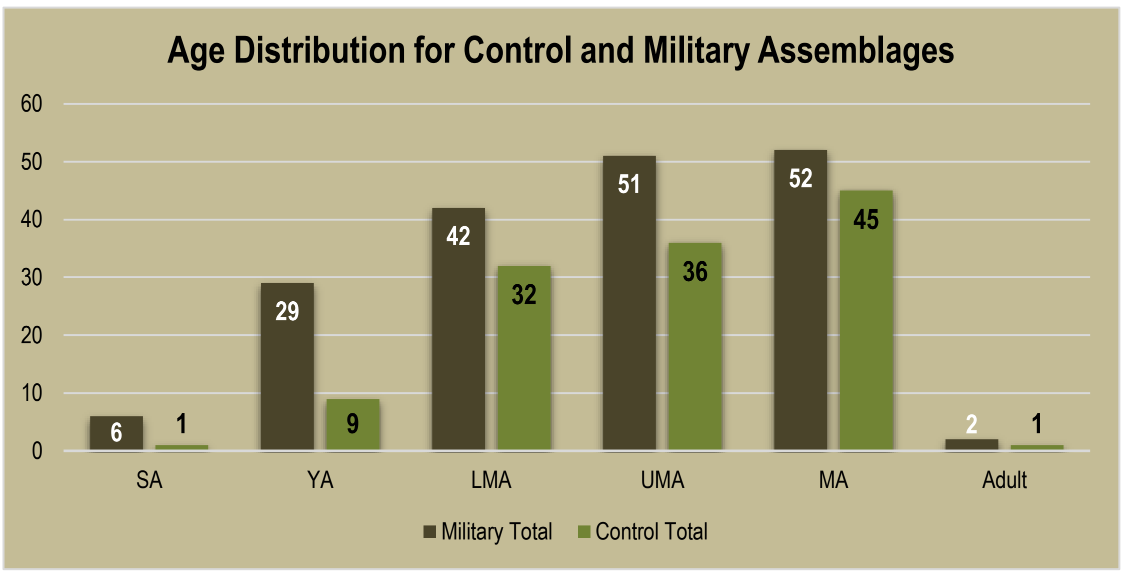
5.1 Assemblage Selection

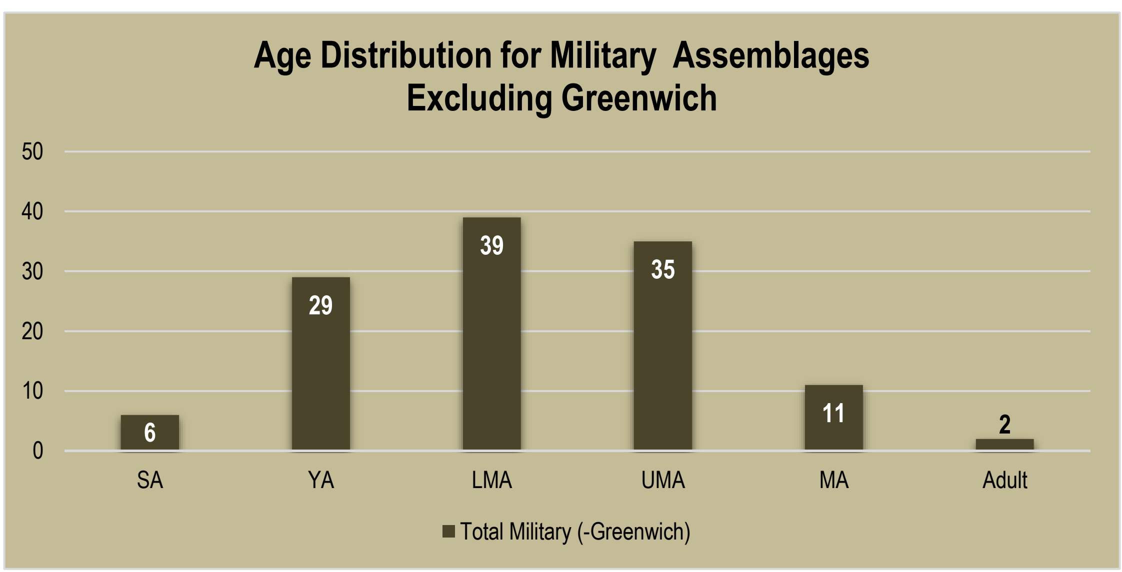
Military assemblages were selected based on them having a background of army or naval service. The burial context of several assemblages were mass graves, including remains from the 1461 Battle of Towton and the 1644 Siege of York. The remaining military assemblages were cemetery contexts from the Stonehouse Royal Naval Hospital in Plymouth and the Royal Hospital Greenwich; both date to the late eighteenth and early nineteenth centuries. These military assemblages were matched with non-military (control) assemblages with comparable dates.

The sex (all male and questionable males) and age demographics of the control assemblages were matched with the military assemblages to the best possible degree. Sex was not difficult to accommodate, but age proved a bit challenging, as archaeological cemetery assemblages tend to be skewed towards the extremes (Waldron 2007). Due to high infant mortality rates, the number of very young individuals is often quite high, as are the number of older individuals, but the middle age ranges are underrepresented by comparison (Waldron 2007). Military skeletal assemblages do the opposite. They contain mostly young to middle-aged adults, but the very young and old are underrepresented. For example, a mass grave of Mexican soldiers who died at the battlefield of Resaca de la Palma predominantly consisted of individuals between 20 and 34 years of age (Wescott 2012). A mass grave of soldiers from Napoleon's Great Army in Vilnius, Lithuania also predominantly consisted of individuals in their 20's (Signoli *et al.* 2004).

With these differences in mind, attempts were made to match the age distributions by examining all male and questionable males available in the lower age categorizations of control assemblages, then randomly selecting numbers from the older categories as necessary to round off the numbers. It should be noted, that all skeletons previously recorded as having spinal fusion, SIJ fusion, or erosive pathology were examined no matter their age categorization. The age demographic for the collective military and non-military assemblages can be seen in **Table 9**; as one can see, the Young Adult categorization was difficult to match due to the differing nature of the assemblages.

Table 9: the top table shows the age distribution for military and control (non-military) assemblages. The Royal Hospital Greenwich assemblage is unique, as it predominantly consisted of older individuals. As such, the top table does not show a typical age distribution for military assemblages. The Greenwich data was removed from the bottom table to show a typical military age distribution. The age categories are Sub Adults (SA) 12-15, Young Adult (YA) 16-25, Lower Middle Adult (LMA) 26-35, Upper Middle Adult (UMA) 36-45, Mature Adult (MA) 45+. Source: created by the author.





The background of each military and control assemblage selected for this research will be discussed in this chapter, but a few details relating to assemblage selection should be noted first. To start, the two naval assemblages (Plymouth and Greenwich) were specifically selected for their unique age distributions. This project largely tests the effects of extrinsic factors, as it has been designed around the assumption that certain arthropathies will be highly prevalent in military populations due to environmental exposures that make arthritogenic bacteria common. This does not mean intrinsic factors are not of interest, as it was highly suspected that age may affect the results obtained in the skeletal investigation.

As mentioned in Chapter 1, reactive arthropathies like SpA most commonly affect younger individuals (mid to late 20's) and symptoms of these conditions make themselves known just a few weeks after the initial triggering infection (Feldtkeller *et al.* 2003; Skare *et al.* 2012). Though SpA has a young age of onset and symptoms are noticed quickly, skeletal changes may take months or even years to develop in a manner that is highly diagnostic; in modern clinical cases, there is often a considerable delay between disease onset and official diagnosis (Chakravarty *et al.* 2014; Cunningham 2014; Feldtkeller *et al.* 2003). The bulk of military populations (past and present) are represented by young adults. When examining the history of military recruitment, it becomes apparent that British policy often dictated that men between the ages of 16 and 60 were eligible for service, but younger men of this range were preferred (Gaunt 2014; Mercer 2010). As previously mentioned, this pattern is often reflected in military skeletal assemblages. Since time is needed for SpA to develop clear diagnostic skeletal changes (in spite of early age of onset), the young age distribution often seen in military skeletal assemblages could be problematic; if an individual died young (relatively soon after disease onset), the skeletal changes may be too underdeveloped for bioarchaeologists to classify (Feldtkeller *et al.* 2003).

To investigate how the intrinsic factor of age may have influenced the identification of reactive pathology, the Greenwich assemblage was selected for direct comparison with the Plymouth assemblage. Both assemblages consist of naval marines and sailors who fought in the Napoleonic Wars, making the assemblages a perfect match minus one important feature: age distribution. The Stonehouse Royal Naval Hospital in Plymouth serviced men who were wounded or became ill during active service, so individuals who died at the hospital were often quite young; many died at ages younger than 25 (Davis 2011). Conversely, the Royal Hospital Greenwich was specifically for Royal Navy pensioners (Boston *et al.* 2008). For their service, retired (and often disabled) Navy men were allowed to live at the hospital and, upon their death, were provided burial in the hospital cemetery (Boston *et al.* 2008). As such, the Greenwich men are considerably older than the men who were buried in the Plymouth cemetery, yet they participated in the same military occupations and conflict. The similarity shared by these assemblages made them appropriate for assessing the influence of the intrinsic factor of 'age,' as their environmental exposures should have been similar. Any marked difference in the number of diagnosed cases of reactive pathology between these assemblages would indicate that age does influence the process of identifying reactive pathology in skeletal material.

Another feature to note about assemblage selection is the sole use of British military skeletal assemblages. This was not out of design. Based on the literature investigation of this project, it was deemed that skeletal assemblages from British and American conflicts would be appropriate. Obtaining access to U.S. military assemblages proved difficult, as military remains are frequently reburied and are not retained in research collections. Since research collections housing military remains were difficult to come by, attempts were made to access U.S. military assemblages that were actively being researched while this project was underway, but these requests were never granted.

A similar pattern was seen in European assemblages as well, where discovery, excavation, research, reburial, and memorialization happen in a relatively short window of time (Jankauskas *et al.* 2011). The remains of military combatants often serve as symbols with social and political meaning (Hawley 2005; Sledge 2007). As wars are often predominant events in history and associated with collective memory, war dead are capable of evoking strong emotions, which means there are many ethical considerations involved in the study of their remains (González-Ruibal *et al.* 2015). Human remains from conflicts only a few generations removed have greater ethical considerations, which determine the type and duration of research deemed acceptable (O'Sullivan 2001). Typically, remains from World War I onward will be treated as forensics cases, where identification and repatriation are of primary concern (Jankauskas 2011). Older conflicts, where positive identification is unlikely, are easier to negotiate in a manner which allows for bioarchaeological/palaeopathological research. For the present project, this pattern translated into access only being granted for skeletal assemblages predating 1850. Fortunately, the U.K. has several military assemblages retained or currently open for research, which provided ample data for this project.

5.2 Background on Selected Assemblages

The present section provides information about the control and military skeletal assemblages selected for this research. The control assemblages are discussed first, which includes the All Saint's Church, Chelsea Old Church, and St. Brides Lower assemblages. Military assemblages are then discussed and includes the Towton, York Mass Grave, Plymouth, and Greenwich assemblages.

5.2.1 All Saint's Church (Medieval)

The medieval All Saint's Church cemetery, which was located just outside the old city walls at Fishergate, York was selected as a control assemblage for Towton. The All Saint's Church cemetery would have been in use during the early years of the War of the Roses, including 1461 when the Towton battle occurred. The church was constructed as a residence for monks in 1091 and was in constant use until 1539 when Henry VIII called for the dissolution of monasteries (McIntyre & Bruce 2010).

Sometime after the church was abandoned, its location was lost and a cattle market was unknowingly constructed on the old church grounds in 1820. This meant the church's location was not lost for long, as contemporary reports state that bones were disturbed by the trampling of cattle (McIntyre & Bruce 2010). Based on this information, excavations were conducted in 2007 before beginning a redevelopment project (McIntyre & Bruce 2010). They expected to find the remains of the medieval church and cemetery, which proved to be true, but they also discovered a mass grave dating to the English Civil War (the York Mass Grave assemblage later discussed).

One of the most interesting medieval burials uncovered from this cemetery belonged to the anchoress described in the introduction of this work, who may be the remains of Lady Isable German (see **Fig. 40**) (McIntyre & Bruce 2010). With this exception, no other possible individual identifications were made and the skeletal assemblage recovered from the cemetery exemplified people of average status living in a medieval urban location (McIntyre & Bruce 2010). A total of 550 medieval burials were discovered during excavation. As expected of a church with a long usage (about 400 years), many of the later graves cut into those of earlier burials, but most graves contained a single set of prone extended remains (McIntyre & Bruce 2010). Such an ‘average’ assemblage was appropriate for comparison with Towton, as the majority of men fighting in the War of the Roses would have come from rather average backgrounds.

Figure 40: this medieval illustration shows an anchoress within her sealed room, with the only access to the outside world being a small window. Source: Hughes-Edwards 2012.

5.2.2 Chelsea Old Church (OCU00)

Chelsea in the early eighteenth century was a rural location despite close proximity to the city of London; it held about 300 houses surrounded by fields, market gardens, and orchards (Cowie *et al.* 2008). By the mid-eighteenth century, Chelsea had become a popular escape from the busy city of London (Cowie *et al.* 2008). Though the majority of the populous residing in Chelsea were of high social status, some were rather poor, as a workhouse was established here in 1737 (Cowie *et al.* 2008).

Excavations of the northern churchyard of Chelsea Old Church (see **Fig. 41**) began in 2000. The excavated graves dated from the eighteenth to the mid-nineteenth century (Cowie *et al.* 2008). The cemetery mainly consisted of upper-class individuals, though the workhouse also had parishioners at Chelsea Old Church (Cowie *et al.* 2008). Coffin plates were found with some of the burials, which allowed 19 of these individuals to be identified. In all, 290 sets of remains were recovered, with only 16.7% of that representation being subadults (Cowie *et al.* 2008). Of the adults, 75 were sexed as males or questionable males (Bekvalac & Kausmally 2005).

The men of the military skeletal assemblages examined for this research came from lower or middle socioeconomic backgrounds before joining the military. Men from lower economic status families were often easy targets for military enlistment, as the promise of food, shelter, payment, and some increased status would have been hard to resist (Lavery 2011; Myerly 1996). The military was also seen as a rather good option for a second or later son of wealthier families, as primogeniture was the rule of the land; a system where the first son is the primary inheritor of wealth and titles (Jamoussi 1999). This left younger sons to find alternative means of maintaining their status and wealth (Jamoussi 1999). Many of these wealthy individuals were on the fast track for officer positions (Lavery 2011). Some of these wealthier men would have been burried in the military assemblages being examined for this research, but, if achieving an officer's rank before death, they would have been buried in cemeteries specifically for officers.

Figure 41: the sketch below is of Chelsea Old Church. Source: Cowie *et al.* 2008.

Though the economic background of the military assemblages does not match that of Chelsea Old Church, another point to consider in the background of the military assemblages is 'where' they were recruited from. Unfortunately, the answer is often from all over, from both urban and rural areas (Roberts 2012). Chelsea is a rather small assemblage, but it does represent a more rural environment. For this reason, Chelsea was examined in combination with the St. Brides Lower Cemetery assemblage, which represents a larger cemetery accounting for individuals of lower economic status from urban areas. This ultimately created a control assemblage with a predominantly low economic status from varied developed environments living in eighteenth and nineteenth century England.

5.2.3 St. Brides Lower (FAO90)

St. Brides was located on Farringdon Street within London (Miles & Conheeney 2005). The lower churchyard had once been used as a garden, but due to expansion in the seventeenth century London population, this land was designated as a burying ground for the poor parish of St Brides in 1610 (Miles & Conheeney 2005). The exact date when the land began to be used as a cemetery is not known, but it was certainly in use by 1624, as burial fee records began to note if plots were located in the 'lower' or 'upper' churchyard (Miles & Conheeney 2005). While the wealthy were buried in the 'upper' churchyard, the 'lower' churchyard is believed to have largely consisted of individuals from Bridewell workhouse and Fleet prison (largely a debtors prison, see **Fig 42**), which were both located near the church (Kausmally 2008).

Figure 42: Fleet Prison in 1691 with a debtor begging through the window grate. Source: Pince 2009.

Excavations of the lower churchyard were conducted from 1991 to 1992 as part of a redevelopment project. During this time, 606 burials (408 adults, 193 children) were excavated (Miles & Conheeney 2005). Though in use in the seventeenth century, the majority of the remains from St. Brides Lower are believed to have come from the eighteenth and nineteenth century; between 1770 and 1849 (Kausmally 2008). The St. Brides Lower Churchyard assemblage was combined with that of Chelsea Old Church to produce a control assemblage that accounts for both urban and rural living backgrounds and status. The St. Brides assemblage makes up the bulk of the control assemblage for seventeenth to nineteenth century England and represents urban, lower social status individuals.

5.2.4 Towton Mass Grave

The War of the Roses was a dynastic dispute between the House of Lancaster (Duke of Somerset) and the House of York (Duke of York), occuring between 1455 to 1487 (Boardman 2007). This war stretched over generations, with many of its battles being noted for their extreme violence. One such battle took place on Palm Sunday, 29 March 1461, just outside the village of Towton. Fought in a storm of sleet and snow, the battle is often referred to as the bloodiest ever fought on English soil (Goodwin 2012). At the time, chroniclers reported approximately 28,000 fatalities, but this figure is probably exaggerated based on closer inspection of primary resources and archaeological evidence (Sutherland 2009, 22; Boardman 2007). Evidence presented by Sutherland (2009) indicates that the fatalities for Towton likely rest closer to 2,800 to 3,800 men; Sutherland further suggests that the figure of 28,000 may be a cumulative figure from three engagements occurring on 28 and 29 March, including Towton, Ferrybridge (approximately 12 miles from Towton), and Dintingdale (approximately 1 mile from Towton).

No matter the true number, the battle would have been ferocious, as the order of no quarter was given by both sides (Boardman 2007). Towton also had a surprise ending. At the beginning of the battle, the landscape favoured the Lancastrian Army, as they had the defensible high ground. Despite these advantages, circumstances (storm winds favoured the Yorkists' arrows and a surprise attack to the Lancastrian's left flank by Norfolk's men) would ultimately result in a clear Yorkists victory (see **Fig. 43**) that would have Edward IV crowned the King of England (Boardman 2007; Goodwin 2012).

In 1996, construction workers uncovered several sets of human remains in one mass grave near the battlefield of Towton (Fiorato 2007). Excavation of the mass grave would result in the recovery of 37 to 38 individuals (Boylston *et al.* 2007). Bioarchaeologists at the University of Bradford determined that the individuals were adult males between 16 and 60+ years of age (Boylston *et al.* 2007; Burgess 2007). There was a high prevalence of perimortem trauma (around the time-of-death), which included blunt force trauma and wounds made by bladed instruments (Novak 2007 [a]). The proximity of the mass grave to the battlefield, the biological profile of the remains, and recovered archaeological artefacts lead to the clear conclusion that the remains were casualties from the Towton engagement in 1461 (Burgess 2007).

Figure 43: the painting below is by historical artist Graham Turner and is called *The Rout.* It depicts the retreat of the Lancastrian army from Towton. Under orders of 'no quarter,' the painting shows the Yorkist victors giving pursuit to fulfil this order. Source: Turner n.d., from the Richard III Society.

The military connection of these remains made them an appropriate assemblage for this research, but some matters must be considered. The information presented thus far has primarily referred to combatants from the seventeenth century onward, but medieval warfare was quite different. With this in mind, one must question if the military lifestyle of medieval combatants would have presented the same challenges as those faced by post-medieval combatants (overcrowding, insufficient supplies, physical stress, sleep deprivation, etc.). Ultimately, though some key differences do exist, it appears these challenges remained much the same.

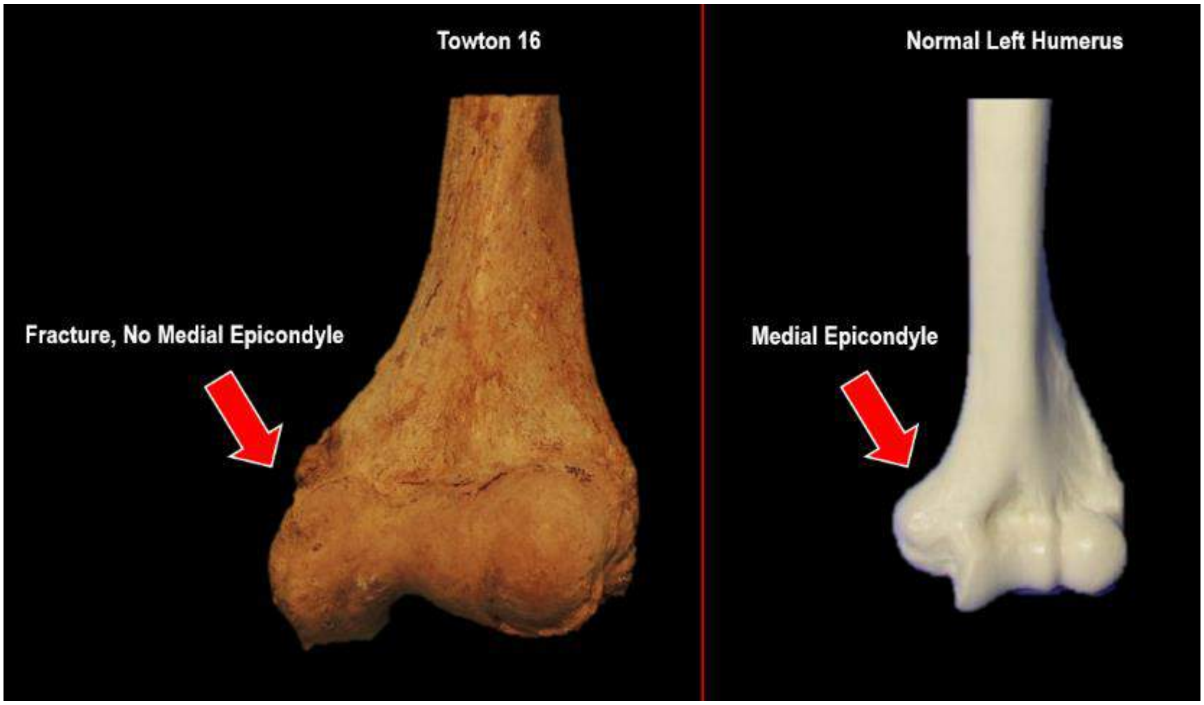
In the early medieval period, the system of ‘feudal warfare’ was employed, meaning enlistment of men was primarily done through obligatory service; for example, vassals had to devote 40 days of military service per year and would do so without monetary return (Bentley 1997, 204; Goodwin 2012). This system meant armies were often disorganized and consisted of men with limited military experience. By the late medieval period and the War of the Roses, such organizational problems had been much improved (Bell *et al.* 2013; Goodwin 2012). Society still resembled that of feudalism, but loosely so (the age of ‘bastard feudalism’), and improvements in “bureaucracy” and “techniques of literate administration” of this time led to a more professional army (Goodwin 2012, 16).

Late medieval enlistment was one area that had changed greatly, as increased emphasis on governmental administrations meant legal contractual agreements between lord and vassal were utilized; contracts promised land or monetary reimbursement for the vassal’s allegiance and military assistance (Goodwin 2012, 124; Gravett 2002, 14). These contractual vassals were often proficient military men trained as knights, mercenaries, and men-at-arms (Bell *et al.* 2013; Goodman 2006; Goodwin 2012). English commoners were also enlisted through campaigns conducted by influential society members (magnates, gentlemen, or religious leaders) who would use their connections, wealth, and charisma to convince common men to go to war (Goodwin 2012, 18–19). With such recruiting methods, men fighting in the War of the Roses would have been a very mixed group from differing social and economic backgrounds with varying degrees of military experience. This mixed background is reflected in the Towton skeletal assemblage.

Skeletal evidence from the mass grave at Towton suggests that some of the men may have been professional soldiers while others were not. One source of evidence is stature. Height and robustness were a preferred measure used in hiring professional soldiers, though common soldiers obtained through recruitment campaigns or providing obligatory service did not face such judgments (Boylston *et al.* 2007). Indeed, the Towton assemblage showed a range of heights, with the shortest man (Towton 23) estimated at 5 foot $2^{1/2}$ inches tall and the tallest (Towton 22 and 33) falling at an estimated 6 foot (Boylston *et al.* 2007). Some of the taller individuals were particularly robust (had prominent muscle attachments) and displayed healed antemortem trauma, which fits the expectation for a professional military combatant. One such example would be Towton 16, who was an estimated 5 foot 9 inches tall, displayed predominant muscle attachments, and had healed traumatic injuries (Boylston *et al.* 2007; Knüsel 2007; Novak 2007 [a]). One particular injury which supports the assumption that he was a professional combatant is a healed blade wound to his lower left mandible. Additionally, Towton 16 had a healed avulsion fracture at the growth plate of the medial epicondyle of the left humerus, which must have occurred during adolescence (see **Fig. 44**) (Boylston *et al.* 2007; Knüsel 2007; Novak 2007 [a]). This type of avulsion fracture was also observed in the remains of medieval military men discovered on the *Mary Rose* wreckage, suggesting a likely connection between this particular injury and medieval military men. One potential explanation for this type of avulsion fracture is participation in archery from a young age (Knüsel 2007).

Professional or common soldiers, what would the late medieval military lifestyle have entailed? Increased emphasis on contractual agreements in the late medieval period made it easier to levy taxes on a large scale, allowing military operations to become larger and more organized, but this did not mean they were easy (Goodwin 2012, 17). Armies are expensive and quite difficult to keep well supplied for extended periods of time, so campaigns in the medieval period (including the War of the Roses) were relatively short and often took place in the winter when farming was not at its peak (Goodwin 2012). As such, medieval armies are unique when compared to modern standing armies; standing armies often faced the strenuous conditions of the military lifestyle for extended periods of time (years), while medieval combatants would have had a reduced length of exposure to these hardships (months). Though medieval combatants were exposed to military hardships for shorter durations, the problems were the same as those experienced by later combatants (Royle 2008).

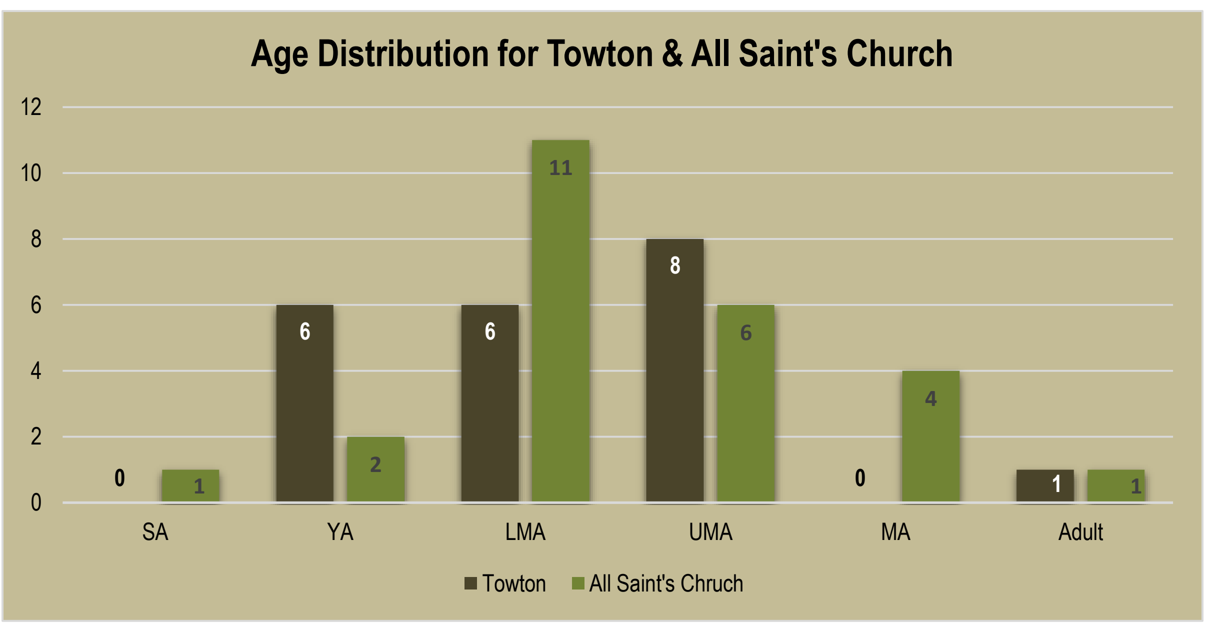
Figure 44: the image below shows the distal left humerus of Towton 16, which is missing the medial epicondyle due to a healed avulsion fracture. Source: created by the author, permitted by BARC.



The Yorkists were not well supplied at Towton, as they had been poorly provisioned the week before in Nottingham according to chronicler Jehan de Waurin (~1398-1474, a scholarly Burgundian soldier) (Goodwin 2012). The Yorkists subsisted on a diet of bread (made from poor quality cereals), dried beans, and peas (Goodwin 2012). Along with poor diet, leading up to Towton the Yorkists demonstrated that the medieval combatant was not exempt from physical stress, as Edward's poorly provisioned forces marched approximately 180 miles in sixteen days to reach Towton (Goodwin 2012, 138). Fatal diseases were also recorded during the War of the Roses. For instance, in the summer of 1485, a highly fatal infection known as the "English sweating sickness" spread across England. It is debated by historians as to whether or not this disease originated among military combatants and later spread to the general populous, but Polydore Vergil wrote (50 years after the outbreak) that the disease first appeared in August of 1485 among the French mercenaries of Henry VII's army (Sadler 2013, 16; Smallman-Raynor and Cliff 2004, 81).

Despite not fitting the traditional concept of a standing army, the traditional military hardships were still present among fifteenth century medieval combatants: overcrowding, poor provisions, physical exertion, and infectious disease (Sadler 2013; Smallman-Raynor and Cliff 2004). For this reason, examination of the Towton assemblage was deemed appropriate and beneficial, because it would serve as an interesting comparison to the assemblages of later time periods. For instance, if less reactive arthropathy is observed in the Towton assemblage, it can be infered that the shortened exposure to common military hardships was advantageous. Alternatively, if reactive arthropathy appears to be consistent with that of other military assemblages, this would indicate there has been consistency in the military expression of these condition since the late medieval period. The age distribution of this assemblage is matched with its control, medieval All Saint's Church, in **Table 10**.

Table 10: the table below shows the age distributions for the Towton assemblage and its control (All Saint's Church). The age categories are Sub Adults (SA) 12-15, Young Adult (YA) 16-25, Lower Middle Adult (LMA) 26-35, Upper Middle Adult (UMA) 36-45, Mature Adult (MA) 45+. Source: created by the author.



5.2.5 York Mass Grave (YMG), from All Saint's Church

When All Saint's Church was excavated between 2007 - 2008 (discussed previously for its use as a control assemblage for Towton), 10 mass graves were unexpectedly discovered. The mass graves containing a total of 113 individuals, which did not coincide with the medieval burials associated with the church (McIntyre & Bruce 2010). These mass graves were found both inside and outside the church foundations (McIntyre & Bruce 2010). It was concluded that the mass graves post-dated the medieval church, as they cut into medieval burial contexts. Furthermore, some of the mass graves overlapped the internal foundations of the church, indicating these walls were no longer present when the mass graves were dug; it appears the mass graves were dug inside the remaining ruins of the old church foundations (McIntyre & Bruce 2010). Though the burials post-date the medieval church, they likely pre-date the eighteenth century, as maps from this period show no indications that any church ruins existed (McIntyre & Bruce 2010). All of this information suggests the mass graves date to some point in the seventeenth century (McIntyre & Bruce 2010).

The remains in the mass graves were buried in pits and placed in parallel rows (see **Fig**. **45**), with the exception of one, which had an additional four skeletons squeezed into the grave at right angles (McIntyre & Bruce 2010). Most individuals were found on their side, though some were discovered on their backs and others face-down. No evidence of material goods, clothing, or coffins were found, suggesting possessions had been removed before burial (McIntyre & Bruce 2010). This burial pattern insinuates the remains were disposed of rather hastily, but their burial within a ruined church (holy ground) indicates respectful motives in their overall placement.

Figure 45: One of the ten mass graves. This photo shows the parallel rows described in-text. Source: McIntyre & Bruce 2010, 37.

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The bone report states there were 87 males, 6 females, and 20 unidentifiable sets of remains (McIntyre & Bruce 2010). None of the skeletons were children or elderly, with the average age of the assemblage falling between 35-49 years (McIntyre & Bruce 2010). This biological profile fits the expectation of what one would find in a military assemblage; the vast majority being male adults between the ages of 16 and 60, who were buried in a non-traditional fashion. This information when examined in line with the dating and location of the mass graves lead to the conclusion they were remains from the 1644 siege of York, which occurred during the English Civil War (1642-1651).

There was an average rate of healed trauma, which suggested that these individuals were not casualties of combat. If not battle, what lead to their mass and hasty burial? McIntyre and Bruce (2010) suggest an epidemic of infectious disease is to blame. This is a reasonable suggestion, as history greatly supports the claim. During this time period, disease kept many military combatants from ever returning home from their campaigns, but combatants participating in siege warfare were especially prone to outbreaks of infectious diseases like dysentery, typhoid fever, and typhus (Duffy 1997; Roberts 2005).

As the church was located outside the city walls, the remains must have belonged to the besieging forces, the Parliamentary Army, whose stronghold was located at Walmgate Bar, not far from the church's location at Fishergate (see **Fig. 46**). According to historical documentation, the Parliamentary Army, which included some 30,000 men, surrounded the city from April to July and suffered from privation, ultimately leading to an outbreak of infectious disease (Holmes 1974; McIntyre & Bruce 2010). This did not go unnoticed by the opposing Royalist inside the city walls, as they noted that a 'strange sickness' and 'fever and flux' thinned the ranks of their enemy (Holmes 1974, 169; McIntyre & Bruce 2010).

Figure 46: This map shows the location of the site relevant to the city walls and Walmgate Bar, which was a parliamentary stronghold during the siege in 1644. Source: McIntyre & Bruce 2010, 37.

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Outside of being part of the Parliamentary Army, who were these men? Unlike medieval armies, the men of the English Civil War would resemble a standing army; however, in the early years of the war (including 1644), this was still a work in progress, as the official creation of the Parliamentary New Model Army (the first official standing army within England) did not come about until 1645 (Roberts 2005). Nevertheless, service was for extended periods of time. Recruitment was primarily done through voluntary service or by levying conscripts (where leading officials of each county would draft men into service) (Roberts 2005). In the early war, obtaining men through voluntary service was favoured, as both sides worried over public opinion and levying was highly unpopular (Roberts 2005).

To obtain volunteers, recruitment campaigns were carried out by individual officers or nobles (Cooke 2004). The target for these campaigns were able-bodied men between the ages of 16-60 and they were not discriminant of social or professional status (Gaunt 2003). Both armies also made use of local militias, but this would have only provided a limited number of individuals (Cooke 2004; Gaunt 2003). The militias were part-time military groups established for the protection of local towns and were composed of able-bodied men. In considering the proficiency of these groups, the majority would have had limited practical military experience, but there were a few exceptions, such as the Lancashire or London militia which received considerably more training than was seen in most militia of the time (Gaunt 2003).

Though voluntary recruitment methods were sufficient in the early war, this became more difficult as the true nature of war became evident to the previously naïve (Roberts 2005). The solution for both armies was to abandon their early aversion to levies and begin forced conscription in the towns they controlled (Cooke 2004). Though the Siege of York occurred rather early in the war, this problem was already underway, so the men fighting for the Parliamentary Army were probably a mixture of voluntary and involuntary obtained servicemen (Roberts 2005).

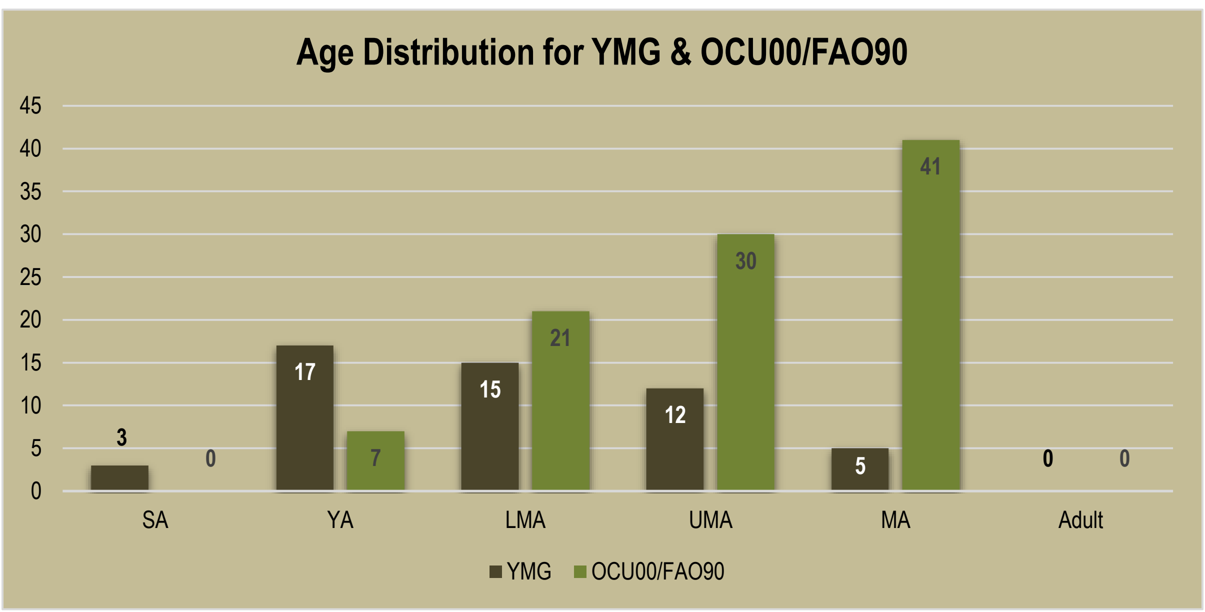
As mentioned, a few women were also discovered in the mass grave assemblage at All Saint's Church, which is unsurprising, as women often followed both armies during the English Civil War. Some were the wives of men serving in the army, but many were unmarried women, who were allowed to follow the army in spite of social conventions (Ailes 2012). Woman camp followers were vital to military operation at this time, serving as nurses, laundresses, cooks, sutlers, and aids in forging/looting expeditions (Ailes 2012). Some women even worked as spies, as a woman's classifications as a 'non-combatant' allowed them easy access across enemy lines; a famous English Civil War example would be Jane Whorwood, who smuggled messages and money to Charles I while he was imprisoned (Ailes 2012). One other potential occupation of female camp followers was, of course, prostitution (Gaunt 2014).

Though there were strong religious underpinnings to the English Civil War and some commanders were well noted for their harsh treatment of prostitutes, they still followed the armies (Gaunt 2014). Moral beliefs do not equal moral conduct under normal circumstances, so under the stress and hardships of war, ideals of 'moral conduct' often get heavily amended or ignored. For example, during the English Civil War, acts of rape, disfigurement, and pillaging were considered acceptable if an army was forced to take a town by siege (all inhabitants were considered guilty and worthy of such punishment) (Ailes 2012; Donagan 1994). During a 1645 attack of Basing House in Hampshire, Oliver Cromwell reported that some women were wounded because they attempted to protect their property, family, or friends once the fortress had fallen. One particular woman tried to, "protect her father from being beaten by soldiers and, in her anger, called them 'Roundheads and rebels to the King.' In retaliation, one soldier grabbed her and 'beat her brains out' " (Ailes 2012, 73).

In spite of the religious connotations of the war, prostitutes did follow armies during the English Civil War and in other contemporary conflicts of Europe; in fact, it was not uncommon for historical accounts to discuss failed attempts to discourage the practice (Ailes 2012; Gaunt 2014; Lynn 2012). As usual, this likely caused problems with venereal disease; Oliver Cromwell's Army is suspected to be responsible for bringing endemic syphilis to Scotland, which caused an epidemic in 1649 (Clemow 1903; Hinrichsen & Chase 1944; Lancereaux 1869).

With the English Civil War demonstrating a clear history with infectious diseases, the York mass grave assemblage from the All Saint's Church excavation was deemed appropriate for this project. The age distribution of this assemblage is matched with its control, the combined figures of Chelsea Old Church and St Brides Lower assemblages, in **Table 11**.

Table 11: the table below shows the age distributions for the York Mass Grave (YMG) assemblage and its control (OCU00 & FAO90). The older age categories are predominant in the control assemblage, as older remains had to be selected for comparison with the Greenwich assemblage, which will be discussed in a later section. The age categories are Sub Adults (SA) 12-15, Young Adult (YA) 16-25, Lower Middle Adult (LMA) 26-35, Upper Middle Adult (UMA) 36-45, Mature Adult (MA) 45+. Source: created by the author.



5.2.6 Plymouth Royal Naval Hospital (EA)

Construction of the Stonehouse Royal Naval Hospital (see **Fig. 47**) begun in 1758 and was fully completed in 1762 (Stevenson 2007; Sinnot 2013). It was built to accommodate 1,200 men and was the first of its kind in England. It was mentioned in Chapter 2 that hospitals were often overcrowded and not the most sanitary of places in the nineteenth century, but the Stonehouse Royal Naval Hospital was advanced for its time. The hospital was designed to allow proper circulation of air and for isolation of wards, which allowed cases of infectious diseases to be blockaded (Stevenson 2007; Sinnot 2013). This point was commented upon in an 1828 guidebook of Plymouth:

> The hospital consists of ten buildings, surrounding an extensive quadrangle, each containing six wards, every one of which is calculated to receive sixteen patients; but in cases of emergency that number can be extended to twenty. From this statement it will be seen that no fewer than twelve hundred sick can be accommodated in the hospital at one time. In the construction of the buildings care has been taken to prevent the spreading of contagious disorders, for they are detached from each other, and have no other communication than what is afforded by a piazza which surrounds three sides of the quadrangle… The vast national importance of this Institution may be gathered from the following authentic statement. Between the 1st of January, 1800, and the 31st of December, 1815, no fewer than 48,452 seamen and marines were received at the hospital, a very great proportion of whom returned to the service as effective men (Carrington 1828, 34).

Though the hospital apparently had a good record according to this account, not all men survived their stay. These unfortunate men were buried in the Stray Park Cemetery, which was excavated as part of a redevelopment project in 2007 (Roberts *et al.* 2012)

Figure 47: the Stonehouse Royal Naval Hospital (1897). Source: Cyber-Heritage, n.d.

A total of 170 remains were excavated from the cemetery, which was used by the Stonehouse Royal Naval Hospital between 1760 and 1826 (Roberts *et al.* 2012). The remains of the men buried here were of seamen and marines who died at the hospital due to injury or disease during active service (Roberts *et al.* 2012). The dates of the cemetery mean the Napoleonic Wars would have been the primary conflict of participation (Roberts *et al.* 2012). Since the men buried in the cemetery died at the hospital during active service, the average age of the assemblage was quite young, with almost a fifth being teenagers (Davis 2011).

In spite of the good record suggested by Carrington (1828), the cemetery was heavily used, as indicated by some of the surviving burial records. Between 1813–1814 there were 421 burials with 73% being seamen, 25.7% marines, and the remainder being miscellaneous skilled labourers hired by the Navy; there were also some prisoners-of-war, including two Americans from the War of 1812 (Roberts *et al.* 2012). These are all low ranking Navy positions, meaning the assemblage represents average members of the Royal Navy. Who were these seamen, marines, and skilled labourers? They would have been land-men (sailors of no previous experience at sea), ordinary seamen (sailors who had some experience, but without a particular skill), able seamen (sailors who were well acquainted with life at sea), petty marine officers and gunners (the fighting-men), and hired skilled labours (cooks, carpenters, etc.) (see **Fig. 48**) (Boston *et al.* 2008; Lavery 2011; O'Brian 1995; Pope 1996).

The seamen were undoubtedly some of the most important individuals aboard their ships, as they were responsible for ensuring the ship ran smoothly. Seamen would steer, manage the sails, and man the guns. Skilled seamen (ordinary and able seamen) were the most common on board ships, making up 40% of the crew on an average ship (Lavery 2011). These experienced seamen were often hired off merchant ships, though some came into their positions through the practice of impressment (Brunsman 2013; Lavery 2011). While experienced seamen were targeted by press gangs, the inexperienced seamen (land-men) were simply hired as needed to accommodate the demands aboard ship. Some of these less experienced seamen would have been ex-prisoners, though not of the hardened criminal variety; crimes for smuggling, debt, and others petty crimes were selected for land-men recruitment, as the Royal Navy thought hardened criminals would cause trouble aboard ship (Lavery 2011). Land-men would have fulfilled the menial labour. If they were placed on a ship at a relatively young age (under 25), they may have eventually become ordinary or able seamen with more desirable jobs, but land-men joining at older ages often spent their whole lives performing menial tasks (Lavery 2011).

Marines were the fighting men (they operated and trained in a military fashion). Some of these individuals would have been recruited to the Royal Navy as young boys from street slums and other less than ideal living situations; the Marine Society frequently viewed these boys as easy targets for recruitment (Lavery 2011). The remainder of the ship would have been filled with skilled labourers. These men were often called "idlers." Unlike the seamen and marines who worked in shifts both day and night, the "idlers" work was only needed during the day, so they were free to do as they wished in the evening hours (Lavery 2011).

As already discussed in Chapter 2, the Royal Navy has a rather extensive history of infectious diseases. The period of the Napoleonic Wars was not an exception to this pattern, in fact, much of the information stated in Chapter 2 comes from this time period. As such, skeletal assemblages of Royal Navy men serving during the Napoleonic Wars are highly appropriate for this research. Furthermore, the young age distribution of the Plymouth assemblages serves as an ideal comparison with the older age distribution of the Greenwich assemblage. The age distribution of this assemblage is matched with its control, the combined figures of Chelsea Old Church and St Brides Lower assemblages, in **Table 12**.

Table 12: the table below shows the age distributions for the Plymouth (EA) assemblage and its control (OCU00 & FAO90). The older age categories are predominant in the control assemblage, as older remains had to be selected for comparison with the Greenwich assemblage, which will be discussed in the next section. The age categories are Sub Adults (SA) 12-15, Young Adult (YA) 16-25, Lower Middle Adult (LMA) 26-35, Upper Middle Adult (UMA) 36-45, Mature Adult (MA) 45+. Source: created by the author.

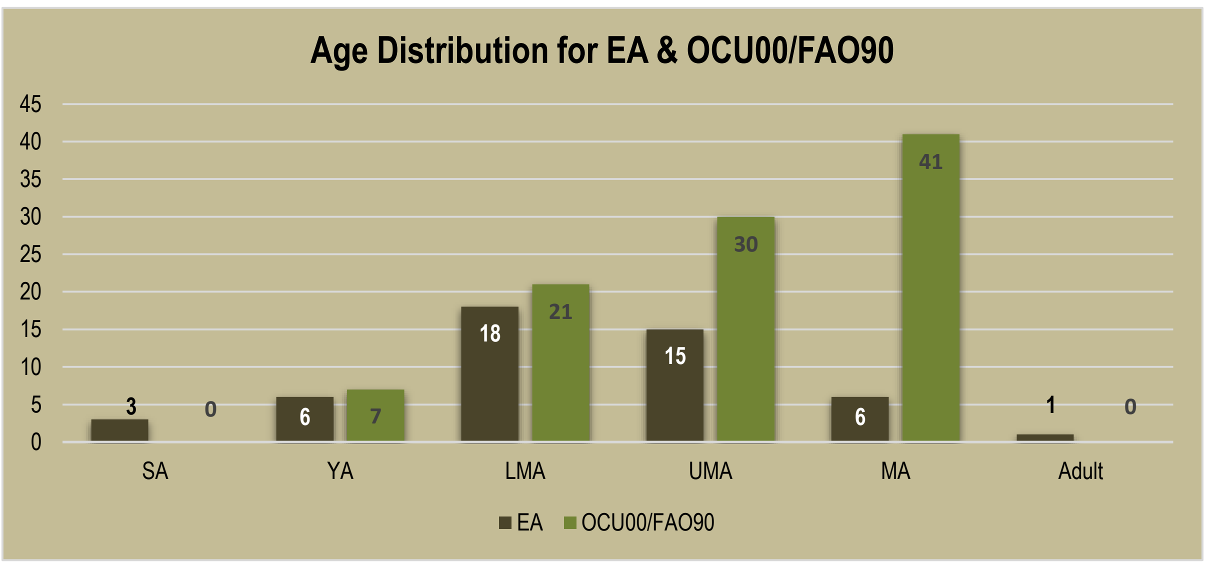


Figure 48: these illustrations depict late eighteenth and early nineteenth century uniforms of the Royal Navy. These illustrations serve as examples of the positions likely held by the men buried in the Stray Park Cemetery.

Image 'A' depicts gunners.

Image 'B' Captain's gig crew (1), seamen (2, 3), and a petty marine officer (4)

Image 'C' a ships cook (1), ship's boy (2), carpenter (3) and a Boatswain's mate (a petty officer, 4)

Source: Haythornthwaite 2012.

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5.2.7 Greenwich Royal Naval Hospital (KWK)

The Royal Hospital for Seamen in Greenwich was the home of Royal Navy pensioners who had served as sailors or marines. In the early years of the hospital, the number of in-pensioners (living within the hospital) was relatively low, but as increasing conflict required more naval men, these numbers grew. The hospital was at full capacity from 1815 through the 1830's, dates which are explained by the ending of the Napoleonic Wars (1815). In 1815, many men were released from service and left to find employment elsewhere. Some of the greatly disabled went directly into the hospital as in-pensioners, but the majority of sailors lived as out-pensioners (living outside the hospital) until increasing age made it necessary to become an in-pensioner. Some men lived up to 25 years in the hospital, but the majority lived in the hospital for a period of 5 to 10 years (Boston *et al.* 2008, 17). Overall, life in the hospital was fair (the building was noted for its grandeur and men were provided with ample food rations), but the military background of the hospital meant pensioners were required to wear uniforms and could be punished or evicted for misconduct (Boston *et al.* 2008; Lavery 2011). In the National Mariners Museum archives, there are numerous depictions of the Greenwich pensioners going about their everyday lives at the hospital (see **Fig. 49**).

As most of these men stayed at the hospital until their death, a plot of land was purchased for use as a pensioner's cemetery. This cemetery was first used in 1749 and closed upon reaching full capacity in 1857. It is estimated that 20,000 retired marines and sailors were buried over this period of time (Boston *et al.* 2008). Given the dates of use, the majority of the men buried at this cemetery would have fought in the Napoleonic Wars (1792-1815), but the Seven Years War (1754-1763), American Revolution (1765 – 1783), War of 1812 (1812-1815), and conflicts with the Spanish and Dutch are also represented (Boston *et al.* 2008). The hospital cemetery was not for high ranking officers. These naval men would have been lower working class and employed as both skilled and unskilled labourers before and after their naval service. When serving in the Royal Navy, the Greenwich pensioners would have been land-men, ordinary seamen, able seamen, petty marine officers, gunners, and other hired skilled labourers (Boston *et al.* 2008; Lavery 2011; O'Brian 1995; Pope 1996). As such, the remains in this cemetery are similar to those of the Plymouth assemblage.

Between 1999 and 2001, Oxford Archaeology excavated a portion of the hospital cemetery in preparation for redevelopment. At the conclusion of the excavation, a total of 107 skeletons were recovered. The vast majority were males of advanced age, but 7 female were also recovered; the hospital did occasionally house wives of seamen and provide widows with work at the hospital, so these individuals likely represent this part of the hospital's history (Boston *et al.* 2008). The amputations seen the *Sling the Monkey* sketch in **Figure 49** were evident in this skeletal assemblage, along with other forms of healed trauma; healed nasal fractures were especially prevalent at 61.8% according to Boston *et al.* (2008) (see **Fig. 50**)

Of more interest to the present project, infectious disease was evident in the Greenwich remains, with several cases of osteomyelitis, tuberculosis, and treponemal diseases (yaws or syphilis) being reported by Boston *et al.* (2008). Of interest to treponemal diseases is **Figure 51,** which is a caricature by James Whittle and Richard Holmes Laurie (1794). It depicts two Greenwich pensioners enjoying a pint, with a woman peering at them over a fence. If one looks to the door frame just behind these men, they will see a chequered decoration, which was known to those of the period to represent 'ladies of easy virtue' (*i.e*. brothel) (Whittle & Holmes 1794). If this caricature is remotely indicative of the reality for the Greenwich pensioners, then it is apparent that age, nor infirmary, gave these men pause in the continuation of the lifestyle they became accustomed to during their time as marines and sailors with the Royal Navy. Indeed, assuming disability did not prevent it, many Royal Navy servicemen kept their connection to this lifestyle at the end of their service by electing to continue working in naval occupation; some even continued working for the Royal Navy in civilian capacities (Bosten *et al.* 2008).

Such an assemblage is certainly ideal for a study of reactive arthropathy, but, as mentioned, the use of this assemblage also allowed the assemblage to be compared with Plymouth to assess the intrinsic factor of age. The age distribution of the Greenwich assemblage is matched with its control, the combined figures of Chelsea Old Church and St Brides Lower assemblages, in **Table 13**.

Table 13: the table below shows the age distributions for the Greenwich (KWK) assemblage and its control (OCU00 & FAO90). The age categories are Sub Adults (SA) 12-15, Young Adult (YA) 16-25, Lower Middle Adult (LMA) 26-35, Upper Middle Adult (UMA) 36-45, Mature Adult (MA) 45+. Source: created by the author.

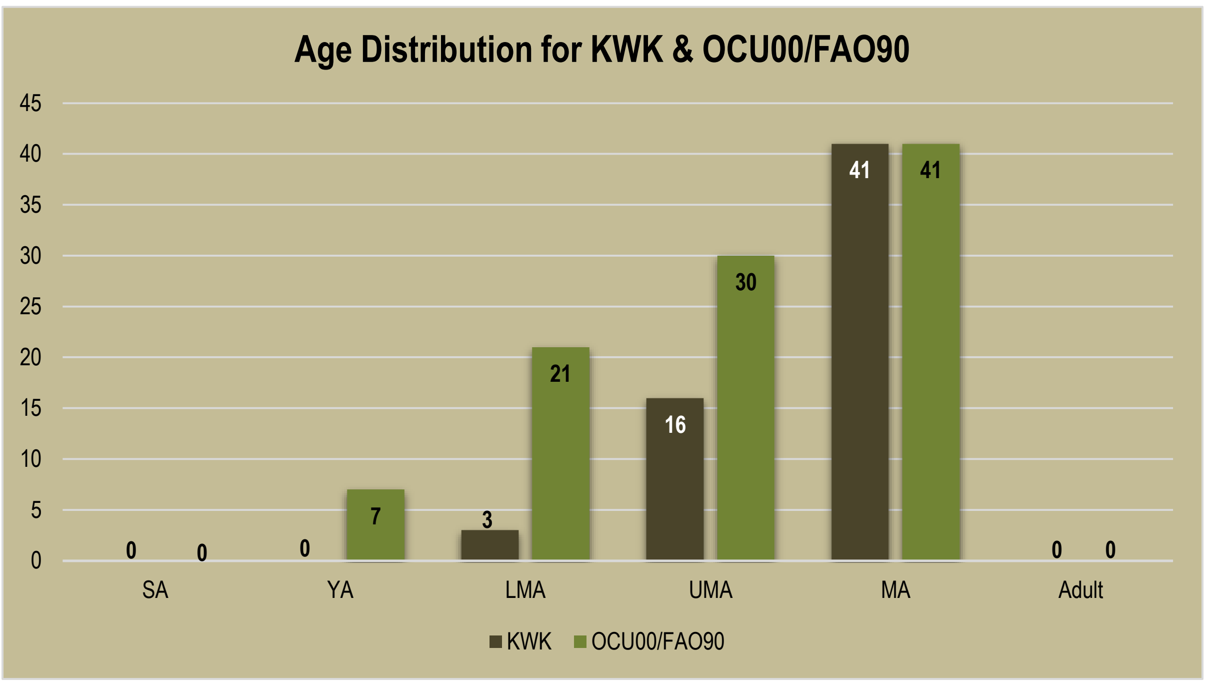


Figure 49: the illustration below is called Sling the Monkey by Cruikshank. It is described in the National Mariners Museum Archives as, “Greenwich Pensioners playing a rough game in Greenwich Park, in which a man with two peg-legs is slung in support by a rope from a tree-branch and then twirled round on his 'pin' as companions haze him with knotted handkerchiefs. He tries to mark one of them with a piece of chalk, who then becomes the next 'monkey'…Although the Pensioner on the left has a right lower leg he wears a peg-leg strapped onto his knee [circled in red]. This was also presumably a necessary part of the game for those with two normal legs.” Source: Cruikshank n.d., from the National Mariners Museum Archives.

Figure 50: healed nasal fractures in three individuals from the pensioner's cemetery for the Royal Hospital for Seamen in Greenwich. Source: photos taken by author, permitted by MOLA.

Figure 51: this caricature by James Whittle and Richard Holmes Laurie (1794) depicts two Greenwich pensioners enjoying a pint. The chequered decoration in door frame (indicated by a red arrow) symbolizing 'ladies of easy virtue' or 'brothel.' Source: Whittle & Holmes 1794, from the National Maritime Museum Archives.

5.3 Summary on Assemblages

The control assemblages were selected based on a few important features: a lack of known military association, their socioeconomic status, their developed environments (urban or rural), and historical period. The selection of military assemblages was largely based on simple proof of a military connection that would ensure exposure to the military lifestyle. Each of the military assemblages has something unique to offer this research.

As Towton is associated with medieval warfare, their military lifestyle differed slightly from later combatants (duration of exposures), yet remained much the same (the exposures were the same). As such, the Towton results can be compared with other military assemblages to determine if length of exposure to the military lifestyle had an impact on the expression of reactive pathology. The mass grave assemblage from York is associated with the English Civil War. This point in history represents the early beginnings of traditional standing armies in England, representing a step forward in the timeline. Finally, the Plymouth and Greenwich assemblages will provide a means of assessing if the intrinsic factor of age influences the identification of reactive pathology in skeletal assemblages. The background for all of the selected assemblages is summarized in **Table 14.**

Table 14: the table below provides background information about the assemblages examined for this research. Source: created by the author.

Summary of Assemblages						
Site	**Dates/Time Period**	**Sample Size**	**Preservation**	**Burial Context**	**Socioeconomic Status**	**Type of Developed Environment**
Control Assemblages						
Medieval All Saint's Chruch	1091-1539	25	Fair, fragmentation was high	Cemetery	Mixed, mostly Low & Middle Status	Urban
Chelsea Old Church (OCU00)	18th-19th Century	36	Good	Cemetery	High Status	Rural/Suburb
St. Brides Lower	17th -19th Century	63	Good	Cemetery	Low Status	Urban
Military Assemblages						
Towton	1461	21	Good	Mass Grave	Middle & Low Status	Likely Mixed
York Mass Grave from All Saint's Chruch	1644	52	Fair, fragmentation was high	Mass Grave	Middle & Low Status	Likely Mixed
Stray Park Cemetery (Plymouth)	1760-1826	49	Good	Cemetery	Middle & Low Status	Likely Mixed
Royal Hospital Burial Ground (Greenwich)	1749-1857	60	Good	Cemetery	Middle & Low Status	Likely Mixed

Review of Introduced Acronyms:

Sub Adult (SA) – 12 to 15

Young Adult (YA) – 16 to 25

Lower Middle Adult (LMA) – 26 to 35

Upper Middle Adult (UMA) – 36 to 45

Mature Adult (MA) – 46+

CHAPTER 6:
Methods

The last major consideration before discussing results is how the primary research question was answered. Two methods were employed. The first was a literature review, intent on providing basic quantitative figures about the commonality of reactive arthropathies in past military populations. The second was a palaeoepidemiological study, which examines the skeletal materials discussed in Chapter 5.

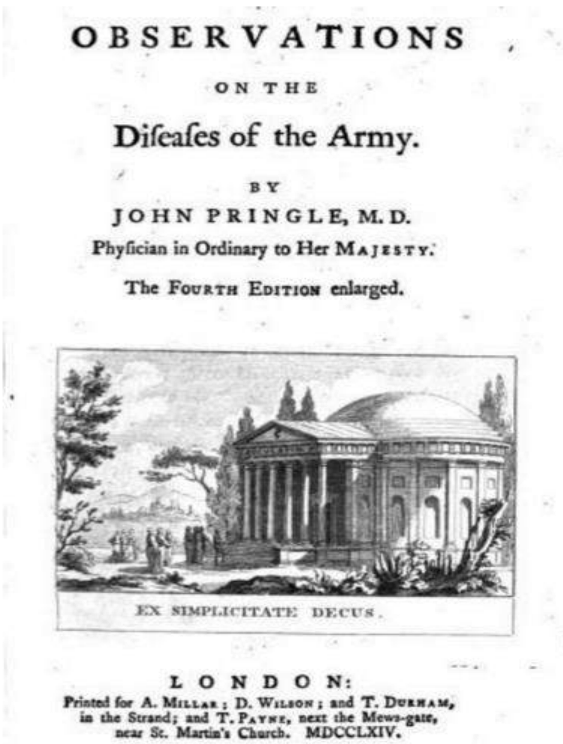
6.1 Methodology: Literature Investigation

The literature investigation was aimed towards assessing whether a connection between reactive arthropathies and past military combatants could be established before perusing the palaeoepidemiological study. This was accomplished by discussing, comparing, and quantitatively listing military versus non-military references of ReA from historical literature. As already mentioned in Chapter 4, the history of this condition is highly fragmented. By assessing both military and non-military historical references to ReA, the literature investigation achieves two important goals. First, it provides a more comprehensive palaeopathological history of this condition and, secondly, it addresses the primary research question.

Medical documents, old or new, are considered highly valuable resources, so the majority of text were easily obtained through digital archives, but a few documents were rare and had to be obtained through interlibrary loan in the form of microfilm. Selection of documents was carried out through a keyword search of scholarly databases. Some of the keywords included: military/naval medicine, camp diseases, diseases of seamen, dysentery, diarrhoea, gonorrhoea, sexually transmitted diseases/venereal diseases, and rheumatism/arthritis.

The majority of the documents came in the form of published texts (see **Fig. 52**), but official reports made to government offices were also common. Though some documents came from mainland European countries, like France and Germany, the majority of documents were from the U.K. and U.S. Most texts yielding relevant information dated to the late eighteenth century onwards, but some older documents also proved useful. References were considered to be 'historical' through World War I; this point was selected as the cut-off for consideration of medical references due to the discovery of 'Reiter-Fiessinger-Leroy syndrome' in 1916, which was the first recounting of a reactive arthropathy to become widely acknowledged in the medical community (Hodgetts & Espinosa 1990; Rothe & Kerdel 1991).

Figure 52: the title pages below exemplify some of the publications that proved useful to this research. Source: images from Google Books.



OBSERVATIONS

ON THE

Diſeaſes of the Army.

BY

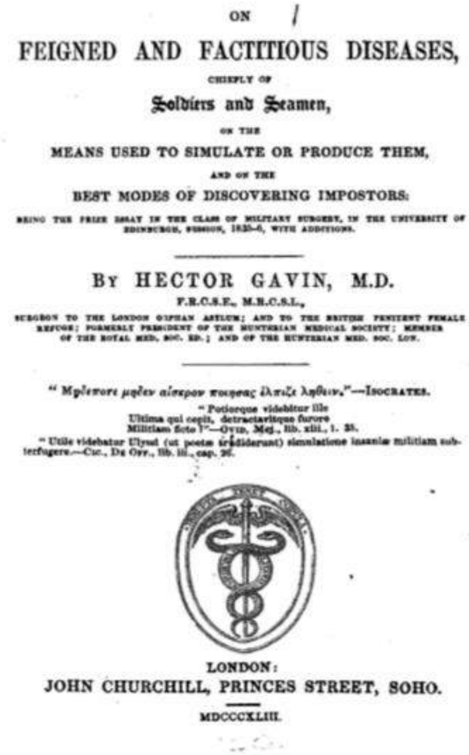
JOHN PRINGLE, M.D.

Phyſician in Ordinary to Her MAJESTY.

The FOURTH EDITION enlarged.

LONDON:

Printed for A. MILLAR; D. WILSON; and T. DURHAM, in the Strand; and T. PAYNE, next the Mews-gate, near St. Martin's Church. MDCCLXIV.



ON

FEIGNED AND FACTITIOUS DISEASES,

CHIEFLY OF

Soldiers and Seamen,

ON THE

MEANS USED TO SIMULATE OR PRODUCE THEM,

AND ON THE

BEST MODES OF DISCOVERING IMPOSTORS:

BEING THE PRIZE ESSAY IN THE CLASS OF MILITARY SURGERY, IN THE UNIVERSITY OF EDINBURGH, SESSION, 1835-6, WITH ADDITIONS.

BY HECTOR GAVIN, M.D.

F.R.C.S.E., M.R.C.S.L.,

SURGEON TO THE LONDON ORPHAN ASYLUM; AND TO THE BRITISH PENITENT FEMALE REFUGE; FORMERLY PRESIDENT OF THE HUNTERIAN MEDICAL SOCIETY; MEMBER OF THE ROYAL MED. SOC. ED.; AND OF THE HUNTERIAN MED. SOC. LON.

"Μηδέποτε μηδὲν αἰσχρὸν ποιήσας ἔλπιζε λήσειν."—ISOCRATES.

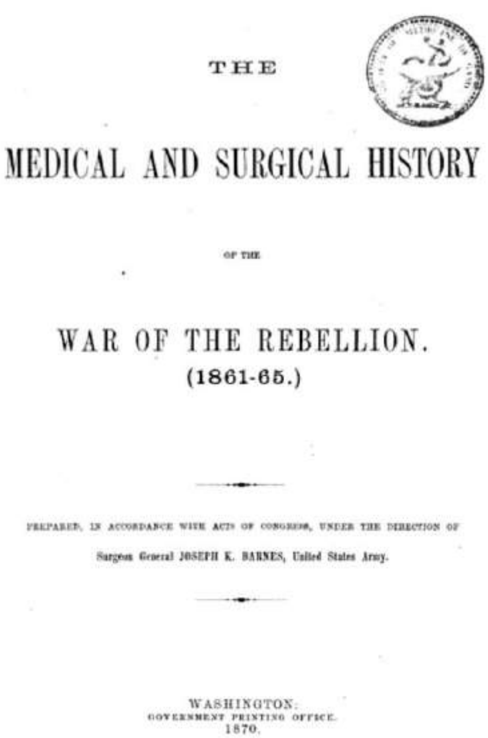
"Potiorque videbitur ille
Ultima qui cepit, detractavitque furore
Militiam ficto!"—OVID, Met., lib. xiii., l. 35.

"Utile videbatur Ulyssi (ut poetæ tradiderunt) simulatione insaniæ militiam subterfugere."—CIC., De Off., lib. iii., cap. 26.

LONDON:

JOHN CHURCHILL, PRINCES STREET, SOHO.

MDCCCXLIII.



THE

MEDICAL AND SURGICAL HISTORY

OF THE

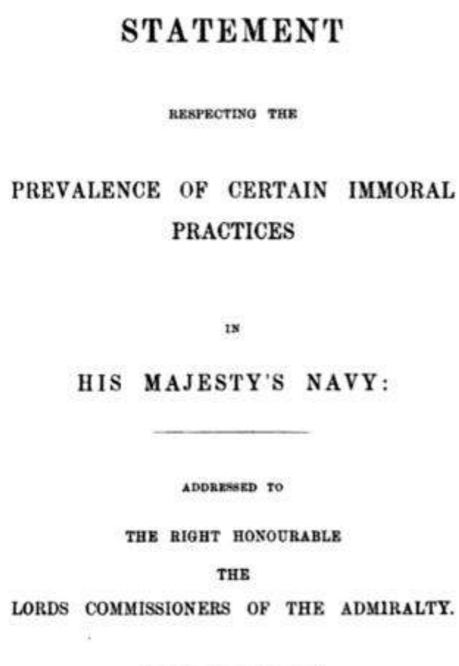
WAR OF THE REBELLION.

(1861-65.)

PREPARED, IN ACCORDANCE WITH ACTS OF CONGRESS, UNDER THE DIRECTION OF

Surgeon General JOSEPH K. BARNES, United States Army.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1870.



STATEMENT

RESPECTING THE

PREVALENCE OF CERTAIN IMMORAL PRACTICES

IN

HIS MAJESTY'S NAVY:

ADDRESSED TO

THE RIGHT HONOURABLE

THE

LORDS COMMISSIONERS OF THE ADMIRALTY.

6.2 Methodology of the Skeletal Investigation

Outside of the selection of skeletal assemblages described in Chapter 5, the methodology involved in the skeletal investigation was comprised of three main components: skeletal recording, pathology identification and classification, and statistical analysis.

6.2.1 Skeletal Recording

Appendix B is a copy of the skeletal recording forms used to document the presence or absence of skeletal elements and pathology. Age and sex information was also recorded in these forms. When pathology was observed, it was described on the recording forms and also photographed whenever possible. The first page and general outline of the recording forms were adapted from those used by Simon Hillson at UCL.

It has been demonstrated that the best method of ageing adult skeletal material is through a multifactorial approach, which uses several methods to determine a likely age range (Bedford *et al.* 1993; Lovejoy *et al.* 1985 [a]). The key features examined for age estimation in this study were: epiphyseal fusion (only an option for young adults, based on McKern and Stewart 1957 and Schaefer *et al.* 2009), dental attrition (compared to Brothwell 1981), changes to the pubic symphysis (using Brooks and Suchey 1990), and changes to the auricular surface of the pelvis (using Lovejoy *et al.* 1985 [b]). After comparing the ages assigned by these various methods, individuals were placed into one of six potential categorizations, which were: Sub-Adult (12-15) [SA], Young Adult (16–25) [YA], Lower Middle Adult (26–35) [LMA], Upper Middle Adult (36–45) [UMA], Mature Adult (46+) [MA], and Adult (unknown).

As with age estimation, sex estimation was done with a multifactorial approach. Both morphological and metric data was utilized. The human skull and pelvis express the largest amount of sexual dimorphism, so morphological features of these elements were assessed using Buikstra and Ubelaker (1994). Sex was also determined through consideration of metric measurements. The primary measurements taken were the maximum diameter of the femur head (FHD1) and the maximum diameter of the humeral head (HuD1); measurements >46.5 mm were considered to be male, unknown between 43.5–46.5 mm, and female in measurements <43.5 mm (Bass 1971). Skeletons were only examined if they could be categorized as a male or questionable male; unknown, questionable female, and female skeletal remains were excluded.

6.2.2 Pathology Identification & Classification

One of the largest problems in the study of paleopathology is the lack of standardization in identification and analysis of pathology, as differing criteria make comparisons between works exceedingly difficult; however, this is vital to the process of determining patterns of disease expression in the past. As such, movement towards the use of standardized operational definitions is certainly called for (Waldron 2007). To bring about more standardization, Waldron 2009 was used as a basis for generating operational definitions for the identification and differential diagnosis of EAs. These definitions can be found in Appendix A. Though the definitions are largely from Waldron 2009, some additional definitions have been generated; for instance, Waldron 2009 provides definitions for specific SpAs, but no general definition of SpA. Such a definition was produced for this project in connsulation with Dr. Waldron and UCL bioarchaeologists. The operational definition generated for SpA is listed in **Table 15**.

Table 15: this table provides the operational definition of SpA generated for this research. Source: created by the author.

Operational Definition of Spondyloarthropathy (SpA)	
SpA can be diagnosed with the presence of **three** of the following:	
1	SIJ involvement in the form of fusion or sacroiliitis (*definition in Appendix A*)
2	Syndesmophyte spinal bone formation and/or fusion in 3 or more vertebrae
3	Enthesopathy expressed through bone formation at the entheses; must be in a minimum of 3 locations, but ideally enthesopathy should be extensive and/or diagnostic (*see Table 1 in Appendix A*)
4	Marginal joint erosions; asymmetric erosions are most common

Consideration of classification for statistical analysis is also of great importance. As discussed in Chapter 1 and Chapter 4, modern clinicians frequently debate issues of SpA classification, as the amount of overlap seen in the SpAs can be confusing (Asquith *et al.* 2014; Carter 2010; Rohekar & Pope 2010). Whereas modern clinicians have medical histories and soft tissue to consider in their diagnosis, bioarchaeologists rarely have such luxuries, meaning 'simpler is often better' in matters of classification; however, specificity also has advantages. For example, distinguishing between ReA and PsA would allow the bacterium (or list of potential bacteria) to be identified in individual cases, but skeletal material providing all necessary evidence needed to be this specific is rare (Waldron 2012). With this in mind, the classification system was organized to allow for differing levels of specificity.

Three primary categories were used to classify relevant pathology observed in skeletal remains. These categories were:

1. Reactive Pathology: cases most resembling the pattern of expression followed by SpA.

2. Nonreactive Pathology: cases most resembling the pattern of expression followed by other EAs - erosive osteoarthritis, gout, and RA.

3. Unidentified Pathology: cases that had pathological changes relevant to EAs, but were not specific enough to be counted in the Reactive or Nonreactive categories.

It is important to clarify what is meant by the 'most resembling' descriptions for the Nonreactive and Reactive categories. Since SpA is not overly common in modern populations, it does not seem likely that clearly defined cases would be commonly found in skeletal assemblages (Waldron 2009). The hypothesis for this project predicts there may be some exceptions when a given group has a higher exposure and susceptibility to the bacterial infections which trigger SpA. Nevertheless, identification of pathology specific enough to completely meet the operational definition of SpA is easier said than done. For starters, skeletal preservation can be problematic, as feet and hand elements are important for diagnosis, but these elements are among the least likely to be recovered in archaeological excavations (Waldron 2007). Such matters often make it difficult to definitively diagnose multifocal conditions in skeletal material. One must also consider intrinsic influences. As mentioned previously, it is suspected that the intrinsic factor of age may hinder diagnosis of SpA in certain assemblages; individuals who died young would have experienced the condition for a shorter duration, meaning the skeletal pathology may not have been fully expressed when death occurred. Finally, the common tendency for SpA to present abnormally (Undifferentiated SpA), means expression is not wholly predictable; SpA is not uniformly expressed, the underlying features of the SpAs are the same (spinal and SIJ involvement, erosions, and enthesopathy), but the manner in which these features are expressed (or not expressed) vary considerably

(Paramarta *et al.* 2013; Zochling *et al.* 2005). Such matters ultimately call for a discerning, yet inclusive means of classifying SpA pathology in skeletal material.

For these reasons, this research does not only seek out the prevalence of SpA in its purest form (*i.e.* only using its operational definition). It looks at all erosive pathology and makes a systematic judgment based on its pattern of expression to determine if the case is most in line with SpA (Reactive Pathology) or other erosive conditions (Nonreactive Pathology). In short, the operational definition of SpA is used as the measuring rod to classify cases, which allows us to determine how drastically the patterns of EA expression differs across assemblages. While Nonreactive Pathology should be relatively consistent across assemblages, Reactive Pathology, which is hypothesized to occur in greater frequencies when exposure and susceptibility to infectious diseases are high, should have a pattern of expression that differs across assemblages based on the microbial environment they experienced in life.

Of course, not all cases are going to be clear cut, for such cases, the Unidentified Pathology category is used. The inability to place Unidentified Pathology cases was often due to matters of poor preservation or the limited amount of skeletal pathology expressed. Some cases were also placed in the Unidentified Pathology category for the opposite extreme. Occasionally, there was plenty of pathology to consider, but it was contradictory; in other words, a fair argument for placement in either the Reactive or Nonreactive categories could be made.

How was the reactive or nonreactive nature of pathology determined? The Reactive Pathology classification was broken down into three subcategories. These subcategories were hierarchal, with each representing a different level of assuredness that the observed pathology was reactive in nature.

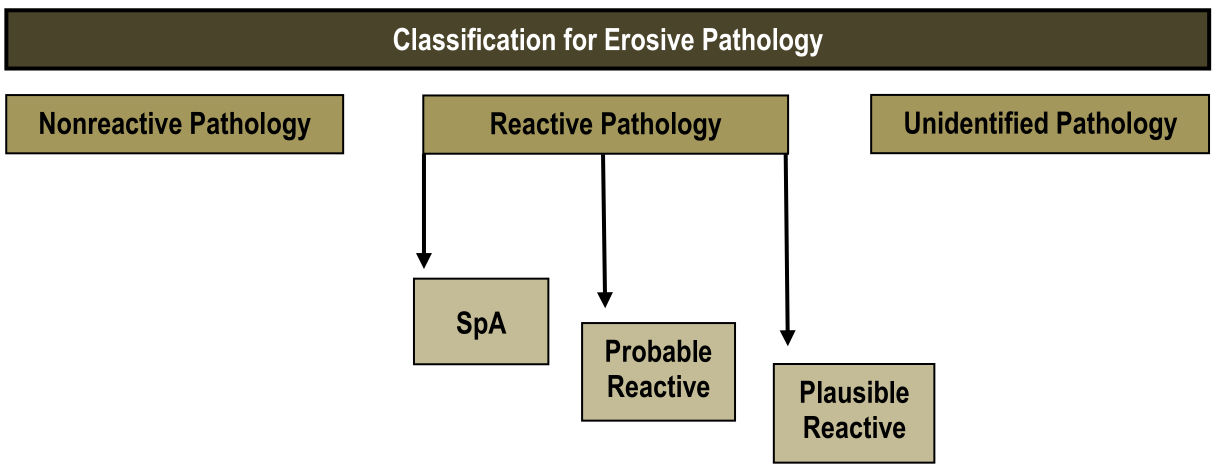
The three Reactive Pathology subcategories were:

1. SpA: the most assured subcategory; definitive cases.

2. Probable Reactive: the second most assured subcategory; likely cases of SpA.

3. Plausible Reactive: the third most assured subcategory; diagnosis of SpA cannot be excluded from consideration (see **Figure 53**).

Figure 53: The diagram below shows the categorical breakdown for pathology classification. The 3 subcategories of 'Reactive Pathology' represent different levels of assuredness that the pathology is reactive in nature. Source: created by the author.



Placement into these Reactive Pathology subcategories was based on a set of criteria used to measure how well the case fit the operational definition for SpA. The criterion used for assessment of cases are listed in **Table 16**. Characteristic enthesopathy for Criterion 4 is listed in **Table 17**.

Table 16: the table below provides the criteria used for the assessment and placement of reactive pathology. Source: created by the author.

Criteria for Reactive Pathology Assessment	
Criterion 1	unilateral or bilateral SIJ fusion **AND/OR** sacroiliitis (*definition in Appendix A*)
Criterion 2	chunky sydesmophyte spinal fusion with skip lesions **OR** three or more vertebrae demonstrating continuous smooth sydesmophyte fusion focused near the disk spaces (annulus fibrosus ossification)
Criterion 3	three or more vertebrae with sydesmophyte bone formation **AND/OR** evidence of fusion/erosion of the zygapophyseal facets, costovertebral facets, or interspinous ligament
Criterion 4	enthesopathy in a minimum of three locations, with at least one of these locations being diagnostic of SpA (*see Table 1 in Appendix A*)
Criterion 5	asymmetric marginal joint erosions in the extremities **AND/OR** marginal joint erosions associated with reactive bone formation (enthesopathy and/or periostitis)

Table 17: the table below lists areas where bone formation has been noted in clinical cases of SpA. Source: created by the author; for source information, see 'suggested reading' in Appendix A.

Bone Formation in SpA	
Cranium & Mandible	Occipital Protuberance (Enthesopathy)
	Nuchal Lines (Enthesopathy)
	Temporomandibular Joint (fibrocartilaginous proliferation)
	Musculus Temporalis Insertion, Coronoid Process (Periostitis)
Spine	Interspinal Ligaments (Enthesopathy)
	Supraspinal Ligaments (Enthesopathy)
	Anterior Longitudinal Ligament (Syndesmophytes or Ankylosis)
	Intervertebral Fibrocartilage (Ankylosis)
	Costovertebral Joints (Ankylosis)
	5th Lumbar Spinous Process (Enthesopathy)
Pelvis	Anterior Sacroiliac Ligament (Enthesopathy or Ankylosis)
	Iliac Crest (Enthesopathy)
	Anterior Superior Iliac Spine (Enthesopathy)
	Posterior Superior Iliac Spine (Enthesopathy)
	Ischial Tuberosity (Enthesopathy)
	Superior Pubic Ligament (Enthesopathy)
	Inferior Pubic Ligament (Enthesopathy)
Thorax	Sternocostal Ligaments (Enthesopathy)
	Intercostal Muscles (Enthesopathy)
Pectoral Girdle	Acromioclavicular Joint (Enthesopathy, Ankylosis, or Erosion)
	Musculus Deltoideus Insertion, Acromion (Enthesopathy)
	Musculus Levator Scapulae Insertion, Scapula (Enthesopathy)
	Coracoclavicular Ligament (Enthesopathy)
	Ischiopubic Rami (Enthesopathy)

Upper Limb	Medial Humeral Epicondyle (Enthesopathy)
	Lateral Humeral Epicondyle (Enthesopathy)
	Supraspinate Tendon Insertion, Humerus (Enthesopathy)
	Flexor Carpi Ulnaris Insertion, Pisiform (Enthesopathy)
	Flexor Carpi Radialis Insertion, Metacarpals II & III (Enthesopathy)
	Extensor Carpi Ulnaris Tendon (Enthesopathy)
	Wrist & Metacarpals (Periostitis)
	General: Metacarp als (Enthesopathy)
Lower Limb	Greater Femoral Trochanter (Enthesopathy)
	Medial Femoral Condyle (Enthesopathy)
	Lateral Femoral Condyle (Enthesopathy)
	Linea Aspera (Enthesopathy or Bone Proliferation)
	Intertrochanteric Crest (Enthesopathy or Bone Proliferation)
	Patella (Enthesopathy)
	Tibia Tuberosity (Enthesopathy)
	Achilles tendon (Enthesopathy)
	Plantar Fascia (Enthesopathy)
	Fifth Metatarsal Tuberosity (Enthesopathy)
	Ligamentum Teres Insertion, Femur (Enthesopathy)
	Musculus Gastrocnemius Insertion, Femur (Enthesopathy)
	Musculus Semimembranosus Insertion, Tibia (Enthesopathy)
	Popliteus Insertion, Tibia (Enthesopathy)
	Occipital Protuberance (Enthesopathy)
	Nuchal Lines (Enthesopathy)
	Temporomandibular Joint (fibrocartilaginous proliferation or erosions)
	Musculus Temporalis Insertion, Coronoid Process (Periostitis)
	Interspinal Ligaments (Enthesopathy)

To place cases of Reactive Pathology into subcategories, certain criteria from **Table 16** had to be met (see **Table 18**). For the most assured subcategory, 'SpA,' three criteria from **Table 16** must be met, as this automatically makes the case compliant with the operational definition of SpA (review **Table 15**). The reactive cases placed under the subcategories of 'Probable Reactive' and 'Plausible Reactive' pathology fulfil less than three of the above criteria and, as such, do not meet the operational definition for SpA. Nonetheless, if expressed in certain combinations, the pathology can still be considered reactive, as it favours SpA aetiology over that of nonreactive EA.

Table 18: the table below provides the criteria needed to place cases into Reactive Pathology subcategories. Source: created by the author.

Criteria for Reactive Pathology Subcategories	
SpA	Fulfilment of any 3 criterion listed in **Table 15**
Probable Reactive	With some exceptions (listed below), any criterion fulfilled in combination with criterion 2 **OR** 5; the following may be considered: Criterion 2 & 1 Criterion 2 & 4 Criterion 2 & 5 Criterion 5 & 1 Criterion 5 & 3 Criterion 5 & 4 when criterion 5 is met in three or more locations Criterion 2 & 3 accompanied by evidence of fusion/erosion of the zygapophyseal facets, costovertebral facets, or interspinous ligament (the first half of criterion 3 is redundant in combination with criterion 2)
Plausible Reactive	The following criterion may be considered: Criterion 1 & 3 Criterion 4 & 5 (2 locations) Criterion 2 Criterion 5 when met in three or more locations

Cases counted under the subcategory of 'Probable Reactive' pathology are those falling just short of meeting the criteria for a full SpA classification. This did not mean any two criteria could be used, as some combinations of pathology can be considered more convincing than others. For instance, enthesopathy and sacroiliitis are suspicious, but due to the propensity for some individuals to be bone formers (individuals with a natural tendency to produce new bone), it is not impossible for the pathology to be unrelated to reactive arthropathy (Waldron 2009; Waldron & Rogers 1990). As this subcategory is meant to represent cases that are highly convincing, it was determined that, *with some exceptions* (see **Table 18**), any criterion paired with criterion 2 or 5 could be considered a 'Probable Reactive' case. The pathology described in criterion 2 and 5 are very specific to SpA and are not likely to be confused with other conditions, so long as care has been taken to eliminate other conditions of possible differential diagnosis using Appendix A.

The exceptions made in regards to the combination of criterion 5 & 4 for a 'Probable Reactive' classification is due to the fact that enthesopathy has many causes. As mentioned, some people tend to be natural bone formers, which can be expressed through bone formation at the entheses (Waldron 2009; Waldron & Rogers 1990). One cause for this excess bone formation is repeatable injury (Waldron 2009). As military men would have participated in strenuous activities (horseback riding, lifting of heavy gear, climbing rigging, fighting, long marches, etc.), the potential for repeatable injury cannot be denied, making enthesopathy expected in military skeletal assemblages regardless of the presence or absence of reactive arthropathies.

That being said, one should not totally exclude enthesopathy from consideration, as modern clinical cases often use enthesopathy as an important means of distinguishing between cases of peripheral and axial SpA (Ehrenfeld 2012; Tubergen 2014; Tubergen & Weber 2012). Most studies focus on axial SpA, but one cohort study in France reported that 25% of their cases were peripheral, which is not necessarily a negligible figure (Costantino *et al.* 2013; Tubergen 2014). As the primary features of peripheral SpA are erosions and enthesopathy, this combination (criterion 4 and 5) should not be disregarded. To ensure that enthesopathy is likely related to reactive pathology, criterion 5 should be observed multiple times, as this creates a stronger reason to suspect a reactive nature, especially if the enthesopathy occurs in the characteristic locations listed in **Table 17**.

Cases counted under the final subcategory of 'Plausible Reactive' pathology included cases that are hard to attribute to any condition other than SpA, but presented with a rather limited amount of pathology to judge. As such, only a few criteria were considered reasonable for consideration, which are once again listed in **Table 18.** As criterion 2 and 5 are very specific to SpA, both criteria can stand alone as evidence in favour of reactive pathology, as long as differential diagnoses have been carefully considered and eliminated; however, there is one exception. Since one erosion can be difficult to confidently diagnose, criterion 5 must be observed in a minimum of three locations to be included in the Plausible Reactive subcategory.

Finally, as spinal and SIJ involvement are key features of SpA, a combination of criterion 1 and 3 should be considered as a 'Plausible Reactive' case, but, one should take care in their differential diagnosis before using these criteria. DISH may also cause spinal bone formation and SIJ fusion, but erosions and inflammatory changes are not characteristic of this condition. As such, this combination of criteria is best used as evidence of reactive pathology when observed with evidence of sacroiliitis, spinal erosion, or bone formation indicative of a reactive nature.

If pathology did not fulfil the criteria as described, then the case could not be considered under the Reactive Pathology classification. The operational definitions in Appendix A were then used to determine if the pathology fit any features of the nonreactive EAs: RA, erosive osteoarthritis, or gout. If evidence favoured one of these conditions, the case was listed under the Nonreactive Pathology classification. For example, a unifocal case of a para-articular erosion on the mediodistal surface of the 1st metatarsal is a location and expression commonly observed in gout, so such a case resembles a nonreactive nature. **Table 19** lists features that are typical of nonreactive erosions. If there was no particular evidence supportive of nonreactive or reactive pathology, or there was contradictory pathology, the case was placed in the Unidentifiable Pathology categorization.

Table 19: the table below lists features that are typical of nonreactive erosions. Source: created by the author.

Typical Features of Nonreactive Erosions
Monoarticular erosions (this not the case for all nonreactive EAs, but it is common)
Para-articular erosions
Articular erosions
Erosions with little/no new bone formation
Erosions associated with infections
Erosions associated with osteoarthritis (this is not impossible for reactive pathology, so differential diagnosis must be considered with the presence/absence of other pathology in the skeleton)

The criteria listed in **Table 16** were carefully crafted to specifically describe pathology that can be considered reactive, but caution should be used by the observer nonetheless. There will always be cases that simply behave abnormally. In such instances, detailed descriptions should be provided along with any assignment of classification given. To reduce confusion, the best course of action is simply to make oneself as familiar as possible with the conditions described in Appendix A; familiarity with the expression of these conditions will ensure that the observer is able to identify when something is amiss. Though the classification system used to differentiate between reactive and nonreactive erosive pathology is intricate, it should be rather easily applied by bioarchaeologists, as they are generally accustomed to such methods. The breakdown of reactive conditions into three levels of specificity allows flexibility (with discernment) that is similar to the methods employed by Martin-Dupont *et al.* (2006).

The Martin-Dupont *et al.* (2006) method produced useful statistical figures for prevalence analysis of SpA and, as such, this project employed a similar methodology. Some adaptations were made to fit the research purposes of this project, but the general application of the methodology was the same; criteria were used to classify pathology in a manner that produced three graduated levels of specificity correlated to a true SpA diagnosis. The method employed by this project uses SpA as the most specific category and described the less specific categories as reactive cases, as the criterion ensure that the observed pathology is more specific to the pattern of expression seen in SpA (reactive) than other EAs (nonreactive). Alternatively, one could also view these categories in a similar manner to those of Martin-Dupont *et al.* (2006): ‘definite,’ ‘probable,’ and ‘unexcluded’ diagnoses of SpA.

6.2.3 Statistical Analysis

Prevalence (P), is the statistical measure of frequency used to determine if reactive pathology is more common in military skeletal assemblages (Waldron 2007). Prevalence is calculated by taking the number of cases with the disease/condition/feature of interest (n), divided by the total number of individuals in the defined assemblage (N); the formula is thus: $P = n/N$. The main program used for prevalence calculation has been the Confidence Interval Analysis (CIA) software, which is from Altman *et al.* (2000). CIA simplifies the process of calculating prevalence by providing 95% confidence intervals, or any other confidence interval selected.

In this research, 95% (and occasionally 90%) confidence intervals were used to assess results. Confidence intervals represent the limits of the true value (prevalence) being tested (Altman 2000; Waldron 2007). One can compare the confidence intervals of two groups (populations) to assess basic significance (Gardner & Altman 2000; Knezevic 2008; Waldron 2007). When confidence intervals do not overlap, this assures the results are significant; there is strong evidence that the prevalence of the two groups greatly differs (Gardner & Altman 2000; Knezevic 2008). When confidence intervals overlap, significance is not necessarily absent, but the strength of the evidence is reduced; the likelihood that the prevalence of the two groups greatly differs is reduced (Knezevic 2008). In this project, lack of overlap in confidence intervals was considered significant (marked difference in prevalence is assured). When the confidence intervals overlapped, significance was not assured, but less than 1% overlap in the confidence intervals was considered as reasonably strong evidence of marked difference despite the lack of assured significance.

Selection of (n)

For the calculation of prevalence, there were two main counts for (n). The first uses the number of Reactive Pathology cases identified as (n) (the combined figure for all Reactive Pathology subcategories: SpA, Probable Reactive, and Plausible Reactive). This is the primary and most assured statistical count used in this research, as the pathology assigned to the Reactive Pathology classification follows the methods described in the previous section.

The second count is less assured and was designed as a secondary means of visualizing the data. With the established methodology, it was found that some cases of Unidentified Pathology provided some evidence to support a reactive nature, but fell short of fitting the criteria necessary for a Reactive Pathology classification. These questionable cases of Unidentified Pathology were counted in a secondary (n) ladled as Reactive Suspect Pathology; this count combined the cases of Unidentified Pathology presenting with some evidence of a reactive nature with the figures obtained for the Reactive Pathology (n). This created a speculative figure that presents the best case scenario for the occurrence of reactive pathology.

Selection of (N)

Selection (N) (admittance into the study) is also an important matter of consideration. For a set of remains to be accepted into a typical prevalence study, all of the skeletal elements used for diagnosis must be present; if the remains are lacking any of the relevant elements, they must be excluded (Waldron 2007). In the case of EAs, this would mean a considerable number of skeletons would have to be excluded, as numerous skeletal elements must be present for confident diagnosis. There are 4 articular surfaces needed for SIJ observation, 24 vertebrae (25 if you count S1), 54 hand/wrist elements, and 52 foot/ankle elements. Archaeological skeletons are rarely complete, meaning it is highly unlikely all of the necessary elements for diagnosis would be present. Furthermore, the feet/ankle and hand/wrist elements are the most likely to be lost in excavation or through processes of taphonomy (Roberts & Manchester 2010; Waldron 2007).

The matter of ‘missing data’ has not been addressed in previous bioarchaeological research of SpA, meaning the current author had to establish an original means of addressing this issue. As whatever approach chosen would be experimental in nature, two separate measures for (N) were created: the Probable (N) and Possible (N). Both measures judge the overall preservation of key elements for inclusion into the study, rather than consider each skeletal element individually.

The Probable N measure is the most specific, but least inclusive, meaning the produced (N) is smaller, but diagnosis (or lack thereof) is more assured. The calculation for the Possible N is less specific, but more inclusive, meaning the produced (N) is larger, but diagnosis is less assured. The Possible N measure can be thought of as a total (Probable N cases + Possible N cases); if criteria are met for the narrow criteria for Probable N, it automatically fits the wider criteria for Possible N. The criteria necessary for inclusion in the Probable and Possible N measures can be seen in **Table 20**.

Table 20: the table below defines the specification for entrance into the study using the Probable N and Possible N measures. Source: created by the author.

(N) Selection	
Probable N	All thoracic and lumbar elements were present **OR** no consecutive vertebrae were missing Both SIJs were present (all 4 articulations observable) At least 50% of the hand and feet elements (carpals/tarsals, metacarpals/metatarsals, and phalanges) were present.
Possible N	Most of the thoracic or lumbar spine was present; no more than two consecutive vertebrae were missing At least one articulation of each SIJ was present (1 right and 1 left articulation) At least 40% of the hand and feet elements (carpals/tarsals, metacarpals/metatarsals, and phalanges) were present.

Unless erosions or a relevant combination of the criteria listed in **Table 16** were observed, skeletons not meeting the specifications for either the Probable N or Possible N measures were excluded from the study. If relevant pathology was observed, the skeletal remains were counted in both N measures in spite of their overall preservation. It should be noted that cervical vertebrae were not counted in the criteria, as spinal pathology of SpA usually begins in the lumbar or lower thoracic region; however, pathology observed in the cervical vertebrae can still be counted for fulfilment of criterion, as cervical involvement is not unprecedented in SpA (Waldron 2009). Though the primary areas of focus were the spine, pelvis, hands, and feet, the whole skeleton was examined and recorded, as erosive pathology can potentially occur in any joint.

The Probable N and Possible N measures are assessed in Chapter 8 and 9 to determine if one was more effective than the other. This was done by calculating the difference between the reported prevalence of each measure.

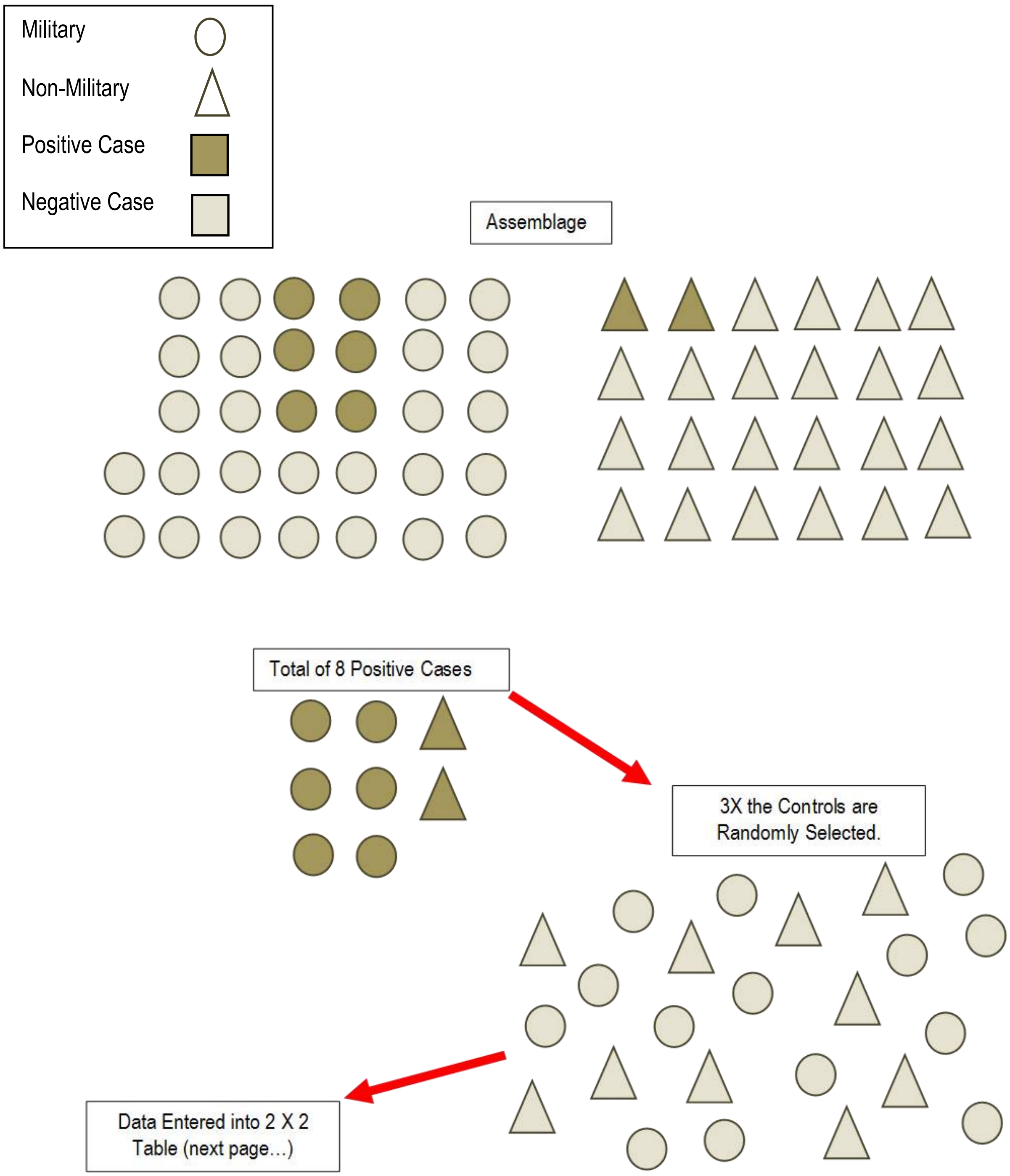
Nested Case Control

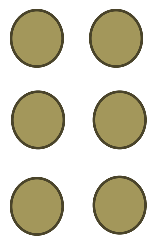
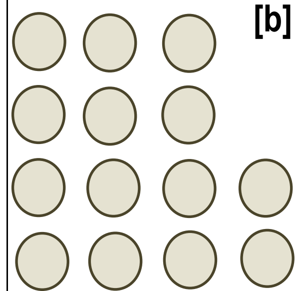
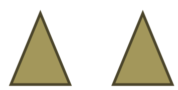
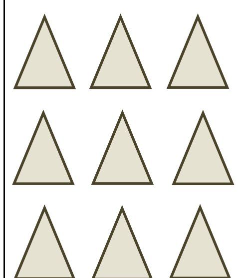
A nested case control study for both Reactive Pathology and Reactive Suspect Pathology was conducted. This method produces an odds ratio [*(a)(d) / (c)(b)*] (Waldron 2007). An odds ratio is a measure of exposure and outcome, that is to say, it is used to determine, “the odds that an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure” (Szumailas 2010, 227; Waldron 2007). In the case of this research, we seek to find out the odds that reactive pathology will occur when exposed to the military lifestyle. Exposure to the military lifestyle is represented by military versus non-military skeletal remains and outcome as the occurrence versus absence of Reactive or Reactive Suspect Pathology. To have the largest study base possible, all remains meeting the specifications for the Possible N measure were used. CIA software was used to calculate the odds ratio. Significance was assessed through the use of p values.

Mantel-Haenszel X^2 test were also run. This test quantifies the strength of association between two variables; the strength of the association between the military lifestyle and the occurrence of Reactive and Reactive Suspect Pathology. Significance was assessed through the use of p values. Mantel-Haenszel X^2 and p values were calculated through the use of MedCalc by Microsoft and JavaStat 2-Way Contingency Table Analysis.

For the calculation of odds ratios, all data (military and non-military) was pooled together (nested). All skeletons with relevant pathology were counted as positive cases, while all skeletons without relevant pathology were counted as negative cases. The total number of positive cases was used to calculate the number of negative cases (controls) needed for the study; for this research, 3X the amount of positive cases were randomly selected using Microsoft Excel. Once controls had been selected, all data was placed into a 2 X 2 table that segregated military and non-military data from positive and negative cases. This information was then used to calculate the odds ratio (see **Fig. 54**).

Figure 54: the diagram on the next two pages is an illustrative example of how the nested case control was conducted. Source: created by the author.



	+ Cases	- Cases	Total
+ Military	[a] 	[b] 	20
-Non-Military	[c] 	[d] 	11
Total	8	23	31

Data Entered into Odds Ratio Formula

Formula

(a)(d) / (c)(b) = odds ratio

(6)(9) / (2)(14) = 54 / 28

54 / 28 = ***1.93***

Age Assessment

As age is suspected to be an intrinsic factor influencing the ability to diagnose reactive pathology in skeletal material, this was assessed in the skeletal results. The first means of evaluating this factor was a simple comparison of the prevalence for Reactive and Reactive Suspect pathology for the Plymouth and Greenwich assemblages. As these assemblages share a common historical background, one would expect a similar prevalence. If this is not the case, this suggests age is a factor that affects diagnosis of reactive pathology, as the main difference between the Plymouth and Greenwich assemblages is their age distribution.

The other means of assessing age was to consider all Reactive and Reactive Suspect Pathology and determine the percentage belonging to certain age categorizations. Considering the amount of data produced, assessment of each specific age category was considered ineffective. As an alternative, age was evaluated by determining the percentage of cases occurring below (SA, YA, LMA categories) and above (UMA and MA categories) age 35. This was analysed by both site (individual military assemblages matched with their specific control assemblages) and type (the total military and non-military assemblage data).

Criteria Assessment

Finally, some assessment of criteria was considered. Each use of specific criterion listed in **Table 16** was noted. This illustrated which criterion were used the most and least. In other words, this analysis indicates the forms of reactive pathology most and least likely to be encountered in skeletal material.

6.3 Examples of Case Classification

The methods used to identify pathology in this research are complex. To aid the reader in understanding how particular types of pathology were classified, a few examples are discussed.

6.3.1 Reactive Pathology Example

Towton 8 fit the SpA classification for reactive pathology because it fulfilled three criterion: 1 (sacroiliitis), 4 (characteristic enthesopathy), and 5 (erosions). The focus of the erosions and enthesopathy were in the feet, which is most characteristic of ReA; however, the pathological changes were not specific enough to fulfil the operational definition of ReA listed in Appendix A.

Two lumbar vertebrae displayed very small areas of bone formation. The surface of the vertebral bodies did not show obvious signs of degeneration and the bone growth originated inferior to the intervertebral disk margin, suggesting ligamentous ossification rather than marginal osteophyte. These changes were not extensive enough to fill criterion 3, as such changes must be observed in three or more vertebrae (review **Table 16**). Nevertheless, SpA was still diagnosed based on fulfilment of criterion 1, 4, and 5.

Criterion 5 was met by the presence of foot erosions, which affected numerous elements (see **Fig. 55**), including:

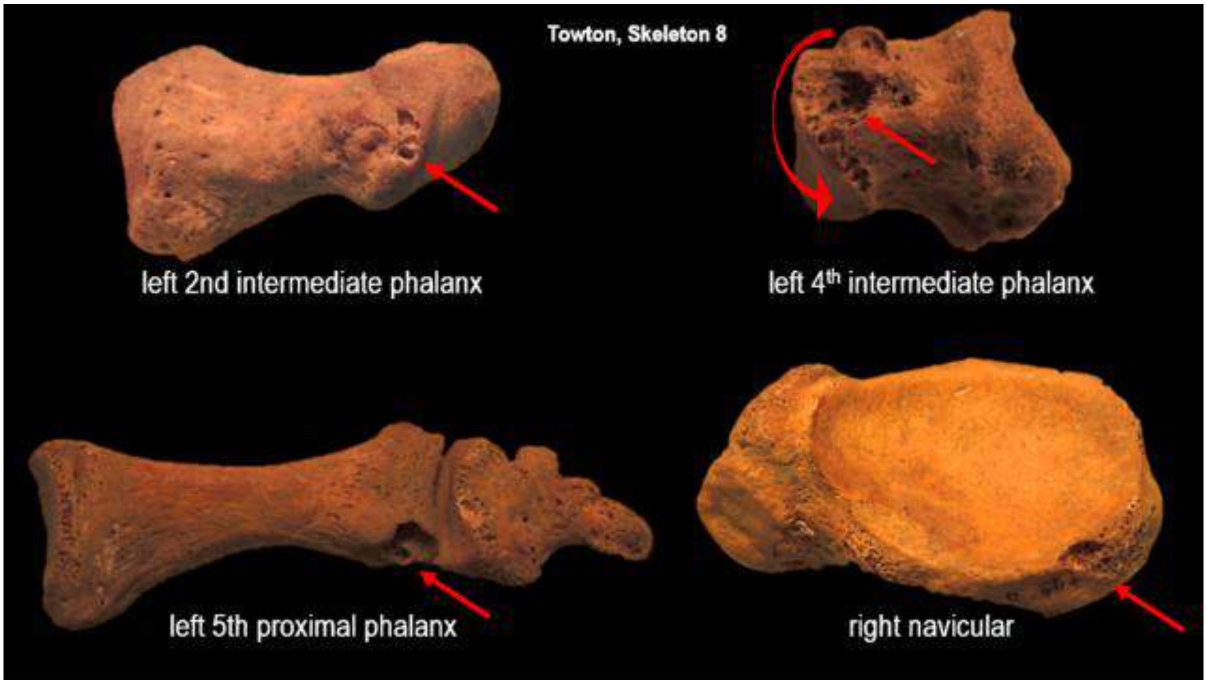
1. The distal end of the left 5th proximal phalanx: marginal and para-articular; was associated with ankylosis of the distal interphalangeal joint

2. The distal end of the left 4th intermediate phalanx: marginal and para-articular

3. The distal end of the left 2nd intermediate phalanx: marginal

4. The proximal surface of the right navicular: marginal.

Figure 55: this image displays erosions (red arrows, curved red arrows indicate continuous erosions following along a joint margin) observed in the left foot of Towton 8. Source: photo taken by author, permitted by BARC.



Criterion 4 was met by characteristic enthesopathy. Both the right and left shaft of the 5th metatarsals had enthesopathy associated with the plantar interossei insertions (2 sites of enthesopathy) (see **Fig. 56**). There was also bone formation at the locations of the anterior superior iliac spine in the pelvis (2 more sites of enthesopathy, total of 4 locations), which have been noted in clinical cases of SpA (characteristic enthesopathy) (Poggenborg *et al.* 2014).

Finally, Criterion 1 was met by unilateral sacroiliitis of the right SIJ, which was defined by:

1. marginal erosions on the superior aspect of the sacrum
2. an area of subcortical resorption on the joint surface
3. lipping suggestive of early ossification of the anterior sacroiliac ligament (see **Fig. 57**).

Figure 56: this image displays enthesopathy (red arrows) of the plantar interossei insertions in the 5th metatarsals of Towton 8. Source: photo taken by author, permitted by BARC.

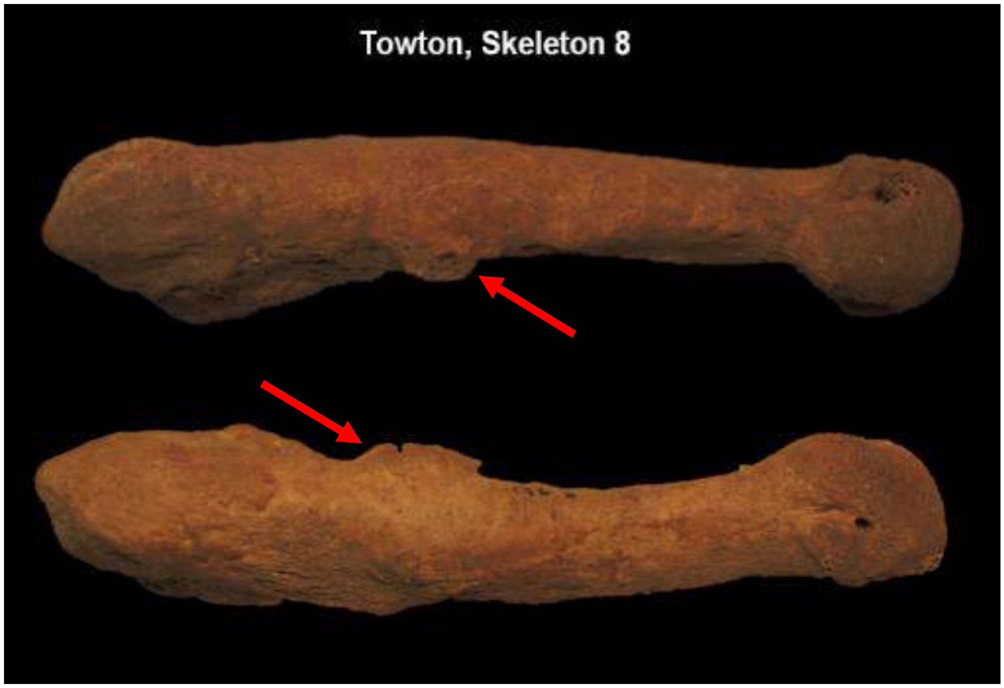
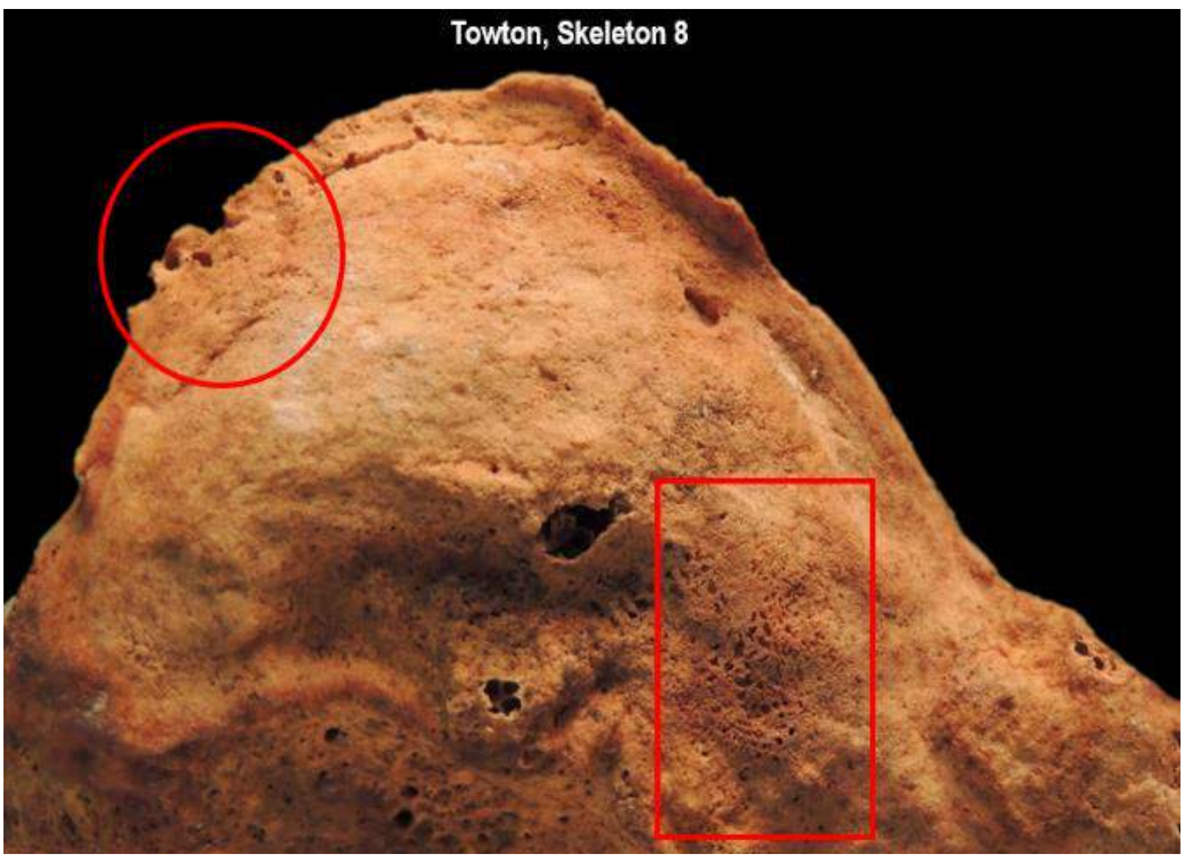


Figure 57: the image below show the right sacrum of Towton 8. The circle indicates a superior marginal erosion and the rectangle notes subcortical changes to the articular surface. Source: photo taken by author, permitted by BARC.



6.3.2 Unidentified Pathology Example

The Unidentified Pathology categorization was used for cases which did not fit either the Reactive or Nonreactive category, either due to contradictory data or because the pathology was ambiguous. The contradictory cases are the most confusing. KWK 3182 was such as case.

Superficially, KWK 3182 appeared to have the main features of SpA: spinal fusion, bilateral sacroiliitis, enthesopathy, and a foot erosion. Closer inspection causes suspicion of these features, as they do not fully fit the criteria listed in **Table 15**. For instance, the spinal fusion was continuous and only observed on the right side from T7 and T12. The changes were contained within the ligament and had the dripped candle wax appearance (see **Fig. 58**). These features are associated with DISH, not SpA. As such, Criterion 2 is not met and differential diagnosis reveals that Criterion 3 is not an appropriate assignment.

The singular erosion observed was not characteristic of SpA. The erosion was para-articular, affecting the mediodistal surface of the right 1st metatarsal (see **Fig. 59**). SpA erosions are typically marginal, while articular or para-articular erosions are more commonly associated with gout. No other erosions were observed (monoarticular), adding to the suspicion of gout. The mediodistal surface of the 1st metatarsal is a favoured location for gout, as well as pressure lesions associated with hallux valgus. Given the location and features of the erosion, a nonreactive nature is most likely, meaning Criterion 5 was not fulfilled.

Criterion 1 was fulfilled. Right SIJ fusion was observed, involving the inferior portion of the joint. Fusion extended across the articular surface. The superior portion of the auricular surface displayed irregular bone formation on the joint surface and pitting. Only part of the left SIJ was observable due to post-mortem fragmentation, but no pathology was evident. The new bone formation and pitting on the superior portion of the right auricular surface could be degenerative, but the inferior fusion of the anterior sacroiliac ligament, which extends across the auricular surface, is suggestive of sacroiliitis (see **Fig. 60**). Though SIJ fusion can occur in DISH, sparing the articular surface is the norm, as bone formation is confined to the ligament, so the SIJ pathology in KWK 3182 is not fully characteristic of DISH (Hannallah *et al.* 2007; Waldron 2009; Waldron & Rogers 1990). Nevertheless, giving the highly characteristic spinal bone formation of DISH in KWK 3182, it is likely the SIJ involvement is associated with DISH.

Criterion 4 was also met. Enthesopathy is another feature that can be seen in both DISH and SpA, with some of the same locations being favoured. Nevertheless, enthesopathy was observed in the following locations:

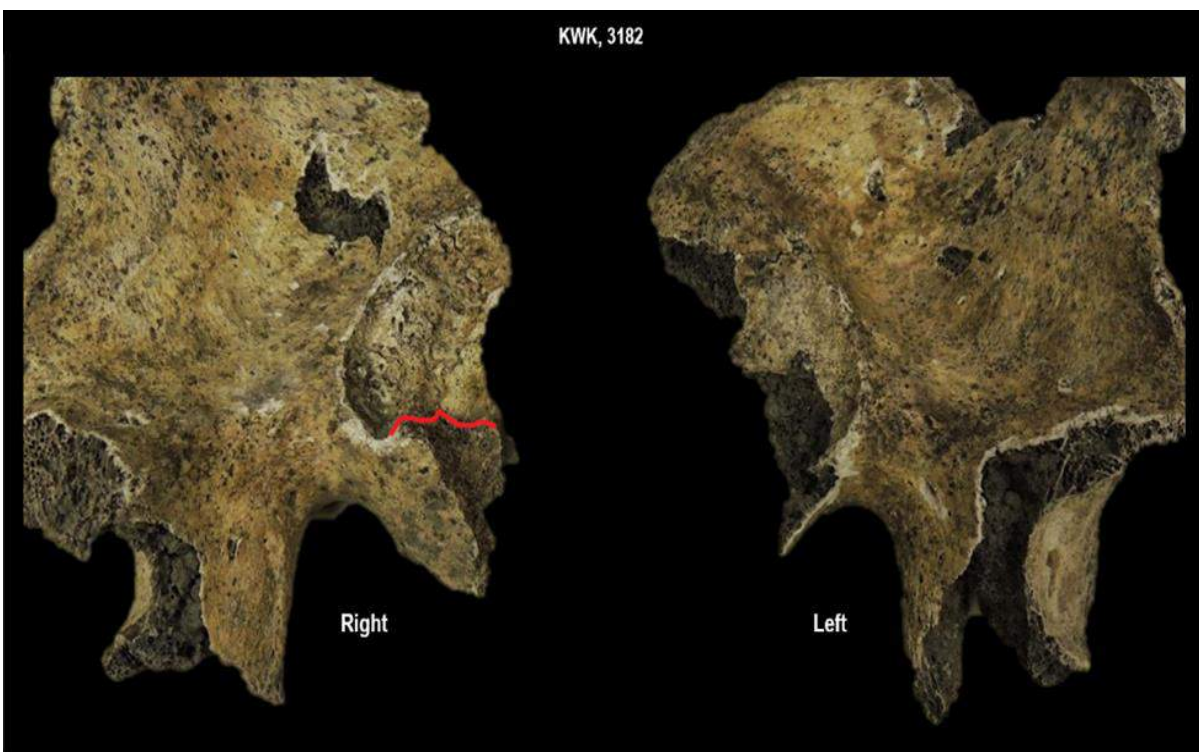
- The right coracoid process of the scapula
- Both radial tuberosities
- The finger flexors of the proximal hand phalanges
- Both iliac crests
- Both ishcia
- The greater and lesser trochanters of both femora
- Both linea aspera of the femora
- The left tibial tuberosity
- The right distal tibia
- The left patella

Did KWK 3182 have an oddly expressed case of SpA or a case of DISH and gout? Though SpA seems superficially simpler, the alternative cannot be eliminated and seems more likely. One of the potential triggers for DISH is an excess build-up of uric acid, which is also the primary aetiological factor for gout; similar dietary factors are also involved in both conditions (Kiss *et al.* 2002). Indeed, some clinical cases have reported gout and DISH occurring together in patients. For example, a study by Littlejohn and Hall (1982) on 99 males with gout found that 43% filled criteria necessary to diagnose DISH. To further add to confusion, it is also possible for SpA and DISH to occur together; PsA and DISH in particular have been diagnoses together (Olivieri *et al.* 2013). Though DISH and gout seems likely, two criteria were met (1 and 4), so the case was counted as having Unidentified Pathology; the control skeleton York 3114 was similar to this case and was categorized in the same manner.

Figure 58: the photo below shows the flowing and continuous spinal fusion between T7 (far right) and T12 (far left) in KWK 3182. This type of fusion is characteristic of DISH. The breaks occurred postmortem. Source: photo taken by author, permitted by MOLA.

Figure 59: the image below shows the para-articular erosions on mediodistal surface of the right 1st Metatarsal of KWK 3182. Source: photo taken by author, permitted by MOLA.

Figure 60: the photo below shows the SIJ fusion in KWK 3182. The red line indicates the border of the fusion in the right SIJ. Below this line, one can see exposed trabecular bone from the sacrum, which broke postmortem. The fusion extends across the joint surface; no joint space was preserved. Above the red line, one can see pitting and new bone formation. What is present of the left SIJ does not express pathology. Source: photo taken by author, permitted by MOLA.



6.3.3 Nonreactive Pathology Example

If cases did not fit with the Reactive Pathology categorizations using the criteria in **Table 15**, the case was then differentially diagnosed from nonreactive conditions listed in Appendix A, with the primary conditions of focus being: Gout, Erosive Osteoarthritis, and RA. If the case shared common features with these conditions, it was placed in the Nonreactive Pathology classification.

For example, one of the control skeletons from St. Brides Lower (FAO90), 1521, was given the Nonreactive Pathology classification because the case presented features described in **Table 18** as being nonreactive. FAO90 1521 had bilateral, round/oval lesions observed in the para-particular locations of both 1st metatarsals (mediodistal surface) (see **Fig. 61**). With no additional pathology to reject the most likely explanation of a nonreactive nature (no criteria of **Table 15** were met), the case was counted in the Nonreactive Pathology classification.

Figure 61: the photo below shows the para-articular changes to the distal 1st metatarsals of FAO90 1521. Source: photo taken by author, permitted by MOLA.

6.4 Summary of Methods

The methods used to examine both historical literature and skeletal material have been designed to provide useful quantitative results for answering the primary research question as to whether reactive arthropathies can be considered an occupation hazard to historical military combatants. Both methods have points of complication, but this chapter has addressed these points and acknowledged how they have been addressed. It has also provided information on how some of these methodological issues will be evaluated in later chapters.

The historical record has areas where poor recording limits the extent in which we can explore this link; for instance, the overall lack of publications in British military medicine before the 1680's (Alsop 2007). Though some gaps exist, the documents that are available can be evaluated to obtain a basic visualization of a potential affinity between military combatants and reactive arthropathy. The skeletal investigation also presents challenges. Many of the EAs are multifocal and intricate in their expression, so inclusion into the study is not a straightforward matter. Diagnosis of specific conditions can also be problematic. Such complications may serve as an explanation as to why few prevalence studies relevant to SpA have been attempted in bioarchaeological research. Even so, there is much palaeopathological and historical information that could be gained by investigating SpA prevalence, so an attempt has been made to establish a methodology that is inclusive, but maintains enough discernment, to provide useful statistical data.

Though this may not always prove true, two methods were considered better than one for this project. By using both historical and palaeoepidemiological research methods, it was ensured that ample data would be gathered and a satisfactory answer obtained for the primary research question. Furthermore, it was hoped that an interdisciplinary approach would provide more diverse data, which would allow for a more in-depth means of interpreting the implications of this project's findings.

CHAPTER 7:
Results for the Literature Investigation

The link between reactive arthropathies and the military lifestyle has not gone unnoticed. Reiter, Fiessinger, and Leroy all made their observations in military combatants following gastrointestinal infections. Some modern scholars have since discovered pre-1916 descriptions of ReA among military combatants (Bollet 1991; Hodgetts & Espinosa 1990; McSherry 1982). This lead Hodgetts and Espinosa (1990) to describe ReA as a 'soldier's disease.' Though the possibility of a connection between ReA and military combatants has been suggested based on evidence from historical documentation, none have attempted to quantifiably substantiate the claim. Though the quality of historical descriptions of reactive arthropathy are considered, one of the primary goals of this chapter is to present a listing that numerically illustrate the existence of a reactive arthropathy-military affinity.

This chapter has focused primarily on ReA to exemplify reactive arthropathies, as the bacterial triggers for ReA are commonly discussed in historical medical literature (diarrhoeal and venereal infections), which increases the chances of finding examples of ReA; however, there is also some consideration of Acute Rheumatic Fever (ARF), as this condition was well recognized during the nineteenth century. The first part of this chapter details reports of ReA made in general medical references, which progresses to discussion of a retrospective case of military reactive arthropathy, and finally discussion of military references. Besides providing the data necessary to establish a military association with reactive arthropathies, discussion of these references indicate that the history of ReA is far more complex than is commonly presented in palaeopathology and rheumatology texts.

7.1 Summary of Utilized Primary Resources

As with Chapter 2, there is need for some consideration of bias and quality of the historical documentation used to investigate a reactive arthropathy-military affinity. The majority of text used in this chapter are quite similar, or the exact same, as those utilized in Chapter 2 (such as *The Medical and Surgical History of the War of Rebellion* and *The Medical and Surgical History of the British Army which Served in Turkey and the Crimea*), so they face some of the same biases. For example, governmental texts have potential to be influenced by their overseeing organization. Though possible, it should be noted that this type of bias was not evident in the subject matter of this chapter. The primary resources used in this chapter are works by historical (works from 1916 and before) medical practitioners, but, as made clear in the historiography section of Chapter 2, the standards of knowledge and background of medical practitioners often varied. The medical profession as we recognize it today, with rigorous standards and scientific backing, did not strongly solidify until the late nineteenth century (Bollet 2002; Gabriel 2013; McCallum 2008). As such, there is no universal standard in which the quality of past physicians can be fully assessed, but, upon research, it was found that all the physicians who authored texts in this chapter had some form of official medical training; they had either attended medical school or apprenticed with well-known medical practitioners.

The sources of this chapter are primarily from medical publications (books, reports) and periodicals (journals such as *The Lancet*). Many of the reactive arthropathy descriptions come from well-known works or were published by medical practitioners of good standing during their respective periods; some of the more notable figures include: Swedinaur (1798), Brodie (1818), Pringle (1753), Lovell (1816), and Woodward (1863). Less formal medical documents were also considered, though they were rather few and were associated with physicians of identifiable backgrounds (example: the personal diary of American Revolutionary War physician Isaac Senter [published in 1846]). Be they well-known or obscure, these practitioners made useful observations that were considered worthy of consideration, as they provide clear evidence of the historical presence of reactive arthropathies, as well as acknowledgment of the existence of these conditions pre-1916 (though the degree of understanding varied).

Unlike chapter 2, observations of symptoms, patterns of disease progression, and consideration of aetiology are of more concern than statistics. While figures for rheumatism were often recorded, the description of 'rheumatism' includes a number of arthritic conditions. Medical practitioners did describe cases of infectious disease related rheumatism, but specific statistics on this phenomenon do not appear to have been recorded. Early recordings make it clear that physicians were curious about the rheumatism-infectious disease cases they observed, but it was a confusing association the begged the question: 'how could rheumatism be feasibly connected to infectious disease?' Since the role pathogens play in disease aeitiology had not been realized or fully appreciated when these texts were written, many of the explanations given to address this question have some bias, as their answers were based partly on observation and partly on personal beliefs about the nature of disease (the miasma theory of disease was popular when these texts were written, though humorism retained some influence as well). Confusion over the aetiology of infectious disease related rheumatism is evident in several texts. For instance, some decided that the involved infectious disease must be a form of rheumatism in order for co-occurrence to be possible, but others more accurately viewed their co-occurrence as a relationship of cause and effect; this debate in relation to dysenteric rheumatism cases can be seen in the works of Akenside (1764), Zimmermann (1765), Lepecq de la Clôture (1765), Stoll (1775), Swedinaur (1798), Harty (1805), and Huette (1869). Despite misunderstandings related to confusion over disease aetiology, many of the historical descriptions are quite detailed, leaving little doubt that reactive arthropathies are a sound explanation for these cases. Furthermore, these texts show clear forward progression in the understanding of reactive arthropathies over time, illustrating an increasing medical awareness of the behaviors of reactive arthropathies and the cause and effect relationship between infectious disease and rheumatism.

7.2 General Medical References

There is great antiquity to the understanding of the link between venereal disease and arthritis. Hippocrates in 460 BC stated that, ‘‘a youth does not suffer from gout [arthritis] until sexual intercourse” (Carter & Hudson 2009, 22; Iglesias-Gammara *et al.* 2005). In 1686, Thomas Sydenham (English physician, 1624-1689) described pain in the limbs after gonorrhoea, but he made no observation of actual joint changes (Carter & Hudson 2009; Iglesias-Gammara *et al.* 2005; Storey & Scott 1998; Sydenham 1850). William Musgrave’s (English physician and member of the Royal College of Physicians, 1655–1721) 1715 publication *De Arthritide Symptomatica Dissertatio* described joint involvement after venereal disease and in 1810 John Hunter (Scottish surgeon, army surgeon and fellow of the Royal Society, 1728-1793) said he found venereal disease to be “the seat of the rheumatism” (Hunter 1841, 33; Storey & Scott 1998). Many of these descriptions are quite vague, so one cannot definitively determine if they are referring to gonorrhoeal arthritis (a form of septic arthritis) or to ReA (a true reactive arthropathy according to the definition provided in Chapter 1). Both gonorrhoeal arthritis and ReA are likely represented among these references, but without descriptions specifically recording back pain or conjunctivitis (one of the ReA triad symptoms), it is difficult to retrospectively distinguish between the two (Carter 2010; Gill *et al.* 2015).

Franz Swediaur’s (British venereologist, 1748-1824) 1798 book on the treatment of syphilitic diseases (*Tralté Complet sur los Symptomes des Maladie Syphilitiques*) provides a very specific description of venereal related arthropathy that befits ReA, stating: “sometimes after blennorhhagica there is swelling of the knee, sometimes both knees and calcaneum” (Scott & Kingley 2007, 128; Storey & Scott 1998, 501). This provides a description of arthritis resembling ReA in regards to its association with venereal disease, the locations affected (knees and the heel of the foot), and the occurrence of a particular skin rash (Keratoderma Blennorrhagica, see **Fig. 62**) which sometimes occurs in ReA cases (Haridas 2015; Szamocki *et al.* 2016).

Figure 62: the image below is an example of Keratoderma Blennorrhagica, which is observed in some ReA cases. Source: Szamocki *et al.* 2016, 19.

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References to rheumatism following dysenteric infections are easier to attribute to ReA, as this condition is the most common reactive arthropathy to be associated with these infections (Carter 2010; Gill *et al.* 2015; Hannu 2006; Hannu 2011; Manasson & Scher 2015; Singh & Karrar 2014). There are references to early observations of dysenteric arthritis, but many of the physicians missed the importance of these observations; though physicians noted cases of dysentery being followed by rheumatism, most viewed this as a coincidence rather than proof of a legitimate link. For example, Charles Huette de Montargis (French physician, 1820–1881) writes that a physician by the name Zimmermann observed an epidemic of dysentery in Bern, Switzerland in 1765 that noted the appearance of rheumatism in some of his patients, but Zimmermann explains this occurrence as a consequence of the treatments being provided (Huette 1869). Huette's publication also discusses Louis Lepecq de la Clôture's (French surgeon, 1736 -1804) 1765 report on long-term complications of rheumatism following dysentery in Caen, France, but Lepecq de la Clôture did not find them to be linked in any meaningful manner (Huette 1869).

In opposition to the naysayers was Dr. Mark Akenside (English poet and physician, 1721-1770), who did believe the occurrence of rheumatism was directly linked to dysentery. Akenside's notes were described in Charles Bucke's (1832) *On the Life, Writings, and Genius of Akenside: With Some Account of His Friends,* where it is stated:

> in 1764, Akenside published the most important of his medical works; viz. *De Dysenteria Commentarius*. On this work the medical fame of Akenside principally rests. The dysentery seems to have been very little understood before his time; and he attributes the causes to nearly the same as those of the rheumatism, between which, he insists, there is a great affinity. Hence he calls the bloody flux a rheumatism of the intestines (Bucke 1832, 147-148).

Though Akenside was correct in his assertion that the occurrence of arthritis and dysentery were connected, his explanation of the link was incorrect; Akenside believed they were the same condition, that dysentery was a rheumatism of the intestines. Also discussed by Huette (1869), physician Maximilian Stoll (Austrian physician and professor at the University of Vienna, 1742-1787) expressed the same view as Akenside. In Stoll's publication *De Nature ct lndole Dysenteriae Commentatio,* he notes a case of rheumatism following a bout of dysentery in France between 1776 and 1777 and states his belief that dysentery was a rheumatism of the bowels (Carter & Hudson 2009; Huette 1869; Merino *et al.* 1999; Iglesias-Gammara *et al.* 2005; Stoll 1794; U.S. Army Surgeon General's Office 1879). Stoll did note involvement of many of the joints consistent with ReA in this cases, including the shoulders, neck, wrists, knees, instep swelling, and sciatica (Huette 1869).

In 1805, William Harty's (Irish scholar and physician, 1781-1854) publication *Observations on the Simple Dysentery and its Combinations…* dedicated a whole chapter to describing the connection between dysentery and rheumatism called 'Analogy Between Dysentery and Rheumatism.' Harty describes Akenside and Stoll's descriptions (along with others) as evidence that, "we may, I believe, admit upon grounds that will not be questioned, the existence of a very close connection between the two cases" (Harty 1805, 22). Though a considerable chapter, the evidence Harty provided in favour of a link between dysentery and rheumatism still suggests that dysentery was a type of rheumatism. Charles Huette interpreted these earlier observations differently than Harty. Huette's *De L'Arthrite Dysentérique* (1869) concluded that the relationship between the two conditions is one of cause and effect. Furthermore, Huette correctly states that these conditions can exist simultaneously or appear in succession (Huette 1869).

Though we can now attribute many of these descriptions to ReA, notation of the famed ReA triad is the normal standard used to assign credit for the discovery of ReA. Outside of Reiter, Fiessinger, and Leroy, one other physician is occasionally noted as the first to describe the ReA triad of post-infectious arthritis, urethritis, and conjunctivitis (often described as ophthalmia). This physician was Sir Benjamin Brodie (English surgeon and fellow of the Royal Society, 1783-1862), who did indeed provided numerous descriptions of the triad in his 1818 and 1836 editions of *Pathological and Surgical Observations on Diseases of the Joints* (Ford 1953; Storey & Scott 1998). These cases are quoted below in **Table 21**. Brodie's descriptions are condensed for the sake of succinctness, but it is clear he understood that the triad of symptoms were the outcome of one syndrome triggered by an infection (gonorrhoea) (Carter & Inman 2011). It is further apparent from the third and fifth case that Brodie knew this condition could have dire consequences, as there was a tendency for relapse and disability ('crippling').

Though this is the earliest non-military reference to the ReA triad, Brodie's description was far from the last to occur between 1818 and 1916; the ReA triad was described in numerous other references, which are listed in **Table 22**. All of these cases were examples of gonorrhoea induced ReA. As gonorrhoea was diagnosed based on the presence of urethritis, this part of the triad is occasionally implied in the references of **Table 22**, but many mention urethritis specifically. Since these descriptions of the triad are very specific and required keen observation to identify as being interconnected, the numerous descriptions of the ReA triad by Brodie and others indicates there was considerable understanding of ReA before 1916. The condition even had a common name pre-1916: Gonorrhoeal Rheumatism.

Table 21: the table below provides translated quotes of Brodie's references to the ReA triad. The elements which fulfil the triad (arthritis, urethritis, and conjunctivitis) are highlighted in **bold.** Source: created by the author; information from Brodie 1818 & Brodie 1836.

ReA Triad Quotes from Brodie 1818 & 1836	
1	A gentleman, forty-five years of age, in the middle of June 1817, became affected with symptoms resembling those of **gonorrhoea**. There was a purulent **discharge from the urethra**... On the 23d of June he first experienced some degree of pain in his feet. On the 24th the **pain in the feet** was rather increased, but not in a sufficient degree to prevent his walking four miles. There was some appearance of **inflammation of his eyes**. June 25th, the pain in his feet was more severe; the **conjunctivae of his eyes were much inflamed, with a profuse discharge of pus** (1818, 55).
2	In one of them the first symptom was **inflammation of the urethra**...This was followed by **purulent ophthalmia**, and that by **inflammation of the synovial membranes** (1818, 61).
3	In the year 1809, he had symptoms resembling those of **gonorrhoea**...This was followed by a purulent **ophthalmia**, and **inflammation of the synovial membranes**. In the year 1814, he had a similar attack, with the exception of the swelled testicle; and in the year 1816, when I was consulted, he still laboured under a chronic inflammation of the synovial membranes of the knees and ankles, the consequence of the last attack, and by which his lower limbs were completely crippled (1818, 63).
4	In the fourth case the patient laboured under a severe **ophthalmia**, which was followed by **inflammation of the urethra**, and then the **joints became affected**: but I had no opportunity of watching the progress of this case, nor have I heard any other particulars of it (1818, 63).
5	In the fifth case the patient laboured under **strictures of the urethra**. He had had four attacks of the disease which has been just described in the course of a few years. The **inflammation of the urethra** was in all of them the first symptom; which was followed by **purulent ophthalmia**, and afterwards by inflammation of the synovial membranes, and **swelling of nearly all the joints**. In two of these attacks, he attributed the discharge from the urethra to his having received the infection of gonorrhoea, and in the two others to the use of the bougie (1818, 63).
6	A gentleman twenty-three years of age, in the beginning of July, 1819, rode 24 miles on horseback, trotting very hard on account of rain. Two days afterwards he observed a slight **swelling of the left knee**; but this did not prevent his going about his usual occupations. About the middle of July, a slight **purulent discharge took place from the urethra**, with little or no pain. On the first of August, he walked a considerable distance, and found the knee to be more painful...August 3d, the pain had much increased, so that it was excruciating...August 6th, the pain was very intense in the knee. The purulent discharge from the urethra was rather increased. There was a slight degree of **inflammation of the conjunctiva** of the left eye (1836, 64).

Table 22: the table below lists references to the ReA triad which occurred between Brodie's 1818 description and the famed 1916 descriptions. Source: created by the author.

References to the ReA Triad from 1818 to 1916	
1	1824, Astley Cooper reported two cases in *The Lancet* under the heading "An Interesting Case of Rheumatic Inflammation, and Purulent Ophthalmia, Following the Suppression of a Gonorrhoeal Discharge."
2	1826, Lawrence published his lecture "Gonorrhoeal Ophthalmia-Rheumatic Ophthalmia" in *The Lancet*.
3	1826, Frick and Welbank link venereal disease (including gonorrhoea) to rheumatism and ophthalmia in *A Treatise on the Diseases of the Eye*.
4	1836, Thomson describes a case of gonorrhoeal arthritis presenting with rheumatism and ophthalmia in *The Lancet*.
5	1836, Storey & Scott (1998) discovered a case history that mentions all elements of the triad in the University College Hospital Records (no interpretation, just a report of symptoms).
6	1838, Storey & Scott (1998) discovered a case history that mentions all elements of the triad in the St. Bartholomews Hospital Records (no interpretation, just a report of symptoms).
7	1866, Tixier described 14 case of the triad according to Scott and Kingsley (2007).
8	1866, Broadhurst describes the triad in a section on "Gonorrhoeal Rheumatism" in *Reynolds A System of Medicine.*
9	1868, Fournier mentions cases of gonorrhoeal arthritis with thirteen cases showing eye involvement (Ford 1953, 178).
10	1870, Johnstone has a chapter in *A System of Surgery: Theoretical and Practical* (Vol. IV) on "Gonorrhoeal Rheumatism" which describes the triad.
11	1872, Bond published "On Gonorrheal or Urethral Rheumatism" in *The Lancet* where he reported that 10% of 300 cases of venereal disease patient in London were of gonorrhoeal arthritis and he goes on to explain that complications of the eye (including ophthalmia) were common.
12	1878, Potter published a book called *Gonorrhoeal Rheumatism,* which describes the triad in several cases.
13	1879, Bumstead's *The Pathology and Treatment of Venereal Diseases* has a chapter on "Gonorrhoeal Rheumatism" that describes the triad.
14	1899, Launois reported on a case of blennorrhagica presenting with arthritis, urethritis, and 'iritis' (inflammation of the iris of the eye) (Ford 1953, 178).

7.3 Retrospective Diagnosis of Reactive Arthropathy

When examining the medical past, some scholars have attempted to make retrospective diagnoses of medical conditions in renowned historical figures. Research into conditions qualifying as reactive arthropathies are no exception, as several scholars have identified historical cases believed to be reactive arthropathies (Anderson 1989; Carter & Hudson 2009; Hodgetts & Espinosa 1990; Iglesias-Gammara 2005; Scott & Kingsley 2007; Storey & Scott 1998). Though certainly an interesting endeavour, retrospective diagnoses can be difficult. Modern physicians, who can personally examine their patients and have numerous medical resources available to them (modern imagery, medical histories, etc.), still make incorrect diagnoses on occasion, so making a retrospective diagnosis without many of these advantages is undeniably a complex task (Karenberg 2009; Mitchell 2011; Muramoto 2014). This, in addition to differing and evolving viewpoints over time, mean attributing specific conditions to historical individuals should be approached with caution (Karenberg 2009; Mitchell 2011; Muramoto 2014). Nevertheless, there is one case relevant to this research that was considered worthy of examination.

The retrospective diagnosis of reactive arthropathy in question is that of military general Robert E. Lee, commander of the Army of Northern Virginia during the American Civil War. Though specific retrospective diagnoses are difficult, the evidence that supports a reactive arthropathy retrospective diagnosis for Gen. Lee's case is compelling and worth examining for a few reasons. If one ignores his status as a renowned military general and looks at the most basic circumstances surrounding his case, it is intriguing enough to be further described and debated; he was a military combatant known to be participating in an active military campaign (which included living in a military encampment environment) when he experienced infectious diseases known to trigger certain reactive arthropathies, which was followed by the development of rheumatic symptoms. Inversely, considering his rather renowned status as a military general of great importance (considered to be so by his contemporary counterparts and historians), there is more information about various aspects of his life that can be considered in addition to the circumstances of his case, which provides further information to contextualize and interpret the wider implications of his condition. The topic of discussion in the present chapter is the evidence that favors or disfavors a reactive arthropathy diagnosis. Though retrospective diagnoses are problematic, it has been noted that they can be of use "in the form of an historical interpretation within a certain historical context;" retrospective diagnoses, presented with hypothesis-construction (discussed from a standpoint of potentials rather than a true or false statement of fact), has potential for historicized interpretation (Karenberg 2009, 144; Muramoto 2014). In line with this justification for retrospective diagnoses, Gen. Lee's case is later explored in Chapter 11 from the standpoint of understanding the potential historical implications that may have been involved when military officers (who had power to make military decision of great importance) suffered from reactive arthropathies as opposed to military combatants of lower rank (where the majority of focus in the present research rests).

Arguments favouring both ReA and ARF can be made. In 1863, Gen. Lee experienced heart troubles that were diagnosed as rheumatic pericarditis and then experienced troubles again in March of 1864 after a throat infection settled into inflammation of the pericardium (Bollet 1991, 1202; Schroeder-Lein 2008). Before his death, Lee again had heart troubles accompanied by shoulder pains and diarrhoea (Field 2010; Welsh 1995). Heart troubles, throat infections, and rheumatism are all symptoms of ARF; however, in the 1864 campaign, Gen. Lee also had 'lumbago,' which refers to rheumatic pains of the lower spine (Bollet 1991). The most commonly affected areas of ARF are the knees, ankles, elbows, and wrists, but the lower spine is not typical of this condition (Chakravarty *et al.* 2014). Lower back pain is highly characteristic of SpA.

Though throat infections were directly linked to his heart problems, Gen. Lee would also be a candidate for ReA. Streptococcal tonsillopharyngitis has been linked to some cases of ReA, but Gen. Lee also experienced frequent gastrointestinal troubles during the war (Morris & Inman 2012; Sarakbi *et al.* 2010). The year of 1864 was no exception. In May, Gen. Lee was greatly hindered by dysentery and, “cross as an old bear” as a result (Bollet 1991; Katcher 2004; Rhea 2014). With this in mind, one cannot discount the possibility that Gen. Lee’s great attack of rheumatism in May 1864 was linked to his gastric ailments.

The last bit of evidence that can be analysed about Lee’s case is the duration of his symptoms. Lee’s heart troubles were a problem until his death in 1870, but so were his rheumatic pains (Bollet 1991; Foote 1974). Lee’s extended heart trouble is certainly within reason for a prolonged case of ARF, which is also supported by the fact that his rheumatism often appeared to accompany his periods of heart complications until his death. Nevertheless, ReA is also not fully discounted as a possibility, as rheumatic symptoms in ARF are not often prolonged and ‘lumbago’ is more characteristic of ReA (Chakravarty *et al.* 2014). Modern clinical research has shown that ReA can lead to heart problems in 10% of patients, causing aortic regurgitation, electrocardiographic conduction abnormalities (5-14% of patients), and pericarditis (quite rare); however, ReA related heart complications are usually linked to cases that have been chronic for prolonged periods of time. The fact that Lee’s heart complications and rheumatism occurred together from the very first reporting of these troubles works against this explanation (Selmi & Gershwin 2014; Stavropoulos *et al.* 2015). The overlap between Gen. Lee’s symptoms lead Bollet (1991) to suggest the possibility he suffered from both ReA and ARF.

It has also been suggested that Lee’s heart troubles after Gettysburg were due to ischemic heart disease (coronary heart disease) and the rheumatic pericarditis recorded by Gen. Lee’s physicians was incorrectly diagnosed due to a “lack of familiarity of American physicians with angina during the 19th Century” (Mainwaring & Tribble 1992, 237). While it is possible that Gen. Lee’s complaints of lumbago and other arthritic pains were completely unrelated to his heart complications, it is argued here that reactive arthropathy cannot be easily discredited as a potential retrospective diagnosis, as the initial onset of this condition was directly attributed to a throat infection and, near the same time, he also suffered from gastrointestinal infections.

Considering what is known of the aetiology of reactive arthropathies, the onset of rheumatic related heart troubles around the time of know triggering infections is certainly suspicious. Furthermore, SpA and ARF are associated with many different types of heart complications (aortic insufficiency, congestive heart failure, strokes, endocarditis, aortitis, angina, and pericarditis), so it would be very difficult to definitively determine his heart complications were not associated with a reactive arthropathy (Gerber *et al.* 2009; Jamnitski *et al.* 2013; Seckeler & Hoke 2011). Acknowledging that a reactive arthropathy is a potential retrospective diagnosis of some merit in Gen. Lee's case, the circumstances are there to make an argument for either ARF or ReA, or perhaps even their co-occurrence, but, given the challenges of making retrospective diagnoses, this is an insidious endeavor that leads to few satisfying conclusions. The best option is simply to state that, considering the timing of his ailments (throat infections, dysentery, and heart complications) with rheumatism (including lumbago) during the war, it seems probable that Lee suffered from some form of reactive arthropathy.

7.4 Military Medical References

In addition to general medical references to ReA, there is a rather extensive list of ReA references from military medical literature. The first half of this section notes direct evidence in the form of quotations that describe cases of ReA. The second part of this section provides a brief discussion ARF, which is also a reactive arthropathy, albeit one that does not leave skeletal evidence.

7.4.1 Direct Quotations of ReA

One of the earliest military references to reactive arthropathy occurred in 1664 when Martiniere, a campaign doctor to Frederick III of Prussia, noted arthritis could be a complication of urethritis; he discovered this while conducting research on venereal disease during an expedition to Denmark (Copeman 1986; Hodgetts & Espinosa 1990). Military descriptions relating to the British Army can be found in John Pringle's 1753 publication *Observations on the Diseases of the Army*. The first is a short reference to venereal arthritis stating: "sometimes venereal pains may be mistaken for rheumatic; at other times, the two may be joined" (Pringle 1753, 167). This is a vague reference, but Pringle also described dysenteric arthritis. During a discussion of diseases observed in the Campaign of Flanders in 1774, Pringle specifically notes dysentery and fevers. Of this same campaign Pringle say, "when the weather grew cold, it was often attended with a cough, infarction of the lungs, or rheumatic pains; which symptoms, as was said above, did not properly belong to the fever, but were only accessions to it from extraordinary colds" (Pringle 1753, 32). Though Pringle does not seem to think rheumatism could be connected to the other diseases being observed, it is quite possible that this was indeed the case. In *Observations on the Epidemical Disease in Minorca from 1744 to 1749*, George Cleghorn (Scottish physician who served with Irish regements, 1716-1799) writes that the heat of some fevers is relieved through stool or urine (referral to gastrointestinal related fever) and "are so complicated with fixed Pains of ...Lumbago, or Rheumatism" (Cleghorn 1809, 159). Gastrointestinal complaints listed in combination with specific referral to lower back pain (lumbago) make ReA a likely diagnosis.

Dr. Isaac Senter also provides a clear description of ReA. Senter, who learned his trade from Scottish physician Dr. Thomas Moffat in New Hampshire, joint the Continental Army after the Battle of Lexington to become a physician for Benedict Arnold's troops during the American Revolutionary War. Over the course of his service, he kept a journal which included numerous references to troubles with dysentery, including the dates of September 25th, 26th, October 6th, and 15th of 1775. Following these complaints of dysentery, on October 16th, Senter links the outbreak of dysentery to three men suffering from rheumatism:

> A block house was erected and christened by the name of Arnold's Hospital, and no sooner finished than filled. Not far from this was a small bush hut …In this they left a young gentleman by name Irvin…the case of this young gentleman was truly deplorable. In the first of our march from Cambridge, he was tormented with a disentery [dysentery], for which he never paid any medical attention. It [dysentery] kept him in a most violent rheumatism I ever saw. Much in the same condition was Mr. Jackson of the same company, and Mr. Greene, my mate. All these three gentlemen were afflicted with the same disease during the beginning of our march (Senter 1846, 105).

Senter's writing indicates that he believed the rheumatism was linked to the occurrence of dysentery, which demonstrates understanding that arthritis could be a valid complication of gastrointestinal diseases.

In 1803, Dr. Henry Dewar, a Scottish military physician, published *Observations on Diarrhoea and Dysentery, As Those Diseases Appeared in the British Army, During the Campaign in Egypt, In 1801.* It appears cases of ReA arose during this campaign, as he notes that diarrhoea and rheumatism can frequently occur together:

> There is often a close connection among the various diseases produced by cold. For example, it sometimes produces diarrhoea and rheumatism together. More frequently, it first produces the one disease, and when that retires, the other succeeds. A rheumatism in the arm or back, often alternates with diarrhoea and pain in the bowels. It is also very common for pains in the bowels sensibly to move backwards, and settle in the muscles of the loins, in the form of lumbago (Dewar 1801, 35).

Dewar's description actually shows rather good understanding of ReA, as he correctly describes the pattern followed, with one (most likely diarrhoea) proceeding and the other following (rheumatism). Further proof of ReA in this description is indicated by his specific referral to lower back pain (lumbago), which is associated with SpA.

In 1806, Baron Alexandre Yvan, a surgeon-in-ordinary for Napoleon I, describes a case of one of Napoleon's captains as follows:

> Un capitaine invalide , âgé de quarante ans , d'une constitution grêle , entra à l'infir merie, le 9 Frimaire An VII , pour se faire traiter d'une **gononhée** qu'il avoit contrac tée depuis quinze jours. Ce militaire s'étbit déjà mis de lui-même au régime, et il avoit fait usage d'une tisane de graines de lin nitrée… Le malade fut de suite affecté d'une **ophtalmie con sidérable sur les deux yeux**. L'impression de la lumière lui devint très-sensible , et l'engorgement des conjonctives fut extrême… **Le zi le malade se plaignit de douleur dans l'articulation du pied droit**. Cette douleur fut accompagnée d'un léger gonfle ment qui s'aggrava de jour eh jour; l'arti culation du genoux devint malade , ainsi que celle de l'avant - bras avec le bras droit , et le condyle externe de l'humé rus se tuméfia. L'extrémité supérieure gauche fut à l'abri de ce …désordre, étant atrophiée à la suite de blessures (Yvan 1806, 120-121).

Above, Yvan describes the case of a 40 year old invalid captain. The captain contracted gonorrhoea and was admitted to the hospital after the military's attempts to treat him were unsuccessful. Of this captain's cases, Yvan describes rheumatism in the feet, knees, and the right arm. He further describes that the Captain had extreme eye conjunctivitis which left him sensitive to light. Yvan concluded that the symptoms were the result of his venereal infection. This case fits known descriptions of venereal induced ReA. Though no direct referral to urethritis is made, the diagnosis of gonorrhoea implies this. This in combination with the description of arthritis and conjunctivitis mean Yvan's description serves as another early example of the ReA triad. Furthermore, this description predates the work of Brodie in 1818, making Yvan's description the earliest reference to the ReA triad uncovered during this research.

The War of 1812 was not without reference to ReA, though the referrals are more general. U.S. Surgeon General Lovell's *Medical Sketches of the Campaign of 1812, 13, and 14…* detail troubles with rheumatism among troops near Niagara in

1814. Describing problems with dysentery, typhus, and other fevers, Lovell states that, “rheumatism, during the whole war, generally put on a remitting form; this was particularly obvious whenever intermittent fever prevailed” (Lovell 1816, 161). The fact that the occurrence of rheumatism was most obvious when fevers were ongoing fits the pattern one would expect of ReA and other reactive arthropathies. Reactive arthropathies would occur during or soon after their triggering infections, so increased occurrence of infectious diseases would coincide with increased outbreaks of rheumatic cases, resembling small-scale epidemics of rheumatism.

The Crimean War is infamous for infectious disease deaths due to cholera and dysentery. This is evident in The Great Britain, Army Medical Service report titled *The Medical and Surgical History of the British Army which Served in Turkey and the Crimea During the War Against Russia in the Years 1854-55-56.* This text has lengthy discussions of dysentery and a few vague references that connect this condition to pains and swelling of the legs, ankles, and feet (Great Britain, Army Medical Service 1858, 98 & 109). Of even more interest, this publication examined the conditions which commonly caused combatants to become invalids during the war. Rheumatism was prominent among the causes. Of the estimated 9,544 British combatants invalided during the war, 1,188 were due to “rheumatic complaints,” holding third place after “Diseases of the Organs of Respiration” (1,338 people) and “Fever” (1,784 people) (Great Britain, Army Medical Service 1858, 229). In this section, it was commented that, “in the instances of rheumatism, the complaint was observed in most of the patients to be a sequela of the fluxes, fevers, or chronic diseases…” (Great Britain, Army Medical Service 1858, 227). This indicates that debilit7ating rheumatism connected to infectious diseases, including those of the bowels (fluxes), were a frequent cause of invalidism during the Crimean War.

Not long after The Crimean War came the American Civil War, which has proven to be one of the best sources for investigating ReA among military combatants. As with the Crimean War, there were many cases of chronic (prolonged) rheumatism during the American Civil War. According to the *Medical and Surgical History of the*

War of the Rebellion, among Union white troops there were 109,187 cases of chronic rheumatism, with 11,779 (10.8%) receiving medical discharge (U.S. Army Surgeon General's Office 1888, 832). Union “colored” (African American) troops were only recorded three of the four years of the war, but 13,726 cases of chronic rheumatism with 874 (6.37%) receiving medical discharge (U.S. Army Surgeon General's Office 1888, 832).

In an *Outline of the Chief Camp Diseases of the United States Armies* (1863), Dr. Joseph Woodward (see **Fig. 63**) described a condition he named ‘pseudo-rheumatism’ (40). He described the condition as being “induced” by “gastric and hepatic disturbances” (40) and later as “complicating” cases of diarrhoea (60). This clearly indicates that Woodward understood the basic causative relationship between gastrointestinal diseases and rheumatism. Woodward also greatly understood how this condition, which is undoubtedly ReA, was expressed:

> The most characteristic group of the cases belonging under the head of pseudo-rheumatism contains most of the ‘sore backs’ and ‘weak backs’ which have been so common among the troops since the breaking out of the war… pains are sometimes acute and cutting, sometimes dull and heavy, but very often do not at first amount to more than a sense of soreness in the parts affected. They may be located in any part of the body, **but their most common seat is in the thighs and legs, and in the small of the back**. **The last is especially the characteristic seat of the disorder, and is more uniformly involved than any other portion of the body**… As the disease progresses, the pain becomes more severe, and, if it is seated in the back or the lower extremities, the patient becomes quite unfit for duty. Sometimes he is confined to his bed, but most frequently he hobbles about with the help of a stick (pp. 319).

The text in bold describes areas most commonly affected in ‘pseudo-rheumatism’ according to Woodward’s observations, which are identical to that of ReA (lower back and lower limbs). Woodward even goes so far as to indicate that changes to the “small of the back” are the “characteristic seat of the disorder;” this is also true of ReA. Woodward described his ‘pseudo-rheumatism’ as being “common among the troops since the breaking out of the war.”

Woodward writes of this condition again in another publication. The *Medical & Surgical History of the War of the Rebellion* was published on the orders of the US Surgeon General Office under Joseph Barnes, but the 1879 volume (volume I, part II) was prepared by Woodward. As with his previous publication, Woodward clearly links the causative relationship between gastrointestinal diseases and rheumatism. He also describes the condition as being common:

> It was common enough during the civil war for patients afflicted with diarrhoea and dysentery, in their chronic forms especially, but also in acute cases, to complain of rheumatic pains in the back and limb… There is evidence enough that genuine rheumatism may complicate acute dysentery either during its progress or more especially during convalescence (406-407).

Figure 63: the photo below is of Dr. Joseph J. Woodward, who was a Union Army surgeon working for the U.S. Surgeon's General Office during the American Civil War. Encouraged by Surgeon General Hammond, Dr. Woodward wrote many texts about military hospitals, camp diseases, and was a major contributor to the *Medical and Surgical History of the War of the Rebellion*. During the war, Dr. Woodward observed and correctly described cases of ReA under the name of "Pseudo-Rheumatism." After the war, Dr. Woodward gained international acclaim, held many illustrious titles, and performed the autopsy of President Lincoln and murderer John Wilks Booth. In poor health and suffering from depression, Dr. Woodward died of apparent suicide in 1884. Source: U.S. Army Medical Department 2009; Source of Information: Bollet 2002.

Finally, in 1864, there is a rather short, but clear quotation linking dysentery to rheumatism. American physician, Alfred Stillé (a professor at the Pennsylvania Medical College [1854 – 1859] and the University of Pennsylvania [1864 to 1884], 1813-1900) writes an entry on dysentery in *Military Medical and Surgical Essays Prepared for the United States Sanitary Commission* where he states: "among the other complications, and which need not here be described, because they do not form any proper union with the dysenteric symptoms, are rheumatism, diphtheria, and parotitis. The first may alternate with dysentery, or rather be suspended during the progress of the bowel affection..." (Stillé 1864, 349-350). Though Stillé appropriately described the expression of ReA with dysentery, his quote makes it clear there was confusion as to how the two conditions (dysentery and rheumatism) could possibly be connected. The connection between rheumatism and dysenteric diseases would not be understood until the 1916 descriptions, which were the first to note the role of bacteria in ReA pathogenesis.

7.4.2 ARF & ReA in Nineteenth Century Conflicts

Non-Military History of ARF

Accounts referring to the complications of ARF have been described since the 1500s, but clear comprehension of the connection between arthritic fever and carditis took some time (Fleming 1977). Sydenham's work from the seventeenth century does not make the connection to heart problems, but he does describe fever associated arthritis that moves from one joint to the next, which is characteristic of ARF: "Rheumatic patients suffer from chills and shivers, and from all the signs and symptoms of fever. After a day or two, sometimes sooner, a sharp pain, now in this, now in that joint, (but most in the wrists, shoulders, and knees) shifts about, leaving redness and swelling in the different parts as it takes them in turn" (Sydenham 1850, 245).

By the early eighteenth century, the connection between ARF and heart disease was certainly beginning to take shape, as descriptions of visceral complications begin to accompany reports of ARF. In 1812, William Charles Wells (Scottish-American physician, 1757-1817) released the first official publication linking ARF to complications of the heart, but credit for the clinical establishment of rheumatic carditis as a medical entity is often attributed to Jean-Baptiste Bouillaud (French physician and president of the Académie de Médecine, 1796-1881) who published *Law of Coincidence of Pericarditis and Endocarditis with Acute Rheumatism* in 1836 (Bouillaud 1836; Fleming 1977, 1045; Seckeler & Hoke 2011). The suggestion that ARF was connected to tonsillitis was not made until 1889 when Walter Butler Cheadle (English paediatrician, 1836 – 1910) published his lectures in *The Various Manifestations of the Rheumatic State as Exemplified in Childhood and Early Life* (Cheadle 1889). Confirmation of this suggestion occurred in 1904 (published in 1907) when James Beattie (Professor of Pathology at the University of Edinburgh, 1868 - 1955) isolated *Micrococcus* (or *Streptococcus*) *rheumaticus* from a patient with ARF (Beattie 1907; Seckeler & Hoke 2011).

Nineteenth Century Military History of ARF

This research primarily focuses on ReA for the literature investigation, as ReA is representative of SpA (the primary focus of the skeletal investigation). Nonetheless, ARF is a reactive arthropathy that is known to have been common in military groups. As indicated in the previous section, most features of ARF had been identified by the mid to late nineteenth century, so military medical documents of this period directly note cases of ARF. During this period, problems with arthritis were recorded as either "acute rheumatism" or "chronic rheumatism" (Bollet 2002). "Acute rheumatism" was a specific referral to ARF, which was understood to be a condition that produced joint inflammation and was associated with fever, nerve damage, and heart complications; essentially, the connection to streptococcal infections was the only missing component (Bollet 2002; Schroeder-Lein 2008). This does not mean there is no evidence of throat involvement in military cases of ARF; for instance, one British soldier from the Crimean War wrote: "I have been all over acute rheumatism & yesterday & the night before had a good deal of fever, but today I am all right with the exception of a very sore throat and pains in my left arm and shoulder" (Dawson 2014).

For British troops during the Crimean War, acute rheumatism accounted for 3.2% of all non-battle related hospital admissions (Glover 1946). This is not overly common, but there is evidence that epidemics of ARF did occur (Shepherd 1991). The winter records for regimental hospital admission from 1854-1855 averaged 15 cases of rheumatism per month. This is not a dramatic figure, but this figure did greatly increase on occasion; for example, in December, this numbers drastically climbed, with the 46th Regiment of the British Army reporting 112 cases of rheumatism. We can infer this spike in rheumatism was related to some form of streptococcal outbreak (probably tonsillopharyngitis), as the 46th Regiment also reported that 10 men died of "pericarditis, a complaint of acute rheumatism" during this time (Shepherd 1991, 326).

During the American Civil War, there were 145,551 cases of acute rheumatism recorded among Union white troops and 18,399 cases among Union African American troops (U.S. Army Surgeon General's Office 1888, 829). In the American Civil War, 'acute rheumatism' was a classification largely consisiting of ARF cases. The large figures for acute rheumatism/ARF in the American Civil War indicate some proof of concept (reactive arthropathies were common among combatants), but the evidence for ReA is far less direct. Though it has been established that some physicians understood ReA quite well in the nineteenth century, this knowledge was not widely known throughout the medical community, so no official figures were ever recorded. Evidence of ReA commonality among combatants has thus been reliant on medical descriptions like those in section 7.3.1. Additionally, Bollet (2002) suggests the presence of ReA among American Civil War troops is indirectly indicated through numerical discrepancies.

American Civil War physicians were puzzled by the low mortality rates observed for acute rheumatism (ARF) during the war, which should have been much higher; they even attempted combining other heart conditions into the figures for acute rheumatism, but still found the insufficient to meet their expectations:

> The fatal cases among the white troops numbered 283, among the colored troops 98, a fatality of .2 and .53 per cent., respectively. If Looms [an Assistant Surgeon 7th NJ] be correct in his assertion that three per cent. is the average death-rate in acute rheumatism, the cases reported as 'acute rheumatism' [ARF] by out medical officers were not all cases of acute articular rheumatism. Even if fatal cases of endocarditis pericarditis – 109 and 250, respectively, among white troops, and 22 and 65 among colored troops - be charged to the account of acute rheumatism, the average death-rate of the disease would be raised only 44 per cent. among white and 1.0 per cent. among colored troops. It is probable, therefore, that the reported cases include a large number of slight or subacute attacks in the progress of chronic cases and of …rheumatism known as lumbago, pleurodynia, etc (U.S. Army Surgeon General's Office 1888, 829).

Bollet (2002) suggests that such discrepancies are due to the fact that "much of the rheumatism, both acute and chronic, was not rheumatic fever but reactive arthritis, which does not [commonly] cause heart disease or death" (312). This assumption is difficult to definitively confirm retrospectively, but the proposal that ReA was among the figures for rheumatism is certainly intriguing. If one recalls Dr. Woodward's description of ReA ('pseudo-rheumatism') as being "common" during the American Civil War, Bollet's suggestion seems feasible (Woodward 1863, 319).

7.5 Summary of Literature Results

A summary of the references to ReA complied over the course of this research are listed in **Table 23**. This table notes whether cases were military or non-military, the level of understanding held by the documenting physician about the condition, and if the ReA triad was mentioned.

Table 23: the table below lists historical references to ReA. Some of the references mentioned in-text are not included due to their unspecific nature. Dysenteric ReA was always listed, but venereal ReA was only counted if there was specific referral to back pain or conjunctivitis. The references include case reports, case histories, general medical descriptions, and retrospective diagnoses. When possible, the level in which the authors understood the nature of ReA was described. References describing the ReA triad are in **bold font**. Acknowledgment of a cause-and-effect relationship and correct pattern descriptions were the defining features of a 'good' level of understanding. Source: created by the author.

Summary of Historical References to ReA		
NON-MILITARY REFERENCES		
#	**Reference**	**Level of Understanding**
1	Akenside 1764	Fair. He believed the joint occurrence of dysentery and rheumatism were linked, but misinterpreted the cause. He believed they were the same condition; dysentery was a rheumatism of the intestines.
2	Zimmermann 1765 (Dysenteric ReA)	Poor. Explains the occurrence of rheumatism following dysentery as a consequence of the treatments being provided.
3	Lepecq de la Clôture 1765 (Dysenteric ReA)	Poor. Noted that he did not believe dysentery and rheumatism were linked.
4	Stoll 1775 (Dysenteric ReA)	Fair. He believed the joint occurrence of dysentery and rheumatism were linked, but misinterpreted the cause. He believed they were the same condition; dysentery was a rheumatism of the intestines.
5	Swedinaur 1798 (Venereal ReA)	Fair. He does not describe it as a specific condition, but described features that are now known to be symptoms of ReA.
6	Harty 1805 (Dysenteric ReA)	Fair. He believed the joint occurrence of dysentery and rheumatism were linked, but explains the connection in the manner of Akenside and Stoll.
7	Scudamore 1827 (Venereal ReA)	Fair? It simply states: "a dysentery, injudiciously treated, shall be changed into a rheumatism" (362).

8	**Brodie 1818** (Venereal ReA)	Good. Accurately and in detail described the ReA triad.
9	**Cooper 1824** (Venereal ReA)	Good. Accurately and in detail described the ReA triad.
10	**Lawrence 1826** (Venereal ReA)	Good. Accurately and in detail described the ReA triad.
11	**Frick & Welbank 1826** (Venereal ReA)	Good. Accurately and in detail described the ReA triad.
12	**Thomson 1836** (Venereal ReA)	Good. Accurately and in detail described the ReA triad.
13	**University College Hospital Records 1836** (Venereal ReA)	Unknown. A simple case history, no interpretation.
14	**St. Bartholomews Hospital Records 1838** (Venereal ReA)	Unknown. A simple case history, no interpretation.
15	**Tixier 1866** (Venereal ReA)	Good. Accurately and in detail described the ReA triad.
16	**Broadhurst 1866** (Venereal ReA)	Good. Accurately and in detail described the ReA triad.
17	**Fournier 1868** (Venereal ReA)	Good. Accurately and in detail described the ReA triad.
18	Huette 1869 (Dysenteric ReA)	Good. He acknowledges the connection between dysentery and rheumatism is a relationship of cause and effect.
19	**Johnstone 1870** (Notes not necessarily only connected to Gonorrhoea)	Good. Accurately and in detail described the ReA triad.
20	**Bond 1872** (Venereal ReA)	Good. Accurately and in detail described the ReA triad.
21	**Potter 1878** (Venereal ReA)	Good. Accurately and in detail described the ReA triad.
22	**Bumstead 1879** (Venereal ReA)	Good. Accurately and in detail described the ReA triad.
23	**Launois 1899** (Venereal ReA)	Good. Accurately and in detail described the ReA triad.
MILITARY REFERENCES		
#	**Reference**	**Understanding**
1	Pringle 1753 (Dysenteric ReA)	Poor. Attributed rheumatism to cold rather than the gastrointestinal diseases occurring among troops.
2	Senter 1775 (Dysenteric ReA)	Fair. Though he does not rationalize the cause, he seems to understand that dysentery is connected to the occurrence of rheumatism.
3	Dewar 1803 (Dysenteric ReA)	Good. He acknowledges the connection between dysentery and rheumatism is a relationship of cause and effect.

4	**Yvan 1806** (Venereal ReA)	Good. Accurately and in detail described the ReA triad.
5	Cleghorn 1809 (Dysenteric ReA)	Poor. He does not describe it as a specific condition, retrospectively diagnosed by author.
6	Lovell 1816 (Dysenteric/Fevers ReA)	Fair. He does not interpret the connection, but shows basic understanding of the cause and effect relationship between infectious fevers and rheumatism.
7	Great Britain, Army Medical Service 1858 (Dysenteric/Fevers ReA)	Fair. The source indicates awareness of the cause and effect relationship between infectious diseases and rheumatism, but does not interpret the cause of this connection.
8	Gen. Robert E. Lee 1863/4 (ReA? ARF?)	Unknown. Retrospective diagnosis by: Bollet 1991; West 2014.
9	Woodward 1863 (Dysenteric ReA)	Good. Clearly understood the connection, symptoms, and pattern followed by the disease he names 'pseudo-rheumatism'
10	Stillé 1864 (Dysenteric ReA)	Good. The source indicates awareness of the cause and effect relationship between infectious diseases and rheumatism and describes patterns of expression.
11	US Surgeon General Office (Woodward) 1879 (Dysenteric ReA)	Good. Clearly understood the connection, symptoms, and pattern followed by the disease named 'pseudo-rheumatism'
12	**Fiessinger & Leroy, 1916.** (Dysenteric ReA)	Good. Understood there was a clear link between dysenteric bacteria and rheumatism.
13	**Reiter, 1916.** (Dysenteric ReA)	Good. Misinterpreted the causative bacterium, but understood there was a clear link between infectious bacteria and rheumatism.

There are clearly more non-military references to ReA than military, but the military references still accounted for 36.1% of the total references considered in this research. Of the referrals to the ReA triad, 16.7% were noted in military documents. Though the ReA triad was noted less often in military assemblages, the oldest reference was by Yvan in 1806, which described ReA in a military Captain. Military versus non-military matters aside, the data makes it plainly evident that Reiter's claims of priority for the ReA triad are false, as 16 references pre-1916 were noted over the course of this research.

7.6 Conclusions & Interpretations

It was hypothesized that an examination of historical military literature would reveal numerous examples indicating a clear link between infectious disease and the development of ReA. This hypothesis was proven true, as 36.1% of documents reported had a military origin, which is a figure that cannot be easily dismissed as coincidence. Furthermore, though not a SpA, recording of ARF in nineteenth century conflicts provides some proof of concept that reactive arthropathies did occur among historical combatants with some frequency.

Apart from providing general quantitative evidence to support the existence of an affinity between the military lifestyle and reactive arthropathies, examination of ReA in medical literature also revealed other interesting patterns. If one excludes cases retrospectively diagnosed in **Table 23**, the first publications to contemplate the relationship held between dysentery and rheumatism occurred in the same year for both military (Pringle 1753) and non-military (Akenside1764) documents. It was also apparent that the understanding of the ReA triad was rather good pre-1916; the percentage of cases reporting a 'good' level of understanding was 56.0% for non-military references and 53.8% for military references, a majority of references in both instances. By 1800, physicians had fully acknowledged that the joint occurrence of infectious disease and rheumatism was a relationship of cause and effect. Furthermore, they were able to provide specifics about the condition's pattern of expression.

The literature review also made it apparent that ReA was frequently noted during or directly following epidemics in great numbers (Zimmerman 1765; Clôture 1765; Lovell 1816; Senter 1770; Stoll 1775). This pattern suggests that ReA and other forms of reactive arthropathy had the ability to behave in an epidemic-like manner. Descriptions like that of Dewar (1803) provide credence to this patterning of expression. This was also true of ARF, as clearly illustrated through the increased co-occurrence of rheumatism and pericarditis in the 46th Regiment of the British Army during the Crimean War.

Finally, a few references indicate that ReA could be debilitating. It was stated that rheumatic invalidism during the Crimean War was often the product of infectious fevers and fluxes; this is convincing evidence of commonality, as rheumatism was the third most common cause of invalidism (Great Britain, Army Medical Service 1858). Further evidence comes from the American Civil War, as Woodward (1863) commented that men could become, “quite unfit for duty,” requiring the use of a walking aid (stick or cane).

The results of this literature investigation are highly basic, but do suggest there was some affinity between reactive arthropathies and military combatants. Though the numerical data gathered in this literature investigation is suggestive of affinity, more definitive data is necessary to answer the primary research question with confidence. This additional data was provided through the palaeoepidemiological investigation.

CHAPTER 8:
Results for the Skeletal Investigation

8.1 Introduction

The results of the skeletal investigation have been divided into five primary sections, each detailing the differing forms of analysis discussed in the methods chapter. The results geared towards answering the primary research question are addressed first: prevalence and the nested case control studies. As a reminder, the primary research question is: can a strong connection between reactive arthropathies and historical military combatants be established (were reactive arthropathies an occupational hazard to historical military combatants)? Before the results for prevalence and the nested case control test can be provided, one must be aware of the diagnoses made and the figures for (n) and (N). These are revealed in **Table 24** and **Table 25**. More information on diagnoses can be found in **Appendix C**.

The remaining sections address results which provide information about the study approach: age analysis, diagnostic analysis, and criteria analysis. Each section provides a brief introduction to summarize what is being addressed and the overall findings.

Table 24: this table shows the number of cases for each of the primary categories and the reactive subcategories. It also shows the number of unidentified cases that were suspected of having a reactive nature (Reactive Suspects). Source: created by the author.

Diagnoses							
Assemblage	Primary Categories (Total # of EA Cases)			Reactive Subcategories			Reactive Suspects
	Nonreactive	Unidentified	Reactive	SpA	Probable Reactive	Possible Reactive	
Non-Military (Control) Assemblages							
All Saints Church	1	1	1	0	0	1	1
OCU00/FAO90	8	2	1	1	0	0	2
Military Assemblages							
Towton	0	3	4	3	0	1	3
York Mass Grave	1	3	1	0	1	0	2
Plymouth	3	3	0	0	0	0	2
Greenwich	4	7	10	3	3	4	6
Total Military & Non-Military Assemblages							
Military	8	16	15	6	4	5	13
Non-Military	9	3	2	1	0	1	3

Table 25: this table shows (n) and (N) for the calculation of prevalence. The figures for (N) are divided into the Probable and Possible measures, as described in the methods chapter. The figures for Reactive and Reactive Suspect (n) are also listed; as a reminder: Reactive Cases = SpA + Probable Reactive + Plausible Reactive cases, Reactive Suspects = Reactive Cases + Unidentified cases suspected of having a reactive nature. Source: created by the author.

Prevalence n & N				
Assemblage	(N)		Reactive (n)	Reactive Suspects (n)
	Probable N	Possible N		
Non-Military (Control) Assemblages				
All Saints Church	17	25	1	2
OCU00/FAO90	68	99	1	3
Military Assemblages				
Towton	19	21	4	7
York Mass Grave	44	52	1	3
Plymouth	37	49	0	2
Greenwich	52	60	10	16
Total Military & Non-Military Assemblages				
Military	152	182	15	28
Non-Military	85	124	2	5

8.2 Prevalence Analysis

8.2.1 Introduction

All figures used to calculate prevalence (P = n/N) were listed in **Tables 24** and **25.** Site comparisons for prevalence are considered first. This compares the prevalence of each military assemblage with its appropriately paired control assemblage (selected by the dates of use, socioeconomic status, and developed environmental backgrounds). Towton (War of the Roses) was matched with the medieval assemblage of All Saint's Church. The York Mass Grave (English Civil War), Plymouth (Navy, Napoleonic Wars), and Greenwich (Navy, Napoleonic Wars) assemblages were all matched with the combined assemblages of Chelsea Old Church and St. Brides Lower. Prevalence was calculated for Reactive Pathology (SpA + Probable Reactive + Plausible Reactive cases) and Reactive Suspect Pathology (Relative Pathology cases + Unidentified Pathology cases with a suspected reactive nature). Prevalence used the Probable N and Possible N measures as described in Chapter 6.

The figures for all military and non-military (control) data were then combined for a 'type' comparison. Once again, prevalence was calculated for Reactive Pathology and Reactive Suspect Pathology, but prevalence for individual reactive subcategories are also reported. Both the Probable N and Possible N measures were used in prevalence calculation. Prevalence results for the military and non-military assemblages are then compared with the prevalence of previous bioarchaeological research. This is later used to validate and interpret the present results in Chapter 9.

All of the results for prevalence are listed and compared in **Table 26**. This table is colour coordinated to indicate the most interesting result.

Table 26: this table summarizes the prevalence results for Reactive Pathology and Reactive Suspect Pathology. It also details both measures, Probable (N) and Possible (N). Each site is paired with its control for comparison. Type data is then presented (Military versus Non-Military assemblages) at 95% and 90% confidence. Finally, data for SpA and SpA + Probable Reactive subcategories is provided (excludes the least assured Reactive subcategory, Plausible SpA).

White cells show no significance (considerable overlap in confidence intervals). Gray cells lack significance, but show a marked difference in prevalence (≥ 5% difference). Light green cells indicate there is ≤ 1% overlap between the confidence intervals, which is evidence of a marked difference in prevalence, but significance is not assured. Tan cells indicate a significance difference in prevalence (there is no overlap between the confidence intervals). Source: created by the author.

Probable & Possible N Prevalence				
Assemblage	Probable N Prevalence (More Exclusive Count)		Possible N Prevalence (More Inclusive Count)	
	Reactive	Reactive Suspects	Reactive	Reactive Suspects
Towton & All Saint's Church				
Towton	21.1% (95% CI 8.5, 43.3)	36.8% (95% CI 19.1, 59.0)	19.0% (95% CI 7.7, 40.0)	33.3% (95% CI 17.2, 54.6)
All Saint's Church	5.9% (95% CI 1.0, 27.0)	11.8% (95% CI 3.3, 34.3)	4.0% (95% CI0.7, 19.5)	8.0% (95% CI 2.2, 25.0)
York Mass Grave & OCU00/FAO90				
York Mass Grave	2.3% (95% CI 0.4, 11.8)	6.8% (95% CI 2.3, 18.2)	1.9% (95% CI 0.3, 10.1)	5.8% (95% CI 2.0, 15.6)
OCU00/FAO90	1.5% (95% CI 0.3, 7.9)	4.4% (95% CI 1.5, 12.2)	1.0% (95% CI 0.2, 5.5)	3.0% (95% CI 1.0, 8.5)
Plymouth & OCU00/FAO90				
Plymouth	0% (95% CI 0 - 9.4)	5.4% (95% CI 1.5, 17.7)	0% (95% CI 0, 7.3)	4.1% (95% CI 1.1, 13.7)
OCU00/FAO90	1.5% (95% CI 0.3, 7.9)	4.4% (95% CI 1.5, 12.2)	1.0% (95% CI 0.2, 5.5)	3.0% (95% CI 1.0, 8.5)
Greenwich & OCU00/FAO90				
Greenwich	19.2% (95% CI 10.8, 31.9)	30.8% (95% CI 19.9, 44.3)	16.7% (95% CI 9.3, 28.0)	26.7% (95% CI 17.1, 39.0)
OCU00/FAO90	1.5% (95% CI 0.3, 7.9)	4.4% (95% CI 1.5, 12.2)	1.0% (95% CI 0.2, 5.5)	3.0% (95% CI 1.0, 8.5)
TOTAL: Military & Non-Military 95% CI				
Military	9.9% (95% CI 6.1, 15.6)	18.4% (95% CI 13.1, 25.3)	8.2% (95% CI 5.1, 13.2)	15.4% (95% CI 10.9, 21.3)
Non-Military	2.4% (95% CI 0.6, 8.2)	5.9% (95% CI 2.5, 13.0)	1.6% (95% CI 0.4, 5.7)	4.0% (95% CI 1.7, 9.1)
TOTAL: Military & Non-Military 90% CI				
Military	9.9% (90% CI 6.6, 24.6)	18.4% (90% CI 13.8, 24.1)	8.2% (90% CI 5.5, 12.3)	15.4% (90% CI 11.5, 20.3)
Non-Military	2.4% (90% CI 0.8, 6.9)	5.9% (90% CI 2.9, 11.6)	1.6% (90% CI 0.5, 4.8)	4.0% (90% CI 2.0, 8.1)

Reactive Subcategories for Military & Non-Military Assemblages 95% CI				
Assemblage	Probable N Prevalence (More Exclusive Count)		Possible N Prevalence (More Inclusive Count)	
	SpA Cases	SpA + Probable Reactive Cases	SpA Cases	SpA + Probable Reactive Cases
Military	3.9% (95% CI 1.8, 8.3)	6.6% (95% CI 3.6, 11.7)	3.3% (95% CI 1.5, 7.0)	5.5% (95% CI 3.0, 9.8)
Non-Military	1.2% (95% CI 0.2, 6.4)	1.2% (95% CI 0.2, 6.4)	0.8% (95% CI 0.1, 4.4)	0.8% (95% CI 0.1, 4.4)

Reactive Subcategories for Military & Non-Military Assemblages 90% CI				
Assemblage	Probable N Prevalence (More Exclusive Count)		Possible N Prevalence (More Inclusive Count)	
	SpA Cases	SpA + Probable Reactive Cases	SpA Cases	SpA + Probable Reactive Cases
Military	3.9% (95% CI 2.1, 7.5)	6.6% (95% CI 4.0, 10.7)	3.3% (95% CI 1.7, 6.3)	5.5% (95% CI 3.3, 9.0)
Non-Military	1.2% (95% CI 0.3, 5.1)	1.2% (95% CI 0.3, 5.1)	0.8% (95% CI 0.2, 3.5)	0.8% (95% CI 0.2, 3.5)

8.2.2 Site Comparisons for Prevalence

Towton & All Saint's Church

The Reactive Pathology results for the Towton and All Saint's Church assemblages display no significant difference for either the Probable N or the Possible N calculation. Though confidence intervals overlap, there is a marked difference between the reported prevalence, so cells in **Table 26** are marked gray. There is a difference of 15.2% for Probable N calculation and 15% for Possible N calculation, with Towton having the higher prevalence.

The Reactive Suspect Pathology results show the same pattern. No significance is present for either N calculation, but a marked difference was noted. There is a difference of 25% for Probable N calculation and 25.3% for Possible N calculation, with Towton having the higher prevalence.

York Mass Grave (YMG) and OCU00/FAO90

The Reactive Pathology results for the YMG and OCU00/FAO90 assemblages are not significant for either the Probable N or Possible N calculation. There is no marked difference between the prevalence for either N calculation.

The same is true for the Reactive Suspect Pathology results. There is no significant difference for either N calculation. The military YMG has a higher prevalence of Reactive Suspect Pathology, but there is less than 5% difference for both N calculation, meaning there is no marked difference.

Plymouth & OCU00/FAO90

The Reactive Pathology results for the Plymouth and OCU00/FAO90 assemblages are not significant for either the Probable N or Possible N calculation. There is no marked difference between the reported prevalence for either N calculation; less than 5% difference.

The same is true of the Reactive Suspect Pathology prevalence. There is no significance for either N calculation. There was no marked difference between the reported prevalence for either N calculation; less than 5% difference.

Greenwich & OCU00/FAO90

There is a significantly higher prevalence of Reactive Pathology in the Greenwich assemblage. Significance is indicated by the lack of overlap between the confidence intervals at 95% confidence (cells are coloured tan in **Table 26**). Significance is evidence for both the Probable N and Possible N calculation.

There is a significantly higher prevalence of Reactive Suspect Pathology in the Greenwich assemblage. There was no overlap in the confidence intervals at 95% confidence. Significance is evident in both N calculations.

8.2.3 Type Comparisons for Prevalence: Military vs. Non-Military

Reactive Pathology & Reactive Suspect Pathology 95% CI

The Reactive Pathology results for military and non-military assemblages are slightly different for the Probable N and Possible N calculation. At 95% confidence, the Probable N calculation does not indicate significance, but there is marked difference between the military and non-military prevalence. There is a difference of 7.5%, with military assemblages having the higher prevalence, so cells are coloured gray in **Table 26**.

The Possible N calculation at 95% confidence does not show significance for Reactive Pathology. Though significance is not assured, there is less than 1% overlap in the confidence intervals. As such, cells are coloured green in **Table 26**.

The results for Reactive Suspect Pathology show a significantly higher prevalence in military assemblages. Significance is indicated by the lack of overlap between confidence intervals at 95% confidence (cells are coloured tan in **Table 26**). This applies for both the Probable N and Possible N calculation.

Reactive Pathology & Reactive Suspect Pathology 90% CI

The Reactive Pathology results for military and non-military assemblages at 90% confidence are not significant using the Probable N calculation. Though significance is not assured, there is less than 1% overlap between the confidence intervals (cells are coloured green in **Table 26**).

The Reactive Pathology results for the Possible N calculation indicate there is a significantly higher prevalence in the military assemblage. Significance is indicated by the lack of overlap in confidence intervals at 90% confidence (cells are coloured tan in **Table 26**).

All N measures for Reactive Suspect Pathology display a significantly higher military prevalence at 90% confidence (cells are coloured tan in **Table 26**).

Reactive Subcategories 95% CI

At 95% confidence, there is no significant difference between military and non-military prevalence for SpA pathology. This applies for both the Probable N and Possible N calculation. Though SpA prevalence is higher in the military assemblages, there is no marked difference (less than 5% difference).

At 95% confidence, there is no significant difference between military and non-military prevalence for SpA + Probable Reactive pathology using either N calculation. For the Probable N calculation, the military prevalence is higher, with greater than 5% difference (5.4%); cells are coloured gray in **Table 26**. For the Possible N calculation, the military prevalence is higher than the non-military prevalence, but the difference is less than 5% (4.7%) and the overlap in confidence intervals greater than 1% (1.4%).

Reactive Subcategories 90% CI

At 90% confidence, there is no significant difference in the military and non-military prevalence for SpA. This applies for both the Probable N and Possible N calculation.

At 90% confidence, there is no significant difference between military and non-military prevalence for SpA + Probable Reactive pathology. For the Probable N calculation, the military assemblage has a higher prevalence (5.4% difference); cells are coloured gray in **Table 26**. For the Possible N measure, there is a higher military prevalence with less than 1% (0.2%) overlap in confidence intervals at 90% confidence; cells are coloured green in **Table 26**.

8.2.4 Prevalence Comparison with Previous Bioarchaeological Research

The findings of the present research are compared with those of previous bioarchaeological studies of SpA prevalence in **Table 27**.

Table 27: this table compares SpA prevalence of past and present bioarchaeological research. The results presented for Banton 2016 were for the Probable N measure (more specific, less inclusive measure). Source: created by the author.

Comparison of Bioarchaeological Reports on SpA Prevalence			
Study	**Population**	**n/N**	**Prevalence**
Rothschild *et al.* 2004	Ancient Italians	1/111 2/79 2/154 1/138	1 - 3%
Šlaus *et al.* 2012	Medieval Croatia (Study only for AS)	4/303	1.3%
Arriaza 1993	Ancient Amerindians from Chile	25/304 15/304	Maximum 7.4% Minimum 4.4%
Martin-Dupont *et al.* 2006	19th–20th century Portuguese sample	34/505 32/505 98/505	6.7% (Definite SpA Cases) 6.3% (Probable SpA Cases) 19.4% (Not excluded)
Banton 2016	British Military Assemblages	6/152 10/152 15/152 28/152	3.9% (SpA) 6.6% (SpA & Probable Reactive) 9.9% (Reactive) 18.4% (Reactive Suspects)
Banton 2016	15^{th} – 19^{th} Century British Sample	1/85 1/85 2/85 5/85	1.2% (SpA) 1.2% (SpA + Probable Reactive) 2.4% (Reactive) 5.9% (Reactive Suspects)

8.3 Nested Case Controls

8.3.1 Introduction

A nested case control study was conducted for Reactive Pathology and Reactive Suspect Pathology. The nested case control study was used to determine the odds [(a)(d) / (c)(b)] that reactive pathology will occur when exposed to the military lifestyle. The significance of the odds ratio was determined through the use of p values. A Mantel-Haenszel X^2 test was also run to determine the strength of the association between the military lifestyle and the occurrence of reactive pathology; significance was measured through the use of p values.

As a reminder, a nested case control pools all data together, both military and non-military. Controls are then randomly selected based on the number of positive pathological cases. For this reason, the term 'control' does not mean 'non-military.' Instead, the term 'control' refers to remains (be they military or non-military) that lack relevant pathology; controls = negative cases.

8.3.2 Reactive Pathology Nested Case Control Study

There was a total of 17 positive cases for Reactive Pathology. Three time this amount of controls (51) were randomly selected using Microsoft Excel. A 2 X 2 table was then constructed to segregate the data, with one axis noting military status (exposure) and the second presence/absence of Reactive Pathology (+/- cases) (see **Table 28**). There were 15 military cases of Reactive Pathology (*a*), 30 military controls (*b*), 2 non-military cases of Reactive Pathology (*c*), and 21 non-military controls (*d*). The odds ratio is therefore (15)(21) / (2)(30) = 5.25 (95% CI 1.08 – 25.42), with a p value of 0.039. This is a significant odds ratio. The Mantel-Haenszel X^2 test was calculated to be 4.86, with a p value of 0.028. This is a significant Mantel-Haenszel X^2 result.

Table 28: the table below shows the 2 X 2 table used to calculate the odds ratio for Reactive Pathology using military and non-military assemblages. The odds ratio and Mantel-Haenszel X^2 results (with p values) are reported below the 2 X 2 table. Source: created by the author.

Odds Ratio for Reactive Pathology			
	+ Cases	**-Cases**	**Total**
+ Military	15	30	45
- Nonmilitary	2	21	23
Total	17	51	**68**
Odds Ratio: 5.25 (95% CI 1.08 – 25.42), p value 0.039 **Mantel-Haenszel X^2:** 4.86, p value 0.028			

8.3.2 Reactive Suspect Pathology Nested Case Control

There was a total of 33 positive cases for Reactive Suspect Pathology. Three time this amount of controls (99) were randomly selected using Microsoft Excel. A 2 X 2 table was then constructed to segregate the data, with one axis noting military status (exposure) and the second presence/absence of Reactive Suspect Pathology (+/- cases) (see **Table 29**). There were 28 military cases of Reactive Suspect Pathology (*a*), 54 military controls (*b*), 5 non-military cases of Reactive Suspect Pathology (*c*), and 45 non-military controls (*d*). The odds ratio is therefore (28)(45) / (5)(54) = 4.67 (95% CI 1.67 – 13.08), with a p value of 0.003. This is a significant odds ratio. The Mantel-Haenszel X^2 test was calculated to be 9.59, with a p value of 0.002. This is a significant Mantel-Haenszel X^2 result.

Table 29: the table below shows the 2 X 2 table used to calculate the odds ratio for Reactive Suspect Pathology using military and non-military assemblages. The odds ratio and Mantel-Haenszel X^2 results (with p values) are reported below the 2 X 2 table. Source: created by the author.

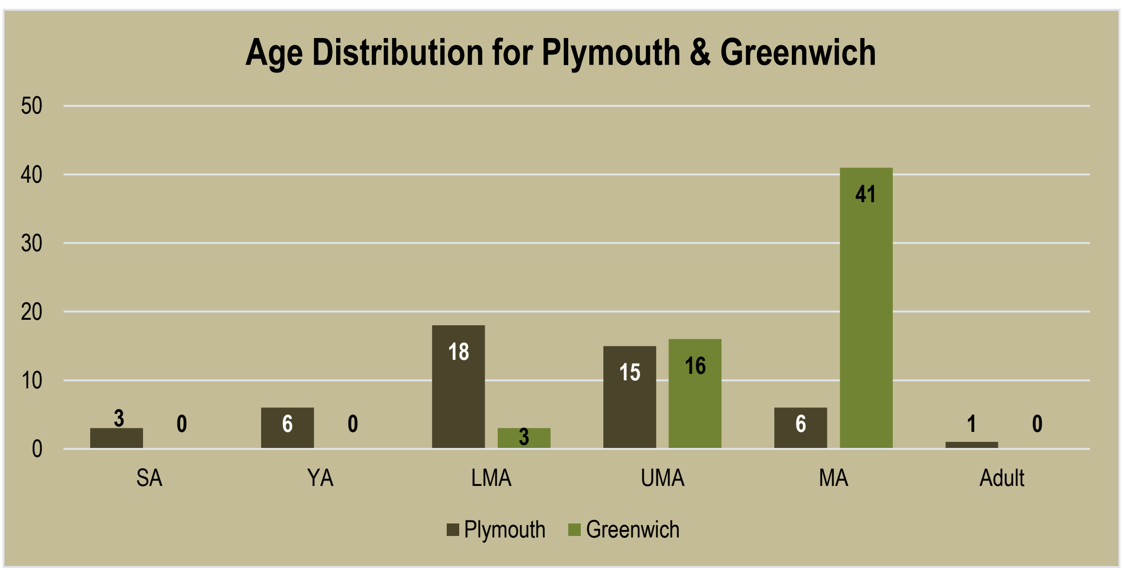
Odds Ratio for Reactive Suspect Pathology			
	+ Cases	**-Cases**	**Total**
+ Military	28	54	82
- Nonmilitary	5	45	50
Total	33	99	**132**
Odds Ratio: 4.67 (95% CI 1.67 – 13.08), p value 0.003			
Mantel-Haenszel X^2: 9.59, p value of 0.002			

8.4 Results for Age Analysis

8.4.1 Introduction

It was suspected that the intrinsic factor of age may influence the ability to diagnose reactive pathology in skeletal material. The skeletal data was analysed in two ways to determine if this was true. The first method compared the prevalence of the Greenwich and Plymouth assemblages. The background of these assemblages was largely identical with the exception of age distribution (see **Table 30**). This made the Greenwich and Plymouth assemblages ideal for comparison, as one would expect a similar prevalence if age were not a factor of influence.

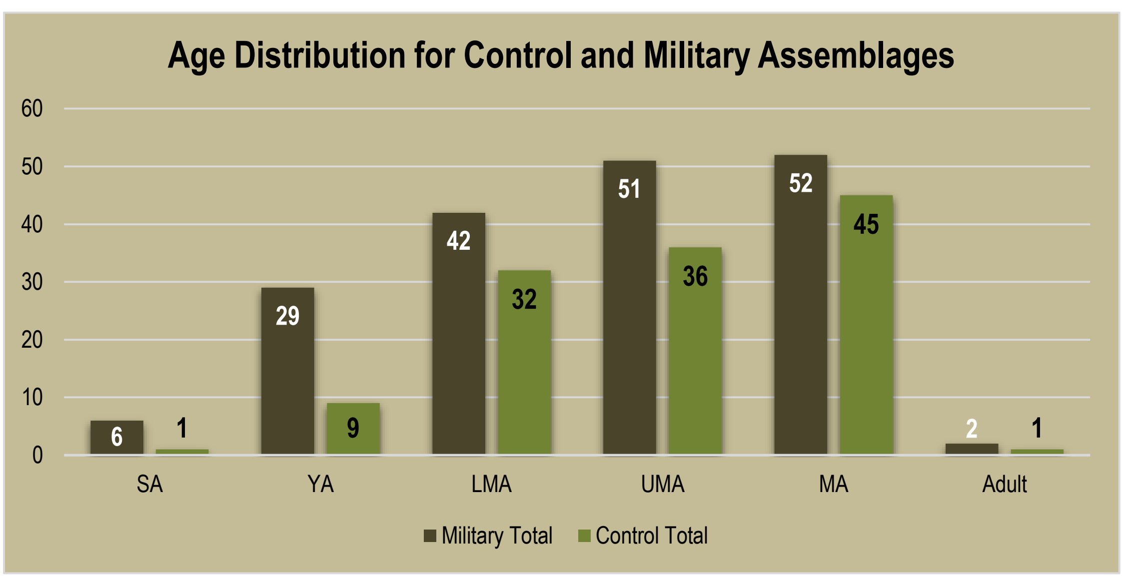
Table 30: the table below shows the age distribution of the Plymouth and Greenwich assemblages. Source: created by the author.



The second method considered the age of diagnosed cases of Reactive and Reactive Suspect Pathology. A percentage was calculated for cases falling below (SA, YA, and LMA age categories) and above (UMA and MA age categories) the age of 35. Site and type comparisons were made to determine whether the pattern between military and non-military assemblages differed. A total percentage was also calculated for the combined military and non-military data to indicate whether the overall pattern suggested diagnosis occurred more frequently in individuals above or below age 35.

As a reminder, when matching the ages for the military and non-military assemblages, the Young Adult (16 to 25 years) category was difficult to match. The Sub Adult (13 to 15 years) category was also difficult to match, but this age category was infrequently encountered in military assemblages, alleviating this from being a major issue within the study design. The remaining age categories had a matching pattern of distribution (see **Table 31**).

Table 31: the table below displays the total age distribution for the military and control assemblages. Source: created by the author.



8.4.2 Greenwich & Plymouth Prevalence Comparison

Table 32 shows the prevalence data for the Greenwich and Plymouth assemblages. No cases of Reactive Pathology were reported in the Plymouth assemblage, but 10 cases were reported in the Greenwich assemblages. The prevalence results were significant for both the Probable N and Possible N calculations, with the Greenwich assemblage presenting the higher prevalence. Significance was indicated by the lack of overlap between the confidence intervals at 95% confidence.

Table 32: this table shows the Reactive and Reactive Suspect Pathology prevalence for the Greenwich and Plymouth assemblages. As with **Table 26,** tan cells indicate there is no overlap between the confidence intervals, demonstrating clear significance. Source: created by the author.

Greenwich & Plymouth Prevalence Comparison				
Assemblage	Probable Prevalence (More Exclusive Count)		Possible Prevalence (More Inclusive Count)	
	Reactive	Reactive Suspects	Reactive	Reactive Suspects
Greenwich & Plymouth				
Greenwich	19.2% (95% CI 10.8, 31.9)	30.8% (95% CI 19.9, 44.3)	16.7% (95% CI 9.3, 28.0)	26.7% (95% CI 17.1, 39.0)
Plymouth	0% (95% CI 0, 9.4)	5.4% (95% CI 1.5, 17.7)	0% (95% CI 0, 7.3)	4.1% (95% CI 1.1, 13.7)

There were 2 cases of Reactive Suspect Pathology in the Plymouth assemblage and 16 for the Greenwich assemblage. The Reactive Suspect Pathology results were significant for both N calculations, with Greenwich having the higher prevalence. There was no overlap in the confidence intervals at 95% confidence.

8.4.3 Site Comparisons for Diagnosis Above & Below Age 35

No patterns could be confidently identified for Reactive Pathology for either the military or non-military assemblages (see **Table 33**).

For Reactive Suspect Pathology, diagnosis in military assemblages displayed some preference for older age categories (over age 35); Plymouth was an exception (see **Table 34**. No patterns could be confidently identified in the non-military assemblages for Reactive Suspect Pathology.

Table 33: this table shows the percentage of cases diagnosed as having Reactive Pathology above and below the age of 35 for each site. Bolded figures indicate the higher percentage. No clear patterns were identified. One Towton case of reactive pathology has been excluded, as age could not be identified in the skeletal remains Source: created by the author.

Site Comparison, Reactive Pathology Above and Below Age 35		
Site	**% Below 35 (SA, YA, & LMA)**	**% Above 35 (UMA & MA)**
Military Assemblages		
Towton	0%	**100%**
York Mass Grave	**100%**	0%
Plymouth	0%	0%
Greenwich	0%	**100%**
Non-Military Assemblages		
All Saint's Church	**100%**	0%
OCU00/FAO90	0%	100%

Table 34: this table shows the percentage of cases diagnosed as having Reactive Suspect Pathology above and below the age of 35 for each site. Bolded figures indicate the higher percentage. Military assemblages show some preference for diagnosis in older age categories. One Towton case of reactive pathology has been excluded, as age could not be identified in the skeletal remains. Source: created by the author.

Site Comparison, Reactive Suspect Pathology Above and Below Age 35		
Site	**% Below 35 (SA, YA, & LMA)**	**% Above 35 (UMA & MA)**
Military Assemblages		
Towton	33.3%	**66.7%**
York Mass Grave	33.3%	**66.7%**
Plymouth	**100%**	0%
Greenwich	0%	**100%**
Non-Military Assemblages		
All Saint's Church	50%	50%
OCU00/FAO90	0%	**100%**

8.4.4 Type & Total Comparisons for Diagnosis Above & Below Age 35: Military vs. Non-Military

Using the combined data from all military assemblages, diagnosis of Reactive Pathology displayed a distinct preference for older age categories; 92.9% of cases were diagnosed in individuals older than 35 (see **Table 35**). Reactive Pathology in the combined data for non-military assemblages displayed an equal occurrence of diagnosis in ages above and below 35, so no preferential pattern could be identified. When all data for military and non-military assemblages was pooled together, there is an overall preference for Reactive Pathology to be diagnosed in older age categories; 87.5% of cases were diagnosed in individuals older than 35.

Table 35: this table shows the percentage of cases for Reactive Pathology diagnosed above and below age of 35 in military and non-military assemblages. Bolded figures indicate the higher percentage. A total percentage is also provided (combined military and non-military data). One military case of reactive pathology has been excluded, as age could not be identified in the skeletal remains. Source: created by the author.

Type Comparison, Reactive Pathology Above and Below Age 35		
Measure	**Below 35 (SA, YA, & LMA)**	**Above 35 (UMA & MA)**
n/N Military	1/14	13/14
n/N Non-Military	1/2	1/2
n/N Total	2/16	14/16
Site	**Below 35 (SA, YA, & LMA)**	**Above 35 (UMA & MA)**
% Military	7.1%	**92.9%**
% Non-Military	50%	50%
% Total	12.5%	**87.5%**

Reactive Suspect Pathology in military assemblages displayed a distinct preference for diagnosis in older age categories; 81.5% of cases were diagnosed in individuals older than 35 (see **Table 36**). In non-military assemblages there was also a majority preference for Reactive Suspect Pathology diagnosis in older age categories; 80% of cases were diagnosed in individuals older than 35. When all military and non-military data was pooled together, there is an overall preference for Reactive Suspect Pathology to be diagnosed in older age categories; 81.3% of cases were diagnosed in individuals older than 35.

Table 36: this table shows the percentage of cases for Reactive Suspect Pathology diagnosed above and below age of 35 for military and non-military assemblages. Bolded figures indicate the higher percentage. A total percentage is also provided (combined military and non-military data). One military case of reactive pathology has been excluded, as age could not be identified in the skeletal remains. Source: created by the author.

Type Comparison, Reactive Suspect Pathology Above and Below Age 35		
Measure	**Below 35 (SA, YA, & LMA)**	**Above 35 (UMA & MA)**
n/N Military	5/27	22/27
n/N Non-Military	1/5	4/5
n/N Total	6/32	26/32
Site	**Below 35 (SA, YA, & LMA)**	**Above 35 (UMA & MA)**
% Military	18.5%	**81.5%**
% Non-Military	20%	**80%**
% Total	18.8%	**81.3%**

8.5 Results for (N) Measures

8.5.1 Introduction

There were diagnostic concerns at the outset of this research related to missing data. Skeletal remains are often incomplete, which can be a major issue when researching multifocal conditions like the EAs, as excluding all remains with missing elements necessary for diagnosis would produce a very small (N) measure. For this reason, two measures were designed for use and evaluation. Probable N was designed to be the most specific measure, but the least inclusive. Possible N was designed to be more inclusive, but is less specific as a result of its inclusiveness.

The difference between the prevalence produced by each measure is used as the primary means of assessing whether the measures provided considerably different results. Results presenting ≥ 5% difference favor use of the Possible N measure. Results presenting with < 5% difference favor the use of the Probable N measure.

8.5.2 Prevalence Differences between (N) Measures

The results for assessing the difference between the Probable N and Possible N measures are presented in **Table 37.** When considering Reactive Pathology, none of the N measures (for site or type) produced a difference ≥ 5%. This pattern was repeated when Reactive Suspect Pathology was considered; none of the N measures (for sites or type) produced a difference ≥ 5%. When military and non-military measures for SpA and SpA + Probable Reactive cases were considered, none of the N measures produced a difference ≥ 5%.

Table 37: this table shows the percentage difference between the Probable N and Possible N measures for Reactive Pathology and Reactive Suspect Pathology. Source: created by the author.

Percentage Difference Between N Measures		
Assemblages	**Difference Probable (N) & Possible (N) Reactive Prevalence**	**Difference Probable (N) & Possible (N) Reactive Suspect Prevalence**
Military Assemblages		
Towton	2.1%	3.5%
York Mass Grave	0.4%	1%
Plymouth	0%	1.3%
Greenwich	2.5%	4.1%
Non-Military (Control) Assemblages		
All Saint's Church	1.9%	3.8%
OCU00/FAO90	0.5%	1.4%
TOTAL: Military & Non-Military		
Military	1.7%	3%
Non-Military	0.8%	1.9%
Total Military & Non-Military for SpA & SpA + Reactive Probable		
Assemblage	**Difference Probable (N) & Possible (N) SpA**	**Difference Probable (N) & Possible (N) SpA + Reactive Probable**
Military	0.6%	1.1%
Non-Military	0.4%	0.4%

8.6 Results for Criteria Analysis

8.6.1 Introduction

The use of specific diagnostic criterion for identifying Reactive Pathology was assessed. No specifications pertaining to site or type were made. Analysis counted the amount of time each criterion was used. This provided a simple means of identifying which criterion are the most and least likely to be encountered in skeletal assemblages. Occasionally criterion were partially filled by Reactive Suspect Pathology, but these cases were not counted.

8.6.2 Numerical Accounting of Criteria

The results for the numerical accounting of criteria for Reactive Pathology cases are listed in **Table 38**.

Table 38: the table below lists the number of times each diagnostic criterion was used for Reactive Pathology identification. Source: created by the author.

Numerical Accounting of Criteria for Reactive Pathology Cases	
Criteria	**Number of Uses**
Criterion 1 (SIJ Involvement)	9
Criterion 2 (Spinal Fusion with Skip Lesions, Chunky Syndesmophytes)	4
Criterion 2 (Spinal Fusion without Skip Lesions, Smooth Syndesmophytes)	1
Criterion 3 (Three + Vertebrae with Syndesmophytes OR Fusion/Erosion of the Zygapophyseal Facets, Costovertebral Facets, or Interspinous Ligament)	6
Criterion 4 (Enthesopathy, 3+ Locations, Including 1 Characteristic Location)	12
Criterion 5 (Marginal Joint Erosions, With or Without Reactive Bone Formation)	14

CHAPTER 9
Interpreting Skeletal Results

9.1 Interpreting Prevalence Results

9.1.1 Site Comparisons for Prevalence

(Review of Table 26)

Probable & Possible Prevalence				
Assemblage	Probable Prevalence (More Exclusive Count)		Possible Prevalence (More Inclusive Count)	
	Reactive	Reactive Suspects	Reactive	Reactive Suspects
Towton & All Saint's Church				
Towton	21.1% (95% CI 8.5, 43.3)	36.8% (95% CI 19.1, 59.0)	19.0% (95% CI 7.7, 40.0)	33.3% (95% CI 17.2, 54.6)
All Saint's Church	5.9% (95% CI 1.0, 27.0)	11.8% (95% CI 3.3, 34.3)	4.0% (95% CI0.7, 19.5)	8.0% (95% CI 2.2, 25.0)
York Mass Grave & OCU00/FAO90				
York Mass Grave	2.3% (95% CI 0.4, 11.8)	6.8% (95% CI 2.3, 18.2)	1.9% (95% CI 0.3, 10.1)	5.8% (95% CI 2.0, 15.6)
OCU00/FAO90	1.5% (95% CI 0.3, 7.9)	4.4% (95% CI 1.5, 12.2)	1.0% (95% CI 0.2, 5.5)	3.0% (95% CI 1.0, 8.5)
Plymouth & OCU00/FAO90				
Plymouth	0% (95% CI 0 - 9.4)	5.4% (95% CI 1.5, 17.7)	0% (95% CI 0, 7.3)	4.1% (95% CI 1.1, 13.7)
OCU00/FAO90	1.5% (95% CI 0.3, 7.9)	4.4% (95% CI 1.5, 12.2)	1.0% (95% CI 0.2, 5.5)	3.0% (95% CI 1.0, 8.5)
Greenwich & OCU00/FAO90				
Greenwich	19.2% (95% CI 10.8, 31.9)	30.8% (95% CI 19.9, 44.3)	16.7% (95% CI 9.3, 28.0)	26.7% (95% CI 17.1, 39.0)
OCU00/FAO90	1.5% (95% CI 0.3, 7.9)	4.4% (95% CI 1.5, 12.2)	1.0% (95% CI 0.2, 5.5)	3.0% (95% CI 1.0, 8.5)

The York Mass Grave and Plymouth assemblages did not provide significant results for Reactive or Reactive Suspect Pathology using either of the (N) measures. The Reactive Suspect Pathology was higher in the York Mass Grave Assemblage by 2.4% (Probable N) and 2.8% (Possible N), but this is not a large difference. Though these assemblages did not provide proof favoring the research hypothesis (that reactive pathology would be markedly more prevalent in military assemblages), the remaining assemblages did.

The Towton prevalence lacked significant results (confidence intervals greatly overlapped), but Towton did have a higher prevalence displaying a marked difference for Reactive Pathology (average difference for Probable and Possible N equaled 15.1%) and Reactive Suspect Pathology (average difference for Probable and Possible N equaled 25.1%). Towton was originally used for a pilot study testing the diagnostic methods used in this research. The assemblage's small size made it manageable for this purpose, but it produced very large confidence intervals, which skew the results. To present the Towton results a bit differently, using the Probable N measure, Reactive Pathology in the Towton assemblage was 3.58 times that of its control assemblage and Reactive Suspect Pathology was 3.1 times that of its control assemblage. Using the Possible N measure, Reactive Pathology in the Towton assemblage was 4.75 times that of its control assemblage and Reactive Suspect Pathology was 4.2 times that of its control assemblage. As such, Towton does have a considerably higher prevalence of reactive pathology despite the overlapping confidence intervals.

Without any extra interpretation needed, the Greenwich assemblage displayed clear significance for both Reactive and Reactive Suspect Pathology using both N measures. This result favours the research hypothesis. The significant results for the Greenwich site comparison contrast those of other site comparisons, which suggest elevated prevalence without obvious significance. This may be partially explained by the older age distribution in the Greenwich assemblage; this is explored in a later section.

9.1.2 Type Comparisons for Prevalence: Military vs. Non-Military

Reactive Pathology & Reactive Suspect Pathology 95% CI

(Review of Table 26)

Probable & Possible Prevalence				
Assemblage	Probable Prevalence (More Exclusive Count)		Possible Prevalence (More Inclusive Count)	
	Reactive	Reactive Suspects	Reactive	Reactive Suspects
TOTAL: Military & Non-Military 95% CI				
Military	9.9% (95% CI 6.1, 15.6)	18.4% (95% CI 13.1, 25.3)	8.2% (95% CI 5.1, 13.2)	15.4% (95% CI 10.9, 21.3)
Non-Military	2.4% (95% CI 0.6, 8.2)	5.9% (95% CI 2.5, 13.0)	1.6% (95% CI 0.4, 5.7)	4.0% (95% CI 1.7, 9.1)

As the compiled military and non-military assemblage figures provided the largest body of data, the type comparison for prevalence was an important measure, as it directly addresses the first bioarchaeological research hypothesis: examination and comparison of military related skeletal assemblages and control (non-military) skeletal assemblages would demonstrate a markedly higher prevalence of reactive pathology in the military assemblages.

Considering the results for Reactive Pathology under the Probable N measure at 95% confidence, there was no significance, but there was relatively small amount of overlap in the confidence intervals (2.1%). There was also marked difference (7.5%) between the military and non-military prevalence. This result does suggest Reactive Pathology is more common in military assemblages.

When the Possible N measure was considered for Reactive Pathology at 95% confidence, there was less than 1% overlap (0.6%) in the confidence intervals. Once again, though confidence interval overlap means one cannot call the results significant at 95% confidence, reactive pathology is noticeably more prevalent in military assemblages. Overall, Reactive Pathology is more common in military assemblages.

The Reactive Suspect Pathology count for (n) was designed to provide the best case scenario for the occurrence of reactive pathology. This benefit of the doubt was applied in the same manner to both military and non-military assemblages. Though the Reactive Suspect measure is speculative, it is still discerning and provides a useful means of further visualizing the pattern of erosive arthropathy expression in military and non-military assemblages. In the military and non-military comparison of Reactive Suspect Pathology, the military assemblage displayed a significantly higher prevalence for all N calculations at 95% confidence; there was no overlap in confidence intervals. It can, therefore, be concluded that Reactive Suspect Pathology is significantly more common in military skeletal assemblages at 95% confidence.

Reactive Pathology & Reactive Suspect Pathology 90% CI

(Review of Table 26)

Probable & Possible Prevalence				
Assemblage	Probable Prevalence (More Exclusive Count)		Possible Prevalence (More Inclusive Count)	
	Reactive	Reactive Suspects	Reactive	Reactive Suspects
TOTAL: Military & Non-Military 90% CI				
Military	9.9% (90% CI 6.6, 24.6)	18.4% (90% CI 13.8, 24.1)	8.2% (90% CI 5.5, 12.3)	15.4% (90% CI 11.5, 20.3)
Non-Military	2.4% (90% CI 0.8, 6.9)	5.9% (90% CI 2.9, 11.6)	1.6% (90% CI 0.5, 4.8)	4.0% (90% CI 2.0, 8.1)

Considering the results for Reactive Pathology under the Probable N measure at 90% confidence, the overlap in confidence intervals was less than 1% (0.3%). When considering Reactive Pathology under the Possible N measure at 90% confidence, there was no overlap between the confidence intervals, indicating significance. Overall, Reactive Pathology is markedly more common in military assemblages.

Reactive Suspect Pathology displayed a significantly higher military prevalence for both N measures at 90% confidence. Reactive Suspect Pathology is more common in military skeletal assemblage based on significant results at 95% and 90% confidence.

Reactive Subcategories 95% CI

(Review of Table 26)

Reactive Subcategories for Military & Non-Military Assemblages 95% CI				
Assemblage	Probable Prevalence (More Exclusive Count)		Possible Prevalence (More Inclusive Count)	
	SpA Cases	SpA + Probable Reactive Cases	SpA Cases	SpA + Probable Reactive Cases
Military	3.9% (95% CI 1.8, 8.3)	6.6% (95% CI 3.6, 11.7)	3.3% (95% CI 1.5, 7.0)	5.5% (95% CI 3.0, 9.8)
Non-Military	1.2% (95% CI 0.2, 6.4)	1.2% (95% CI 0.2, 6.4)	0.8% (95% CI 0.1, 4.4)	0.8% (95% CI 0.1, 4.4)

There were no significant differences in the prevalence for SpA or SpA + Probable Reactive pathology at 95% confidence. The SpA + Probable Reactive prevalence for the Probable N measure presented with greater than 5% difference (5.4%). Though none of the results were significant, the military prevalence was higher overall, so tests were also run at 90% confidence.

Reactive Subcategories 90% CI

(Review of Table 26)

Reactive Subcategories for Military & Non-Military Assemblages 90% CI				
Assemblage	Probable Prevalence (More Exclusive Count)		Possible Prevalence (More Inclusive Count)	
	SpA Cases	SpA + Probable Reactive Cases	SpA Cases	SpA + Probable Reactive Cases
Military	3.9% (95% CI 2.1, 7.5)	6.6% (95% CI 4.0, 10.7)	3.3% (95% CI 1.7, 6.3)	5.5% (95% CI 3.3, 9.0)
Non-Military	1.2% (95% CI 0.3, 5.1)	1.2% (95% CI 0.3, 5.1)	0.8% (95% CI 0.2, 3.5)	0.8% (95% CI 0.2, 3.5)

There was no significance for the most specific measure of SpA for either the Probable N or Possible N calculation at 90% confidence. The military prevalence was higher, but not distinctly so (less than 5% difference).

The combined cases of SpA + Probable Reactive pathology for the Probable N measure were not significant, but they did display marked difference. The military assemblages presented the higher prevalence and the confidence intervals overlapped by 1.1%. Though significance is not assured, this illustrates a trend for notably higher military prevalence at 90% confidence for the Probable N measure.

The combined cases of SpA + Probable Reactive pathology for the Possible N calculation were not significant, but there was a higher military prevalence (difference of 4.7%). There was less than 1% (0.2%) overlap in the confidence intervals. Once again, though significance is not assured, this illustrates a trend for higher military prevalence at 90% confidence for the Possible N measure.

As revealed in the next section, the SpA measure utilized in this research is quite narrow compared to previous bioarchaeological research, so the lack of significance is unsurprising. The SpA + Probable Reactive measure is a closer comparison to previous research. Given the marked difference in prevalence for SpA + Probable Reactive pathology at 90% confidence, the pattern favouring higher military assemblage prevalence is discernible when using both the smaller subcategory measures and the larger Reactive Pathology measure.

9.1.3 Prevalence Comparison with Previous Bioarchaeological Research

Table 39: the table below compares the results of this project to those of previous bioarchaeological research. Conclusions made about these results have also been provided. Source: created by the author.

Comparisons of Bioarchaeological Reports on SpA Prevalence				
Study	**Population**	**n/N**	**Prevalence**	**Conclusions**
Rothschild *et al.* 2004	Ancient Italians	1/111 2/79 2/154 1/138	1 - 3%	Normal/Average Prevalence
Šlaus *et al.* 2012	Medieval Croatia (Study only for AS)	4/303	1.3%	Normal/Average Prevalence
Arriaza 1993	Ancient Amerindians from Chile	25/304 15/304	Maximum 7.4% Minimum 4.4%	High Prevalence
Martin-Dupont *et al.* 2006	19th–20th century Portuguese sample	34/505 32/505 98/505	6.7% (Definite SpA Cases) 6.3% (Probable SpA Cases) 19.4% (Not excluded)	High Prevalence
Banton 2016	British Military Assemblages	6/152 10/152 15/152 28/152	3.9% (SpA) 6.6% (SpA & Probable Reactive) 9.9% (Reactive) 18.4% (Reactive Suspects)	High Prevalence
Banton 2016	15th – 19th Century British Sample	1/85 1/85 2/85 5/85	1.2% (SpA) 1.2% (SpA + Probable Reactive) 2.4% (Reactive) 5.9% (Reactive Suspects)	Normal/Average Prevalence

Table 39 displays the same data as **Table 27**, but conclusions about these results have been added. The Martin-Dupont *et al*. (2006) approach to analyzing SpA prevalence was similar to that taken by this research, as it used three levels of specificity; however, the criteria used for this research was more exclusive, so these levels were not a perfect match. The Martin-Dupont *et al*. (2006) 'Not Excluded' measure is most similar to the Reactive Suspect Count used in this research. The Martin-Dupont *et al*. (2006) 'Probable SpA' and 'Definite SpA' measures are most similar to the Reactive Pathology and SpA + Probable Reactive measures used in this research. Other bioarchaeological investigations into SpA prevalence have presented data as a maximum (including less diagnostic cases) and minimum result (including

only diagnostic cases) (Arriaza 1993; Rothschild *et al.* 2004). Ultimately, all of the methods for diagnosing SpA differ, making direct comparisons difficult. Nevertheless, the results show similarities.

Arriaza (1993) reported the minimum prevalence of SpA as 4.4%, while this research reported SpA prevalence as 3.9% for the military assemblage. The maximum SpA prevalence for Arriaza (1993) was 7.4%, Probable SpA prevalence for Martin-Dupont *et al*. (2006) was 6.3%, and present research 6.6% (SpA+Probable Reactive) and 9.0% (Reactive) for the military assemblage. The 'Not Excluded' category of the Martin-Dupont *et al*. (2006) reported a prevalence of 19.4%, which is comparable to the military Reactive Suspect Pathology prevalence of 18.4%. The SpA prevalence reported in the Martin-Dupont *et al*. (2006) and Arriaza (1993) articles were described as being 'high' (Arriaza 1993; Martin-Dupont *et al.* 2006). This research also concludes that military skeletal assemblages have a high prevalence of reactive (SpA) pathology. The similarities between the present and past results provide credence to this conclusion.

The data for the control (non-military) assemblages is also comparable with previous research. The SpA and SpA + Probable Reactive prevalence (1.2%) is well matched with the prevalence of 1-3% reported in Rothschild *et al*. (2004) and the 1.3% prevalence reported in Šlaus *et al.* (2012). Rothschild *et al.* (2004) and Šlaus *et al.* (2012) both concluded that their findings were within the normal range for SpA prevalence. The similarity between the control (non-military) prevalence results and those of Rothschild *et al.* (2004) and Šlaus *et al.* (2012) confirm that the control assemblage was not abnormal and thus a fair comparison for the military assemblage.

9.2 Interpreting the Nested Case Control Results

The nested case control studies were run to test the second bioarchaeological research hypothesis: a nested case control study would produce a significant odds ratio and Mantel-Haenszel X^2, indicating exposure to the military lifestyle is associated with increased odds for the occurrence of reactive pathology.

9.2.1 Reactive Pathology Nested Case Control

The nested case control for Reactive Pathology provided significant results. The odds ratio, 5.25 (95% CI 1.08 – 25.42), provided a p value of 0.039, proving there was a significant difference between the groups. This means exposure to the military lifestyle increases the odds for the occurrence of Reactive Pathology; the odds of Reactive Pathology occurring in a military skeletal assemblage is 5.25 times greater than a non-military skeletal assemblage. To measure the strength of the association between the military lifestyle and the occurrence of Reactive Pathology, a Mantel-Haenszel X^2 test was conducted, which came to 4.86 with a p value of 0.028. The p value is significant, indicating a strong association. With significant results for both the odds ratio and Mantel-Haenszel X^2, it can be concluded that the association between the military lifestyle and the occurrence of Reactive Pathology is strong and not likely due to chance.

9.2.2 Reactive Suspect Pathology Nested Case Control

The nested case control for Reactive Suspect Pathology also provided significant results. The odds ratio, 4.67 (95% CI 1.67 – 13.08), provided a p value of 0.003. This proves there is a significant difference between the groups. Exposure to the military lifestyle increases the odds for the occurrence of Reactive Suspect Pathology; the odds of Reactive Suspect Pathology occurring in a military skeletal assemblage is 4.67 times greater than a non-military skeletal assemblage. Mantel-Haenszel X^2 was used to measure the strength of the association between the military lifestyle and the occurrence of Reactive Suspect Pathology. The Mantel-Haenszel X

^{2} was calculated to be 9.59, with a p value of 0.002. This is a significant p value, indicating a strong association. With significant results for both the odds ratio and Mantel-Haenszel X^2, it can be concluded that the association between the military lifestyle and the occurrence of Reactive Suspect Pathology is strong and not likely due to chance.

9.3 Conclusions on the Primary Research Question

The primary research question inquired whether bioarchaeological research methods could be used to establish the presence of a strong connection between reactive arthropathies and historical military combatants; were reactive arthropathies an occupational hazard to historical military combatants? When evaluating the site comparisons for prevalence, there was some evidence to suggest that reactive arthropathies were more prevalent in military skeletal assemblages. The results for the Towton assemblage showed an elevated occurrence of reactive pathology and the Greenwich assemblage provided a significantly higher prevalence of reactive pathology.

The prevalence 'type' comparisons for the combined military and non-military data also indicated significance. In the case of Reactive Pathology, significance was not assured, but there was marked difference in the prevalence. It was concluded that the Reactive Pathology results highly suggest that the first bioarchaeological research hypothesis is true; reactive pathology is markedly more common in military skeletal assemblages. Applying the same hypothesis to Reactive Suspect Pathology, the research hypothesis is confirmed; Reactive Suspect Pathology was significantly more prevalent in military skeletal assemblages.

The nested case control studies for Reactive and Reactive Suspect Pathology both provided significant odds ratios and Mantel-Haenszel X^2 tests. This means the second bioarchaeological research hypothesis was proven true for Reactive and Reactive Suspect Pathology. It can be concluded that the military lifestyle is associated with increased odds for the occurrence of reactive pathology.

Prevalence, odds ratios, and Mantel-Haenszel X^2 tests were the statistical measures used to determine if there was a strong connection between the occurrence of reactive pathology (reactive arthropathies) and military skeletal assemblages (historical military combatants). As all tests provided results which suggested or confirmed significance, it can be concluded that there is considerable palaeoepidemiological evidence favouring a shared affinity between reactive arthropathies and historical military combatants. The statistical results indicate that reactive arthropathies can be considered an occupational hazard to historical military combatants.

9.4 Interpreting Methodological Results

9.4.1 Interpreting the Intrinsic Factor of Age

It was suspected that the young age distributions seen in many military skeletal assemblages could be problematic, as it may be more difficult to confidently diagnose cases of reactive pathology in younger skeletal remains. The prevalence of Reactive and Reactive Suspect Pathology in the Greenwich and Plymouth assemblages were compared as one means of assessing the intrinsic factor of age. The men of these assemblages likely faced similar environmental exposures during life, so a similar prevalence of reactive pathology would be expected if age was not a factor of influence.

(Review of Table 32)

Greenwich & Plymouth Prevalence Comparison				
Assemblage	Probable Prevalence (More Exclusive Count)		Possible Prevalence (More Inclusive Count)	
	Reactive	Reactive Suspects	Reactive	Reactive Suspects
Greenwich & Plymouth				
Greenwich	19.2% (95% CI 10.8, 31.9)	30.8% (95% CI 19.9, 44.3)	16.7% (95% CI 9.3, 28.0)	26.7% (95% CI 17.1, 39.0)
Plymouth	0% (95% CI 0, 9.4)	5.4% (95% CI 1.5, 17.7)	0% (95% CI 0, 7.3)	4.1% (95% CI 1.1, 13.7)

This was not the case. The Greenwich assemblage (with the older age distribution) had a significantly higher prevalence of both Reactive and Reactive Suspect Pathology for both N calculations. This result either implies age does have a strong effect on the ability to diagnose cases of reactive pathology in skeletal material or, that for some unforeseeable reason, the environmental exposures of these assemblages differed during life. The second conclusion seems unlikely considering the known history of these assemblages.

Comparison of the ages in which skeletal cases of reactive pathology occurred served as further evidence supporting the conclusion that age is an intrinsic factor of influence. Site comparisons were hindered by the limited data available, so patterns of age expression were not easily identified. Though the use of site comparisons was limited, the ‘type’ comparisons did prove useful.

Military assemblage results indicated that Reactive Pathology and Reactive Suspect Pathology were more commonly diagnosed in older age categorizations (above age 35); 92.9% and 81.5% of cases respectively. The non-military assemblage results for Reactive Pathology remained skewed by the small body of data, but cases of Reactive Suspect Pathology showed a preference for diagnosis in older age categorizations; 80% of cases were older than 35. The combined total for military and non-military data indicated the same pattern, older age categorization were favoured, with 87.5% of Reactive Pathology cases and 81.3% of Reactive Suspect Pathology cases being diagnosed in individuals older than 35.

Overall, the results suggest age is an intrinsic factor of influence. It is easier to diagnose/categorize cases of reactive pathology when the individual experienced the condition for a longer duration before death. This result was expected based on observations made during data collection. The observer felt erosive pathology in assemblages with younger age distributions (Plymouth and the York Mass Grave) was underdeveloped rather than nonspecific. For example: a marginal erosion occurring on a foot phalange is not uncharacteristic, but the presence of only one such erosion cannot be confidently diagnosed.

9.4.2 Interpreting the Results for (N) Measures

The usefulness of the Probable N and Possible N measures was assessed to determine if one measure was more or less useful when considering reactive pathology in skeletal material. This judgement was based on the percentage difference produced between the two measures. Results presenting ≥ 5% difference were considered to favor the Possible N measure (more inclusive, less specific). Results presenting with < 5% difference were considered to favor the Probable N measure (less inclusive, more specific).

None of the results for Reactive or Reactive Suspect Pathology provided a difference ≥ 5%; all results presented with < 5% difference. As there was minimal difference in the recorded prevalence, this favors use of the more specific and less inclusive measure, Probable N. Though use of the different measures allowed the Reactive Pathology prevalence results to be interpreted in a slightly different manner, the conclusions were much the same (significance was not assured, but there was marked difference in prevalence). Since less than 5% difference in prevalence does not majorly influence the interpretation of results (at least not in this research), use of the more specific count, Probable N, is preferable.

As a side note, the Possible N measure may still prove useful for other research. All of the assemblages examined for this research were reasonably well preserved. The worst preserved remains came from the All Saint's Church and York Mass Grave assemblages. Bearing in mind that a cattle market once existed on the site location, this is unsurprising; however, preservation was still fair. Though fragmentation was prominent, most of the joints were still observable. This may not prove true of every assemblage. Should one wish to investigate the prevalence of SpA in assemblages with especially poor preservation, then use of the Possible N measure may prove more useful. If one is uncertain whether preservation will be an issue of great influence, the use of both measures is suggested; one can always assess the difference produced after analysis has been conducted.

9.4.3 Interpreting Criteria Results

(Review of Table 38)

Numerical Accounting of Criteria for Reactive Pathology Cases	
Criteria	**Number of Uses**
Criterion 1 (SIJ Involvement)	9
Criterion 2 (Spinal Fusion with Skip Lesions, Chunky Syndesmophytes)	4
Criterion 2 (Spinal Fusion without Skip Lesions, Smooth Syndesmophytes)	1
Criterion 3 (Three + Vertebrae with Syndesmophytes OR Fusion/Erosion of the Zygapophyseal Facets, Costovertebral Facets, or Interspinous Ligament)	6
Criterion 4 (Enthesopathy, 3+ Locations, Including 1 Characteristic Location)	12
Criterion 5 (Marginal Joint Erosions, With or Without Reactive Bone Formation)	14

Creating a numerical accounting for the use of criteria was seen as a means of identifying which criterion were most and least likely to be encountered in skeletal material. Criterion 5 was used the most followed by Criterion 4. Criterion 5 is diagnostic of SpA pathology when used in the manner described in Chapter 6, but Criterion 4 must be considered carefully as it may or may not have a reactive origin. As such, Criterion 4 must be observed in combination with other criterion. Over the course of this project, it was noted that the combination of Criterion 5 and 4 was especially common.

Criterion 1 was also noted frequently. This includes both SIJ fusion and general evidence of sacroiliitis. Sacroiliitis is another form of pathology that may or may not be directly related to reactive pathology, so it must occur in combination with other criterion to be considered ‘reactive’ in nature. Criterion 3 was noted six times. Pathology described for Criterion 3 are characteristic of SpA, but differential diagnosis should be carefully considered, as similar changes can be found in DISH and vertebral trauma. For this reasons, Criterion 3 was considered ‘reactive’ only when paired with other criterion as described in Chapter 6.

Criterion 2, which is highly specific to SpA pathology, was noted the least. Of the two differing forms of spinal fusion detailed under Criterion 2, the typical pattern observed in ReA and PsA (spinal fusion with skip lesions, chunky syndesmophytes) was noted most frequently. The pattern of spinal fusion followed by AS (spinal fusion without skip lesions, smooth syndesmophytes) was only noted in 1 case. It should be noted that some of the cases described as presenting with ReA and PsA characteristic fusion had smooth as well as chunky syndesmophytes. In such cases, it was the presence of skip lesions that ultimately identified the case as being most similar to the ReA and PsA varieties of SpA.

9.4.4 Conclusions on Methodological Results

It was confirmed that reactive pathology is easier to diagnose in older individuals. This may have been an influential factor for the elevated, yet non-significant, prevalence seen in most of the site comparisons outside of the Greenwich assemblage. In retrospect, the problems in evenly representing the Young Adult age categorization in control assemblages may have skewed the results of some site comparisons; this would have favored more cases occurring in the control assemblages. Nevertheless, the type comparisons produced a higher prevalence of reactive pathology in military assemblages in spite of the disadvantage.

The other important methodological consideration for future research is the appropriate use of the Probable N and Possible N measures. It was concluded that Probable N should be used on assemblages with good preservation. If the overall preservation of an assemblage is fair, it may be advantageous to use both measures and determine which is appropriate after analysis; this can be done by assessing the difference in the reported prevalence (greater or less than 5%). In poorly preserved assemblages, it may be difficult to obtain a useful sample size using the Probable N measure, so Possible N may prove more effective. More experimental use of both measures is needed to confirm this proposed approach.

9.5 Conclusions on Skeletal Results

Apart from the methodological conclusions just made, the statistical results for the skeletal investigation allowed the first and second bioarchaeological hypotheses to be proven true. It was therefore concluded that reactive arthropathies were an occupational hazard to historical combatants. The quantitative data of this skeletal investigation adds credibility to the results of the literature investigation (Chapter 7), which provided numerical evidence and statements suggestive of an affinity between reactive arthropathies and past military combatants. With both the literature and skeletal investigation providing evidence to support the proposal that reactive arthropathies were an occupation hazard to past combatants, the current project has demonstrated that death was not the only consequence of the military lifestyle's connection to infectious disease (war epidemics). Another consequence potentially faced by combatant was the development of reactive arthropathy.

Military infectious diseases can now be investigated with new perspective by addressing the secondary research questions listed in Chapter 3; however, before entering this discussion, a case study of a combatant with reactive arthropathy will be presented. This case is quite exceptional, as medical history, skeletal remains, and other life details are available for consideration. Historical skeletal remains rarely provide this much background information, so this case offers a unique opportunity to discuss personal experience alongside scientific analysis. The experience of this particular combatant is later used for comparative and interpretive purposes in the discussion chapter (Chapter 11).

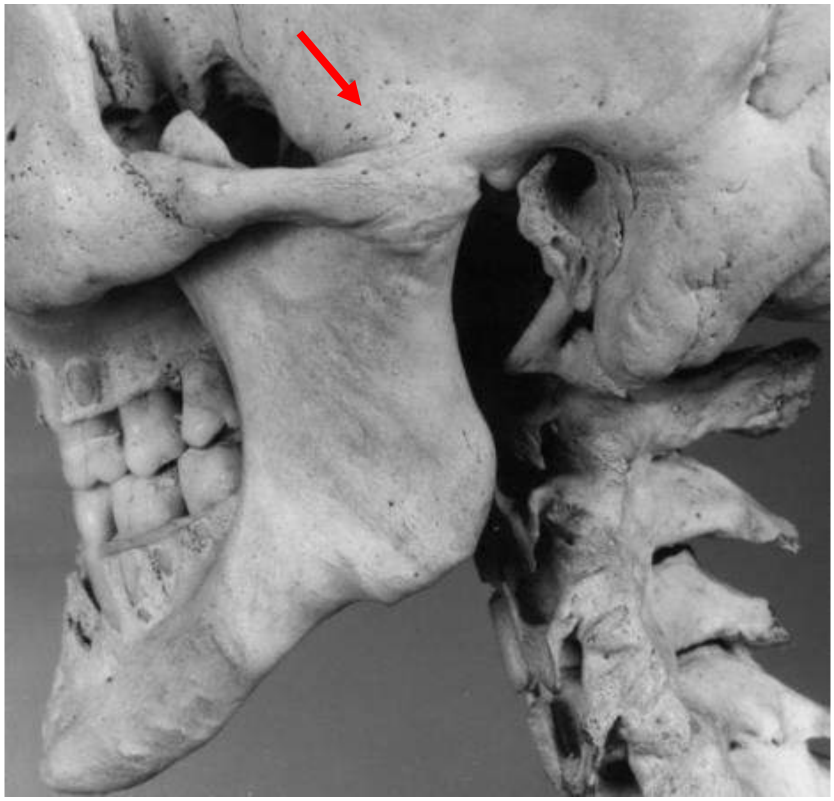
CHAPTER 10
One Man's Experience: A Case Study

10.1 Case Background

Pvt. Peter Herman Cluckey was born 16 September 1882 in Lansing, Michigan. As a young adult, he served two enlistments with the U.S. Army. His first enlistment commenced in 1899 at age 17 and he was discharged in 1903 at age 21, but reenlisted in 1904 (Gilmore & Stecher 1955; National Museum of Health and Medicine [NMHM] Archives). During this second enlistment, Pvt. Cluckey experienced pain in the joints. He received treatment at the Army and Navy General Hospital in Arkansas and was honourably discharged with a certificate of disability on 4 July 1905 at age 22 (two month shy of his 23rd birthday). At this time, his condition was described as "rheumatism chronic, articular" characterized by stiff and swollen joints (Gilmore & Stecher 1955; NMHM Archives). Though his arthropathy started in just a few joints (feet, ankles, shoulders, and right knee), his conditions would ultimately result in fusion of "practically all joints" (Gilmore & Stecher 1955; NMHM Archives). The fusion of joints steadily progressed over many years and was extremely debilitating. Since he could not care for himself, Pvt. Cluckey spent much of his life in assisted living at the United States Soldiers' Home in Washington D.C.

As his disease progressed, Pvt. Cluckey's overall health declined. At his second enlistment he weighed 138 pounds, but during his 1910 hospitalization he was described as "emaciated," weighing only 104 pounds (Gilmore & Stecher 1955; NMHM Archives). He was prescribed opiates for pain management and it appears he formed an addiction (Gilmore & Stecher 1955). He had experienced stiffness in his left jaw since 1913 and it was noted that he "was fearful" that it would become "stiff" (fused) like many of his other joints (Gilmore & Stecher 1955, 433). Indeed, he began to lose use of his jaw and, by December of 1920, his left temporomandibular joint had completely fused (see **Fig. 64**). In February 1920, physicians removed several of Pvt Cluckey's front teeth so he could be fed more easily (Gilmore & Stecher 1955).

Figure 64: this image shows fusion of Pvt. Cluckey's left temporomandibular joint (indicated by the red arrow). Source: NMHM Archives (Acc. MM4223).



Over the 20 year duration of his condition (1905 – 1925), he had been subjected to numerous treatments, including: Fowler's Solution (a tonic containing potassium arsenic), an injection of 0.5% solution of formalin in glycerine, hydrotherapy, sodium salicylate, potassium iodide, and quinine (Gilmore & Stecher 1955; NMHM Archives). None of these treatments halted the progression of his arthropathy. Frustration over the failure to diagnose and effectively treat his condition may have motivated Pvt. Cluckey's decision to state in his 1921 Will that his remains be autopsied and subsequently donated to the Army Medical Museum, now the NMHM (NMHM Archives). His request was granted after his death on 10 September 1925 at age 42 (six day shy of his 43 birthday). Of the soft tissues, only the liver was preserved, but his skeletal remains were mounted and displayed within the museum; his remains are still part of the museum's permanent exhibit today (see **Fig. 65**).

Figure 65: the remains of Pvt. Cluckey on display at the NMHM in Silver Springs, Maryland, U.S. Some of the original bones have been lost and replaced with those of another individual (yellowish in colour). Source: NMHM 2014.

Thirty years after his death, Pvt. Cluckey's case was re-examined by Gilmore and Stecher, who reported their findings in a 1955 article in *Military Medicine*. The information in this publication is very useful; interviews with people who knew Pvt. Cluckey were conducted and it also summarized the physical features of his condition. Gilmore & Stecher (1955) concluded that Pvt. Cluckey had, "chronic progressive ankylosing rheumatoid arthritis, and spondylitis" (438). Today, this conclusion can be viewed as a description of the expression of Pvt. Cluckey's arthropathy, but it cannot be considered a diagnosis. As mentioned in Chapter 4, until the 1960's, SpA conditions were seen as 'rheumatoid variants' rather than separate conditions with differing pathological processes (Weissman 2009). Furthermore, it was not until 1972 that the connection between SpA and HLA-B27 was suggested (Schlosstein *et al.* 1972). Clearly, much advancement has been made in the field of rheumatology since the publication by Gilmore & Stecher (1955), but no reassessment of Pvt. Cluckey's case has occurred since this publication.

The present chapter provides this reassessment and argues Pvt. Cluckey's condition is SpA. This conclusion is based on both textual and skeletal evidence. The information obtained for this assessment came from medical records housed at the NMHM archives and examination of his skeletal remains.

10.2 Description of Skeletal Changes: Differential Diagnosis

A key feature of Pvt. Cluckey's case was extensive joint fusion (ankylosis), including the spine and pelvis. Bone formation was limited to the joints and did not affect muscular tissues, which eliminates fibrodysplasia ossificans progressiva (a condition which ossifies muscular tissues) from being considered as a potential diagnosis (Mahboubi *et al.* 2001; Waldron 2009). Erosions were the other key feature of his condition. Erosive changes are observable in the right foot of his skeletal remains and descriptions in the NMHM archives note "extensive bone absorption" in the metacarpal-phalangeal joints of the hands; the autopsy report states these joints were "destroyed and frail like" (Gilmore & Stecher 1955, 434; NMHM Archives). Since Pvt. Cluckey's death, both hands and the left foot have been lost, making it difficult to evaluate many of the erosive changes. Nonetheless, descriptions of "swelling and tenderness" and "stiffness" in the NMHM records indicates that Pvt. Cluckey's arthropathy was of an inflammatory nature. Inflammatory arthritis in combination with erosions firmly places Pvt. Cluckey's case into the category of erosive arthropathy, but what kind? RA and SpA are the only reasonable suggestions.

RA is characterized by: symmetrical marginal erosions, sparing of the SIJs, lack of spinal fusion, and minimal to no new bone formation; ankylosis can occur, but is usually limited to joints with extensive deformity caused by erosive changes (Jacobson *et al.* 2008; Rothschild *et al.* 1990; Waldron 2009). Unfortunately, the absence of both hands and the left foot from Pvt. Cluckey's skeleton make it impossible to address the question of symmetry, but friability is still observable in the remaining right foot, along with possible 'licked candy stick' deformity in the 5th proximal phalanx (see **Fig. 66**). This type of deformity can be observed in cases of RA, but is also a deformity found in PsA and leprosy; leprosy does not fit his case due to the lack of rhino-maxillary syndrome, lack of any report of nerve loss, and the presence of spondylitis and SIJ fusion (Prasad *et al.* 2013;Waldron 2009; Zias & M (itchell 1996).

Figure 66: this photo shows fusion of metatarsophalangeal and phalangeal joints, as well as the 'licked candy stick' deformity (indicated by red arrow). Source: photo taken by author.

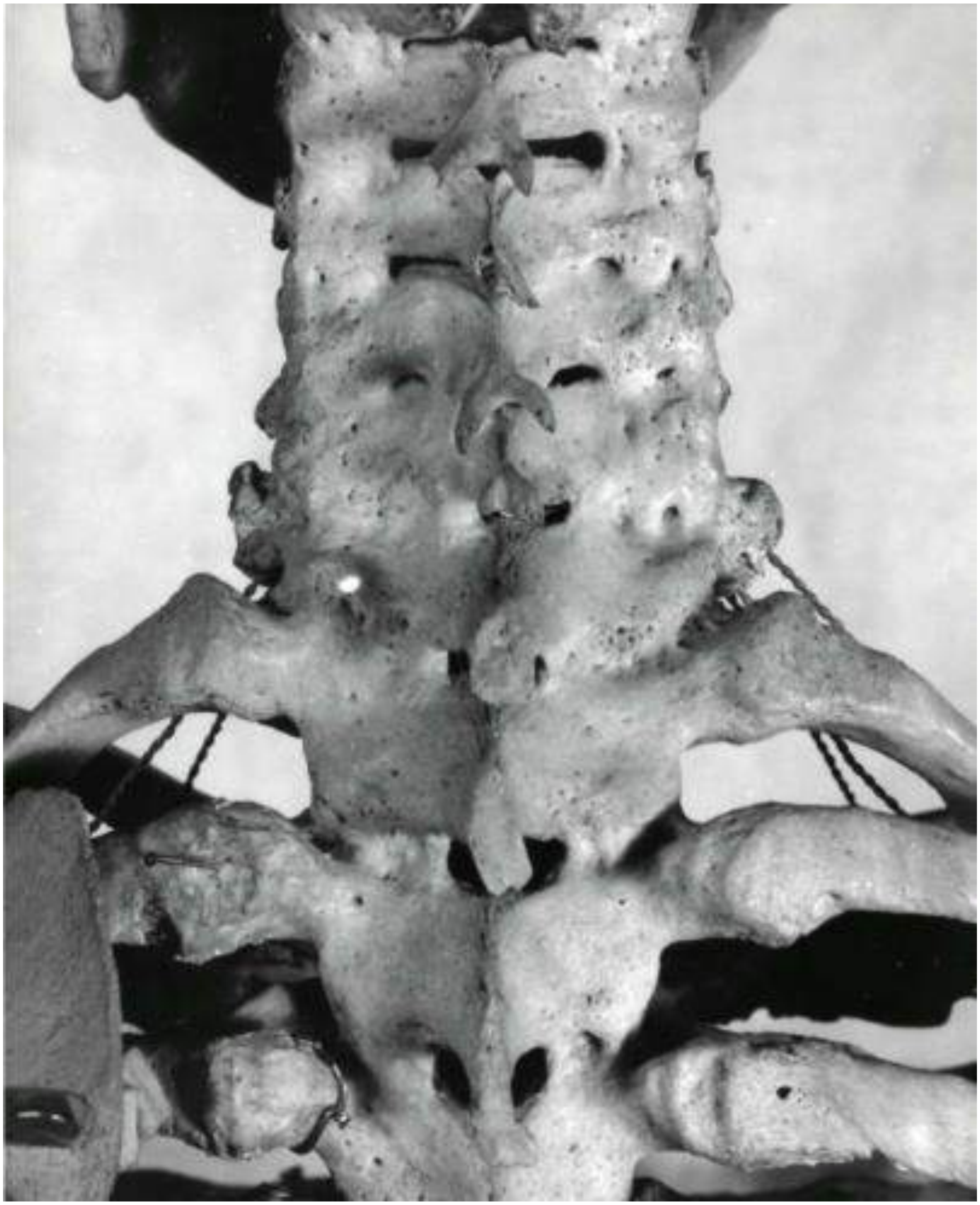
Apart from erosive changes, Pvt. Cluckey's skeletal remains display several important features that do not support a diagnosis of RA: enthesopathy (plantar spurs), spinal fusion, SIJ fusion, and ankylosed joints which lack extensive erosive deformity. Though these are not features of RA, they are all highly diagnostic features of SpA (Arriaza 1993; Jacobson *et al.* 2008; Rothschild *et al.* 1999; Rothschild *et al.* 1990). Pvt. Cluckey's case is extreme, but the features fit the criteria described in Chapter 6 to diagnose SpA: 1 (bilateral SIJ fusion), 2 (continuous spinal fusion, smooth syndesmophytes), 3 (ossification of the interspinous and costovertebral ligaments), 4 (enthesopathy), and 5 (erosions, though the nature is difficult to determine).

The number of ankylosed joints in Pvt. Cluckey's skeleton is extreme by any standard, but axial and peripheral ankylosis is not uncommon in SpA cases, especially PsA, as it has been noted that, "exercise to maintain optimal joint function may be particularly important because of the tendency to both axial and peripheral joint ankylosis" (Jadon & McHugh 2014, 260; Cawley & Paine 2015). Where joint ankylosis can occur without erosive changes in cases of SpA, this is not typical of RA ankylosis. Most of Pvt. Clucky's ankylosed joints do not show erosive changes; erosive pathology appears to have been primarly confined to the hands and fee. The amount and type of joint ankylosis present in Pvt. Cluckey's case places considerable doubt on a RA diagnosis, but serve as strong marks in favour of a SpA diagnosis (Jacobson *et al.* 2008; Rothschild *et al.* 1990; Waldron 2009).

There is also the nature of the spinal bone formation to consider. The type of formation observed in the spine is most typical of AS. The bone formation can be characterized as continuous (lacking skip lesions) with smooth syndesmophyte formation concentrated at the intervertebral disk margins (annulus fibrous) (see. **Fig. 67**). All of the costovertebral facets have fused in the thoracic region, as well as the interspinous ligaments (see **Fig. 68**). Fusion in the SIJs presents with bilateral symmetry, which is also characteristic of AS. Though the axial changes are most characteristic of AS, the extensive nature of Pvt. Cluckey's case must be remembered, as modern clinical cases show a tendency for one form of SpA to develop into another; most start as Udifferentiated Spondyloarthropathy (USpA), ReA, or PsA which then develop into AS (Asquith *et al.* 2014; Paramarta *et al.* 2013).

Figure 67: this photo displays the fusion observed in Pvt. Cluckey's lumbar vertebrae, which is characterized by smooth syndesmophyte formation near the intervertebral disk margins. Source: NMHM Archives (Acc. MM4223).

Figure 68: This photo displays fusion of the interspinous ligaments and the costovertebral facets. Source: NMHM Archives (Acc. MM4223).



10.3 Description of Medical History

As mentioned previously, it is rare that a bioarchaeologist has the luxury of a medical history, but Pvt. Cluckey's case is an exception. Pvt. Cluckey was born in Lansing, Michigan on September 16, 1882. His father (Samuel Cluckey) and mother (Minnie Acker Cluckey) were immigrants, from France and Germany respectively (Gilmore & Stecher 1955). As a child he had measles, mumps, chicken pox, whooping cough, and scarlet fever (Gilmore & Stecher 1955; NMHM Archives). In 1897 he developed malaria and rheumatism, though he denied having rheumatism in his 1904 enlistment papers (Gilmore & Stecher 1955).

The military of Pvt. Cluckey’s day would have still faced serious challenges with disease. For instance, when he enlisted in 1899 he was sent to the Philippine Islands until 1903 as part of the Philippine-American War (1899-1902). This conflict faced many of the issues discussed in chapter two relating to military infectious diseases. Given the location, tropical diseases were problematic (such as malaria), but so too were diseases associated with crowds and poor sanitation, including dysentery which had a near constant presence during the Philippine-American War; these conditions thrived due to disorganization and sanitation issues that occurred in spite of regulations (example: locals frequently flooded their lands for agricultural purposes, which drained into and contaminated clean water sources) (Anderson 2006; Silbey 2008). Venereal disease was also an issue, as it was not unusual for troops to face months with little activity, resulting in boredom that caused troops to “turn to anything that would provide entertainment. Cockfighting became popular. Venereal disease rates—a sign of the oldest form of entertainment—jumped. The men drank anything they could find: *beno*, a potent native liquor, was popular, as was the beer served in bars set up by American” (Silbey 2008, 81).

Upon his return from the Philippines, Pvt. Cluckey was discharged, but re-enlisted in 1904, joining the 15th Cavalry Regiment at Fort Ethan Allen, Vermont (Gilmore & Stecher 1955; NMHM Archives). Two months later, after a drill in cold rain, Pvt. Cluckey began to experience joint troubles. His arthropathy would lead to numerous hospital admissions and medical discharge on July 4, 1905 with a certificate of disability (Gilmore & Stecher 1955; NMHM Archives).

Due to the connection between SpA and HLA-B27 (a genetic feature), family history was investigated. The results of this effort were limited. At the time of his death, Pvt. Cluckey had one brother (Frank Cluckey) and two sisters (Rose Rider and Marie Hayes) (Gilmore & Stecher 1955; NMHM Archives Archives). Of interest to Pvt. Cluckey's case, his brother (presumably Frank) also had rheumatism, but no further detail is given (NMHM Archives). The attempts to discover more about Frank and his case of rheumatism were unsuccessful, so there is simply a tantalizing (yet frustrating) hint that there may have been a familial link.

A basic premise of the current research project has been the proposal that SpA was more common in military populations due to their increased exposure and susceptibility to arthritogenic bacterial. With this in mind, it should not be overly surprising that Pvt. Cluckey's records revealed several infections occurring during his service. For one, he had gonorrhoea a year before his reenlistment in 1904 (Gilmore & Stecher 1955; NMHM Archives Archives). Though a year between gonorrhoea and the onset of arthropathy does not fit the typical timeline for SpA, Pvt. Cluckey's case did occur before accepted use of antibiotics, which could mean there was a prolonged course. Nevertheless, gonorrhoea is not the leading infectious suspect in his case.

Of more interest was the reported 20 to 30 cases of tonsillitis (caused by *Streptococcus pyogenes*) he suffered before, during, and after the development of his arthropathy (Gilmore & Stecher 1955; NMHM). The commonality and timing of his tonsillitis infections fit the expectation for a reactive arthropathy trigger. Perhaps the most convincing evidence of a link to tonsillitis was the fact Pvt. Cluckey's joints "flared up" when he experienced an episode of tonsillitis (Gilmore & Stecher 1955, 433). The high number of tonsillitis infections is also of interest, as some research suggests persistent or repeated infections could be related to SpA taking a chronic course rather than acute (Siper 2007). Pvt. Cluckey's case was indeed chronic and was associated with many Streptococcal tonsillitis infections.

In addition to a medical history of infections, there are soft tissue changes described in his medical history that could fit a SpA diagnosis. Though psoriasis was not mentioned specifically, there were descriptions of his skin being "scaly and hard" and that his toenails were "deformed" (Gilmore & Stecher 1955; NMHM). Though not shown due to their sensitive nature, autopsy photos in the NMHM archival records show nail deformity in the hands. No further explanation or detail is provided in relation to these observations. Dry scaly skin cannot be ruled out or confirmed as psoriasis, but nail deformity is certainly common in both psoriasis and PsA (Dhir & Aggarwal 2013; Kleinert *et al.* 2007). If psoriasis was present, this would match well with Pvt. Cluckey's history of infections, as Streptoccocal tonsillitis is a trigger for PsA (Chandran & Raychaudhuri 2010).

Some information about the progression of his condition can also be evaluated based on his medical records. Pvt. Cluckey's arthropathy appears to have begun as a peripheral case. At his first hospital admission in 1904, it was noted that the left ankle was involved first, which progressed into involvement of the right ankle, the right knee, and both shoulders (Gilmore & Stecher 1955; NMHM). Over the course of this hospital stay, his arthropathy worsened and additionally involved the left ankle, left knee, both hips, the right elbow, and the right 3rd and 4th metatarsal-phalangeal joints (Gilmore & Stecher 1955, 432). These joints were swollen, stiff, and tender (Gilmore & Stecher 1955; NMHM).

By his next admission in 1909, the pain was still predominantly in his knees, ankles, feet, and hips. Furthermore, Pvt. Cluckey could no longer walk, as his knee function had been reduced to one third of the normal range (Gilmore & Stecher 1955, 433). Upon entering the United States Soldiers Home in 1910, ankylosis of the knees was recorded and reduced motion of the hips and left elbow were noted; his left wrist was also added to the list of affected localities (Gilmore & Stecher 1955; NMHM). By

1913, he was no longer able to feed himself. His upper body's rage of motion was limited to partial movement of his mandible and slight movement of the neck (side to side), shoulders, elbows, and fingers; motion in the lower joints was nearly non-existent (Gilmore & Stecher 1955; NMHM). There is no clear indication in his records as to when spinal involvement became apparent, but it is clear it must have begun before 1913, as ankylosis had reached the neck and greatly restricted its movement by this point.

10.4 Updated Retrospective Diagnosis

Pvt. Cluckey's condition fits most closely with a SpA diagnosis. His case hits every requirement for SpA, but fails to meet all RA requirements. This can be seen in **Table 40**, which compares the pathological features of his cause with SpA and RA. The repeated and numerous attacks of tonsillitis seems to be the most plausible bacterial trigger identified in his medical history, which would suggest PsA. Though PsA seems reasonable, it is important to remember that the SpAs often behave strangely. Cases may start as one variety and develop into AS or can be present with a unique mixture of features that make specific diagnosis difficult (Asquith *et al.* 2014; Carter 2010; Chandran & Raychaudhuri 2010).

AS and EnA tend to be axial in nature, with limited peripheral changes; when peripheral changes do occur, they are often found in larger joints such as the knee. PsA and ReA can cause extensive axial involvement or very little, but extensive peripheral involvement is standard. Pvt. Cluckey's case is a unique combination of features; peripheral involvement is marked, but so are the spinal changes, which most resemble AS. Given the unusual pattern of expression, Pvt. Cluckey's case would likely have been diagnosed as Undifferentiated Spondyloarthropathy (USpA) were he alive today (Ehrenfeld 2012; Stolwijk *et al.* 2012). It is interesting to note that USpA is now largely accepted as a fifth subgroup of SpA (representing 40% of SpA cases), which is noted for its aggressive expression and "suboptimal" response to modern treatments (Paramarta *et al.* 2013, 1874; Samsel *et al.* 2014).

Table 40: this table compares the features of SpA, RA, and Pvt. Cluckey's case. His case fulfils all features of SpA, but shows some inconsistencies with RA. Source: created by author.

Comparison SpA, RA, and Pvt. Cluckey's Case			
Feature	**SpA**	**Peter Cluckey**	**Rheumatoid**
Ankylosis of SIJ	Yes; one or both	Yes; both	No
Vertebral Fusion	Yes	Yes	No
Erosions	Yes	Yes	Yes
Enthesopathy,	Yes	Yes	No
Joint Ankylosis	Yes; with or without erosive deformity	Yes; extensive, not observed with obvious erosions	Occasionally; minimal and with erosive deformity
Symmetrical Erosions	Occasionally	Unknown	Yes
'Licked Candy Stick' Deformity	Yes	Yes; distal right 5th MT	Yes
Telescoping of Digits	Yes	Possible; photography of hands (no shown, autopsy photos)	Yes
Associated Skin Lesions	Yes; PsA & ReA	Possible; "skin scaly and hard"	Yes; but rare
Nail Deformity	Yes; PsA and ReA	Yes; Photography of hands (no shown, autopsy photos)	Occasionally
Associated with *Streptococcus*	Yes; PsA	Yes	No
Associated with *N. gonorrhoea*	Yes; ReA	Possible	No

10.5 Conclusions

As noted, the 1955 study is the only official and published research conducted on Pvt. Cluckey's case. Though this article provided useful information, many advancements in rheumatology have been made since. This chapter has provided an updated assessment of the available evidence. Though his case is unique, the evidence suggests that his condition was likely some form of SpA.

Overall, Pvt. Cluckey's condition serves as an example of the negative effects of SpA. His condition began at the young age of 22. Four years after onset (1905-1909) he had lost his ability to walk and he was almost completely immobilization eight years after onset (1905-1913). His condition was painful and he was prescribed opiates for pain management, but became addicted to their use. His lived twenty years (1905-1925) with this condition, with most of this time spent in assisted living.

Review of Introduced Acronyms:

National Museum of Health and Medicine (NMHM)

CHAPTER 11:
Discussion

11.1 Reactive Arthropathy as an Occupational Hazard of Past Combatants

As the literature investigation, skeletal investigation, and case study of Pvt. Cluckey have all provided evidence to support the claim that reactive arthropathies were an occupational hazard to past military combatants, the implications of this discovery must now be considered. The most direct implication is an acknowledgment that the connection between the military lifestyle and infectious disease had consequences beyond high fatality rates and disruption to military campaigns. Combatants were also susceptible to the development of reactive arthropathies like SpA and ARF, as many of the infectious diseases found among past combatants were caused by arthritogenic bacteria. By quantifiably confirming this through historical and bioarchaeological research methods, the present project has contributed new information to an old topic. Though this finding is certainly interesting, confirmation of this connection brings forth new questions, which will be addressed in this chapter.

11.1.1 Were Reactive Arthropathies a Hazard to all Military Groups?

What military groups experienced reactive arthropathies as an occupational hazard? All or just some? Since medieval armies were exposed to the hardships of the military lifestyle for shorter durations than later standing armies, it was considered possible that the Towton assemblage may not provide ample evidence of reactive arthropathy; that the difference between the military and control (civilian) prevalence would not greatly contrast. This did not prove true, as Reactive Pathology did occur at a higher prevalence than its control assemblage, with the Towton prevalence being 3.58 times that of the control. This suggests that reactive arthropathies were more common among military combatants than civilians of the medieval period and, thus, was an occupational related hazard.

Though the Towton assemblage indicates reactive arthropathies were an occupational hazard, the length of exposure to the military lifestyle may have remained important. It was mentioned in Chapter 5 that some individuals within the Towton assemblage may have been professional combatants, "individuals who spend a disproportionate time in training for and in the performance of movements associated with using weapons in combat" (Knüsel 2007, 103). Identification of such individuals was based on the height, robustness, and presence of healed antemortem trauma (Boylston *et al.* 2007). Three of the erosive cases recorded in the Towton assemblage fit this profile (Boylston *et al.* 2007; Knüsel 2007; Novak 2007 [a]). These were the Unidentified, Reactive Suspect Pathology cases of Towton 22, 25, and 41 (see **Table 41**); this is 42.9% of the erosive pathology cases observed in the Towton assemblage. Medieval professional combatants were presumably exposed to the military lifestyle at a more regular rate than medieval common soldiers, so duration of exposure may be a matter of some influence. As the Towton assemblage was quite small, analysis of other medieval military assemblages should be conducted to further investigate this line of thought.

Table 41: the table below describes the skeletal profile of individuals discovered to have erosive pathology and evidence suggesting status as a professional combatant. Source: created by author; information from Boylston *et al*. 2007; Novak 2007 [a].

Descriptions of Towton 22, 25, and 41	
Towton 22	Healed antemortem trauma in the cranium (blunt force trauma on the left parietal) and estimated to be 6 foot in height
Towton 25	Healed antemortem cranial trauma (blunt force trauma on the frontal bone) and estimated to be 5 foot 9 inches in height.
Towton 41	Healed antemortem trauma in the cranium (blunt force trauma on the frontal bone and right parietal, as well as sharp force trauma to the left parietal and frontal bone) and estimated to be 5 foot 8 inches in height.

What of non-European military combatants, would they have been susceptible to reactive arthropathies like SpA? For reactive arthropathies to occur, one must be exposed to the appropriate triggering bacteria. Fulfilment of this criteria is rather simple, as historical research indicates that infectious disease was a nearly universal problem for pre-twentieth century militaries (Smallman-Raynor & Cliff 2004 [a]). Considering the rather broad list of bacteria involved in reactive arthropathies like SpA, it is likely that most armies, regardless of geographical location, would have been exposed to at least some of these bacteria.

The genetic component of these conditions must also be considered. As mentioned in Chapter 1, HLA-B27 positivity is connected to the occurrence of SpA, though the strength of this association varies between the SpAs (Reveille & Alkassab 2007; Reveille 2010). The prevalence of SpA does vary across populations, with higher prevalence occurring in populations where HLA-B27 is common and lower prevalence occurring in populations where HLA-B27 is less common (Ehrenfeld 2012, 139; Stolwijk *et al.* 2012; van Tubergen 2014). For example, SpA prevalence is very low among the Chinese (0.2%) and Japanese (<0.5%), which coincides with their low prevalence of HLA-B27, 8% and 1% respectively (Feltkamp *et al.* 2001; Stolwijk *et al.* 2012).

With this in mind, it seems likely that military groups from populations with low rates of HLA-B27 would have a lower prevalence of SpA than military groups from populations with higher HLA-B27 prevalence. For instance, a Chinese military assemblage would likely have a lower prevalence than the British military assemblages examined for this research. But what if a Chinese military assemblage was matched with a Chinese civilian assemblage? In this case, the military group may still illustrate an elevated prevalence due to their increased exposure and susceptibility to arthritogenic bacteria, in spite of a low HLA-B27 prevalence.

Evidence to support this possibility was reported in a clinical article by Wu *et al.* (2004), which investigated the prevalence of SpA within the Chinese armed forces.

They discovered that the prevalence of SpA (AS and undifferentiated SpA) in the Chinese Army was similar to that of the civilian Chinese population, but SpA was more prevalent in the Chinese Navy when compared to the civilian population (Wu *et al.* 2004). Though this has yet to be investigated in skeletal assemblages, it seems plausible to suggest that the prevalence of reactive pathology varies across genetic populations (example: British assemblage versus Chinese assemblage), but military groups likely have an elevated prevalence of reactive pathology when compared to appropriately matched genetic population (example: Chinese military assemblage versus Chinese civilian assemblage). If true, reactive arthropathies were a universal occupational hazard.

11.1.2 What Varieties of SpA Afflicted Past Military Populations?

Based on the literature investigation, descriptions attributed to ReA were quite common in military medical documentation. In skeletal material, it is rare that one can specifically diagnose any particular form of SpA. This is not surprising, as multifocal conditions like SpA can be difficult to specifically diagnose due to matters of preservation (Waldron 2007). Despite these challenges, ReA was diagnosed in two military case. Both individuals were from the Greenwich (KWK) assemblage: KWK 3044 and KWK 6113. The operational definition for ReA provided in Appendix A was fashioned after Waldron (2009) and is stated in **Table 42**.

Table 42: the table below lists the operational definition for ReA. Source: created by author; definition adapted from Waldron 2009.

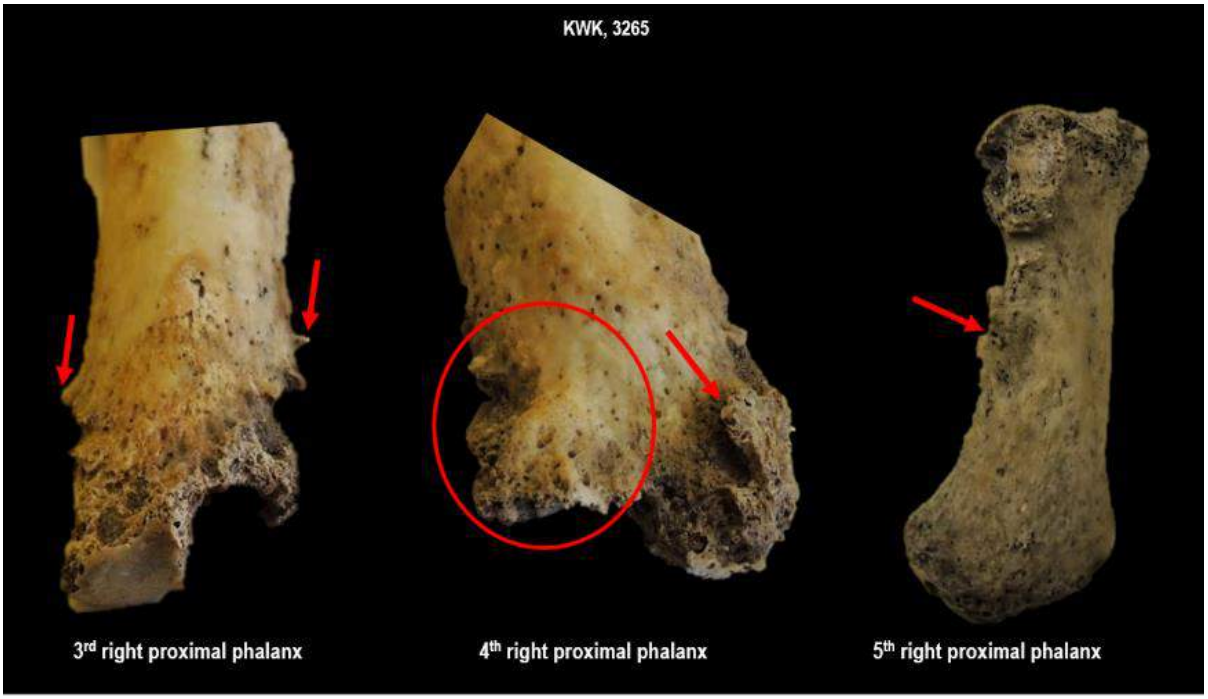
Operational Definition of Reactive Arthritis (ReA)	
Meets all of the following:	
1	Asymmetric fusion of one or both sacroiliac joints
2	Characteristic paravertebral spinal fusion with skip lesions
3	Asymmetric marginal erosions of the small joints of the feet

Both cases fulfilled all 5 criteria described in **Table 16** (Chapter 6) in some fashion. Criterion 1 was met by unilateral SIJ fusion in both individuals, though bilateral sacroiliitis was also noted in KWK 3044. Criterion 2 was met through spinal fusion with skip lesions. Criterion 3 was met in both cases through ossification of the interspinous ligaments. Criterion 4 was met by enthesopathy noted in numerous locations, which was primarily distributed in the lower extremities in each cases. Finally, Criterion 5 was observed in both cases through the presence of marginal foot erosions; some of these erosions were associated with new bone formation (see **Fig. 69**). Apart from KWK 3044 and 6113, no other specific diagnoses were made, but the SpA cases reported in the Towton assemblage were expressed in a manner most suggestive of ReA, with erosions and enthesopathy showing clear preference for the lower extremities.

Figure 69: this image shows pathology from KWK 6113, which was observed in the 2nd proximal phalanx of the right foot. The red arrow indicates a small corner erosion. New bone formation can be seen along the shaft. Source: created by the author.

The ReA variety of SpA appears to have been fairly common among historical combatants, but another form of SpA that must be considered is PsA. One case from Greenwich potentially represents the symmetrical variant of this condition, though this could not be confirmed with any great confidence; RA is also a likely diagnosis, but there was enough inconsistency to cause suspicion. KWK 3265 had extensive symmetrical erosions of the hands, feet, and wrists, which occurred with new bone formation in the form of periostitis and enthesopathy (see **Fig. 70**). Extensive distal interphalangeal joint involvement was also a feature of KWK 3265, which is more common to PsA than RA.

Figure 70: the proximal hand phalanges in the image below exemplify the bone formation observed in the hands of KWK 3265. Enthesopathy (red arrows) was small, but consistently found in the proximal phalanges of both hands. Some erosive areas also displayed slight swelling that could indicate a periosteal reaction (red circle). Source: created by the author.



There was a lack of extensive axial bone formation in KWK 3265. One small comma-shaped syndesmophyte was noted in a lumbar vertebrae. Only one SIJ was present, but it did display postauricular enthesopathy and porosity on the auricular surface. Erosions were noted in both the cervical and lumbar regions. The lack of convincing axial bone formation means PsA cannot be confirmed, but is not means for full exclusion, as axial involvement does not always occur in PsA (only in 20-40% of cases) (Jacobson *et al.* 2008; Waldron 2009). Due to such inconsistencies, KWK 3265 was marked as having Unidentified Pathology, but was considered as a reactive suspect.

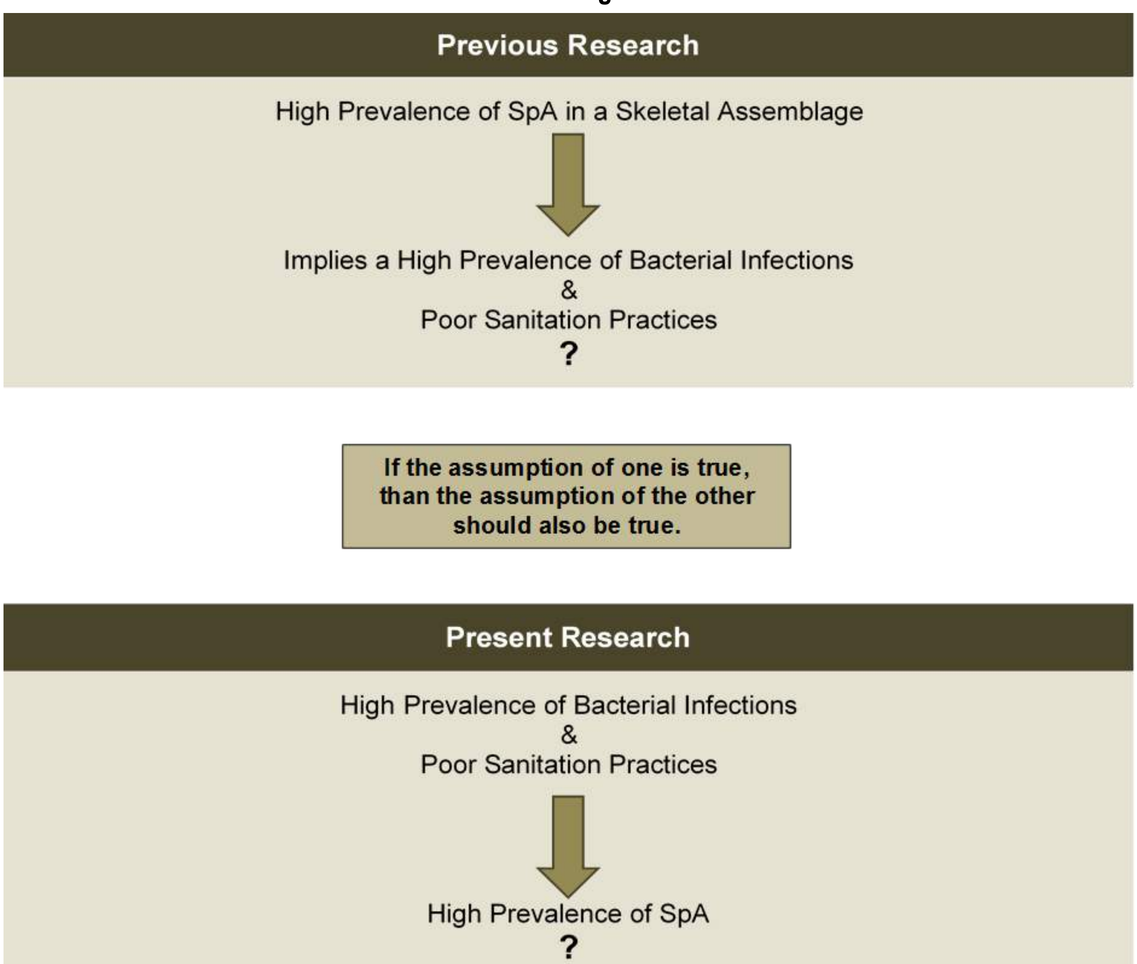
PsA should also be considered based on Pvt. Peter Cluckey's case. As was described in Chapter 10, his arthropathy was strongly associated with numerous infections of tonsillitis, which is caused by *Streptococcus pyogenes*, the primary bacterium involved in PsA. On the other hand, the spinal bone formation in Pvt. Cluckey's case is most similar to AS. Pvt. Cluckey's arthropathy is not average, making USpA the most appropriate designation, but the clear involvement of *S. pyogenes* means PsA should not be disregarded from consideration. Since clinical research continues to find similarities between SpA varieties, no form of SpA should be excluded from consideration in military assemblages, but ReA and PsA appear to be predominant based on historical evidence (Carter 2010; Tubergen 2014; Tubergen & Weber 2012).

With both the textual and skeletal data suggesting ReA and PsA were varieties of SpA occurring among historical combatants, the following bacteria can be suggested as the most likely suspects for the development of military SpA: *Salmonella enteritidis, Campylobactera jejuni, Yersinia enterocolitica, Shigella dysenteriae, Shigella flexneri, Escherichia coli, Clostridium difficile, Chlamydia trachomatis, Neisseria gonorrhoea,* and *Streptococcus pyogenes*. The occurrence of these bacteria among past combatants is not surprising, as their presence was already known (or highly suspected) based on historical descriptions of military epidemics. Nevertheless, the presence of specific SpAs in military skeletal assemblages serves as an indirect means of authenticating this information.

11.1.3 Does the Presence of Reactive Arthropathy Reflect on Sanitation Practices?

As mentioned in Chapter 4, previous bioarchaeological research on SpA prevalence has loosely focused on the reactive nature of these conditions (Arriaza 1993; Martin-Dupont *et al.* 2006; and Rothschild *et al.* 2004). Prior assumptions were made. If a high prevalence of SpA is observed in a skeletal assemblage, then infectious diseases must have been common in the living population (Arriaza 1993; Martin-Dupont *et al.* 2006). Rothschild *et al.* (2004) also assumed that the prevalence of SpA could be used to assess sanitation practices in past societies, as most of the infectious diseases associated with SpA thrive in unsanitary and overcrowded living conditions. These assumptions are based on knowledge of SpA pathogenesis, but, as was shown in **Figure 37** of Chapter 4 (reviewed below), these projects have all worked in one direction.

Review of Figure 37



Past bioarchaeological research has used SpA prevalence to infer information previously unknown about sanitation practices and rates of infectious diseases in past societies, but researchers have not tested this assumption by examining populations known to have poor sanitation and high rates of infectious diseases to determine if SpA prevalence does in fact produce a high prevalence because of these factors. By examining military skeletal assemblages, which are known to have suffered from poor sanitation and infectious diseases, the present project has worked in this previously unexplored direction. If the assumptions of this project were proven true, then the assumptions made about SpA prevalence in previous bioarchaeological research should also be true.

This project has confirmed that SpA related pathology was more prevalent in military skeletal assemblages. It also confirmed that the military lifestyle is associated with increased odds for SpA related pathology. These findings indicate the assumptions and interpretations made by previous bioarchaeological researchers are sound. When information about sanitation practices and rates of infectious diseases are unknown in past societies, SpA prevalence can be used to obtain a baseline understanding. Alternatively, in societies known to have poor sanitation and high rates of infectious diseases, one should expect a higher than average prevalence of SpA related pathology.

11.1.4 Could Reactive Arthropathies Influence the Outcome of Military Campaigns?

Gordon (1898) describes the considerable number of bowel related deaths witnessed during the American Civil War and remarked that, "it was a standing joke in our department that to be a good soldier here bowels are of more consequence than brains" (Gordon 1898, 141). Sun Tzu, a famous Chinese military strategists, philosopher, and author of *The Art of War* commented that, "an army which does not suffer from one hundred diseases is said to be certain of victory" (McNeilly 2015, 273). Indeed, the impact of disease is no small matter. Epidemics of infectious disease have caused disruption to military campaigns throughout history by reduing the fighting strength of armies with high fatality rates or by making men unfit for service (Smallman-Raynor & Cliff 2004 [a]).

Where infectious diseases could be troublesome on their own, the present project has revealed that cases of reactive arthropathies would have accompanied these diseases. These arthritic conditions were also no trivial matter. ARF, which was noted in nineteenth century military documents, is capable of restricting movement for weeks, causing prolonged heart problems, or even death. Historical literature indicated that SpA could also be quite aggressive; after a military epidemic of dysentery, Dr. Senter stated that the resulting rheumatism was the "most violent" he ever saw (Senter 1846, 105). It is not difficult to imagine that these conditions could have rendered men unfit for service.

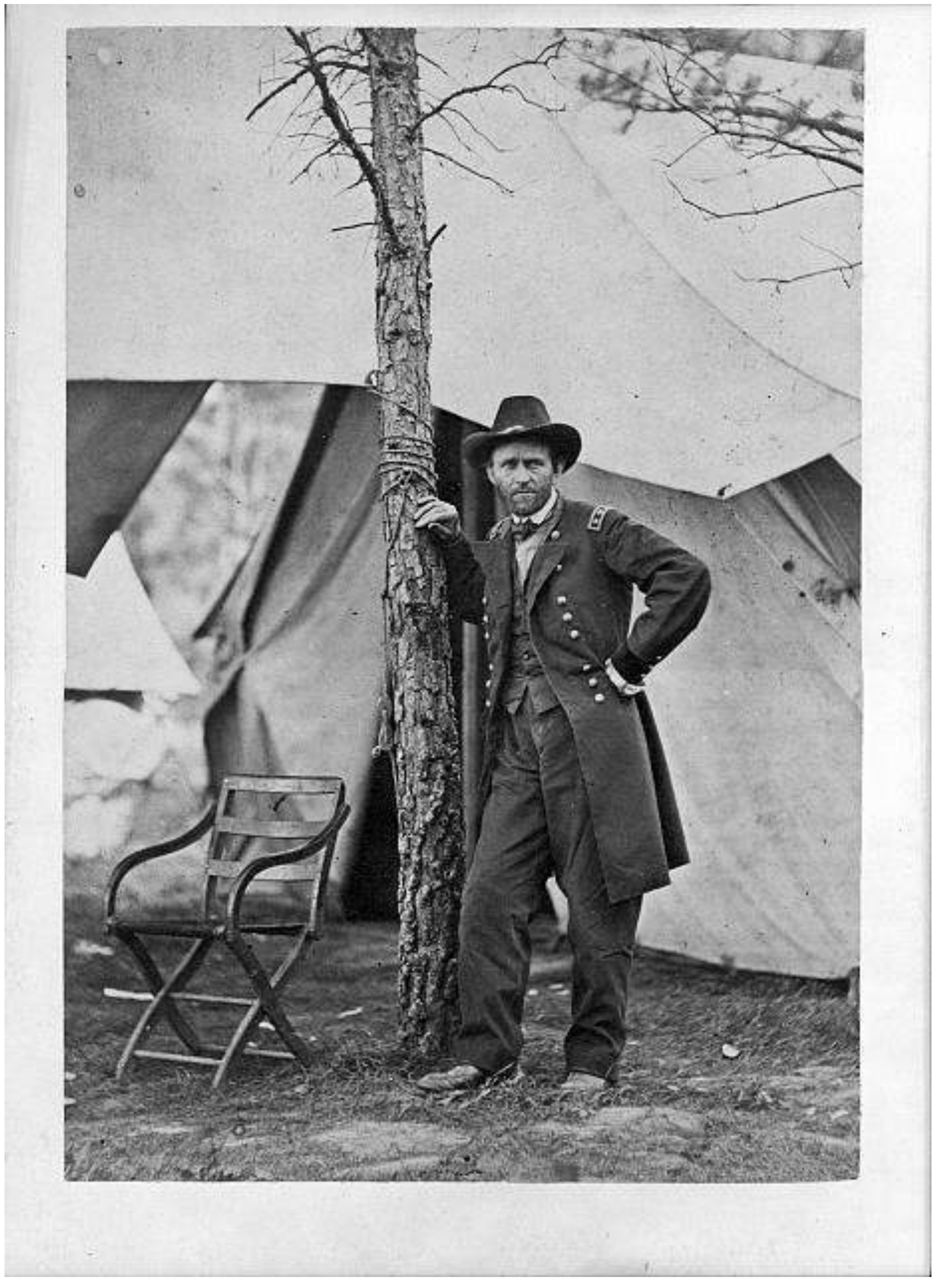
Though a few cases of reactive arthropathy would not have been detrimental, evidence suggests the timing of reactive arthropathies would have been highly inconvenient. The literature investigation discussed in Chapter 7 revealed that both SpA and ARF were capable of epidemic-like behaviour (occurring in greater numbers during or just after major outbreaks of infectious disease). With this behaviour in mind, reactive arthropathies were probably among the medical conditions which forced men out of commission during disease epidemics. In this way, reactive arthropathies would have been among the conditions reducing the fighting strength of armies and, thus, contributing to the disruption of military campaigns.

The matter of ‘whom’ is affected can also be important. General Robert E. Lee’s serves as a perfect example. During his bout of rheumatism (which is quite possibly a case of ARF and/or ReA), Gen. Lee was involved with an active campaign at The Wilderness, but he was so poorly he took, “a brief reconnaissance mission riding in a carriage, rather than on horseback” (Bollet 1991, 1202). After The Wilderness, Gen. Lee continued to recuperate by staying in the Clark family home (Bollet 1991). Any researcher of American Civil War history knows that Gen. Lee’s character is a popular topic of research. To those accustomed to such knowledge, it is quite clear Gen. Lee’s rheumatism of May 1864 must have been exceedingly painful. He was an established horsemen (see **Fig. 71**) who frequently rode into battle, presenting a façade of calm normality, commenting he, “did not wish to have the appearance of being nervous under fire in the presence of men” (Forehand 2007, 136). Gen. Lee was also noted to regularly refuse offers to stay with local homeowners in favour of his tent (Fremantle 2012). For Gen. Lee to ride in a carriage during an active campaign and accept an offer to reside in a local home is not consistent with his normal character, indicating the seriousness of his ailment (Bollet 1991; Fremantle 2012).

Gen. Lee’s rheumatism affected his ability to command his army after the Battle of the Wilderness in 1864. On 23rd May 1864, Gen. Lee split his army, intending to set a trap for opposing General Ulysses S Grant (see **Fig. 72**), but, suffering from his bad bout of rheumatism, he was forced to stay in bed beginning 25th May (Davis 1956). Gen. Lee’s temper worsened and it was noted by Colonel Venable that: “as he [Lee] lay prostrated by his sickness, he would often repeat: ‘We must strike them a blow-we must never let them pass us-we must strike them a blow’” (Bollet 1991, 1202; Davis 1956). Gen. Lee’s ailment grew worse, but he refused to relinquish command fearing defeat as a result of such a decision, but Gen. Lee was hindered by his inability to observe the field of battle for himself (Bollet 1991; Davis 1956). Ultimately, Gen. Grant was able to avoid the trap and Gen. Lee lost his opportunity to strike a decisive "blow" (Bollet 1991; Davis 1956). Though Gen. Lee's condition did not wholly contribute to this failure, it clearly contributed to a series of events which did not favour Confederate success.

Figure 71: Gen. Lee riding his horse Traveller during the American Civil War. Traveller was a favourite of Gen. Lee's and is buried near him at Washington & Lee University in Lexington, VA. Source: Washington & Lee

Figure 72: General Ulysses S Grant at Cold Harbor, Virginia. Source: Anon. 1864, form Library of Congress



Gen. Lee's case of rheumatism is interesting beyond its potential influence following the Battle of the Wilderness, as his heart and rheumatic troubles continued for the rest of his life. For example, in 1869, Gen. Lee had another attack of heart inflammation that was paired with rheumatic pains (Field 2010). According to a close friend, William Preston Johnston, after this attack, Gen. Lee was weary and depressed (Field 2010). He took a trip to stay in the warmer climates of Florida and Georgia for the winter months. Upon his return, Gen. Lee's physical condition had not greatly improved, but he was in a better emotional state and returned to his position at Washington College in September 1870 (Field 2010). He did not continue his duties for long, as Gen. Lee suffered a stroke and died on 12 October 1870 (see **Fig. 73**). Gen. Lee's experience reveals that military reactive arthropathies were not a temporary problem, but conditions potentially associated with prolonged complications for individual combatants.

Figure 73: *Recumbent Lee* by Edward Valentine. This statue sits outside Gen. Lee's tomb at Washington & Lee University in Lexington, VA. Source: Highsmith 1980, from Library of Congress.

11.1.5 SpA and Mortality

Though historical evidence of deadly reactive arthropathies frequently refer to ARF, historical combatants who developed chronic SpA may have had a shorter life expectancy, as modern clinical evidence suggests SpA influences mortality. It was observed in a 2009 National Health and Nutrition Examination Survey that HLA-B27 prevalence was lower in people older than 50 (Walsh *et al.* 2015). To explain this observation, it was suggested that HLA-B27 is connected to mortality. Walsh *et al.* (2015) conducted a study to test this hypothesis, focusing their research on a cohort of U.S. Veterans. They found that HLA-B27 is significantly associated with mortality rate, further suggesting that SpA is a likely contributor to this figure (Walsh *et al.* 2015). This statement is supported by the work of other clinicians.

Kiltz *et al.* (2011) state, "approximately one third of AS patients will develop a severe disease state in which the mortality rate is increased by 50%" (473). A study by Bakland *et al.* (2011) reported that mortality was increased in AS patient (crude mortality rate of 14.5%) with circulatory disease being the leading cause; ReA, PsA, and AS are all associated with heart complications when the disease has a prolonged course, though the strength of the association varies between conditions (Haroon *et al.* 2015 Jamnitski *et al.* 2013; Selmi & Gershwin 2014; Stavropoulos *et al.* 2015). If this pattern differed between past and present, the mortality rate of historical SpA cases would likely be greater, as disease altering treatments were unavailable.

11.1.6 Living with SpA: Was Disability and Discharge Likely?

In conducting the literature investigation, it became apparent that military physicians were highly suspicious of rheumatic complaints, especially when the combatant was qualified for a pension upon dismissal (Gavin 1843). In the nineteenth century, several physicians wrote about fictitious claims of rheumatism, stating rheumatism was among the most likely conditions to be feigned, but also one of the hardest to invalidate (Ballingall 1844; Gavin 1843; Marshall 1839). Gavin (1843) writes that the main means of identifying fictitious cases is to simply watch for inconsistencies and contradictions in their history, noting that: "[if] the impostor is discovered playing at different games, or amusing himself by exercises, which his sufferings if they were real, would not admit of" (227). Gavin further states that some physicians successfully identified imposters through less noble means, for example: "tartar emetic having been introduced into the food of an impostor, and produced sickness and vomiting - alarmed him so much as to cause him forthwith to send for a priest, and speedily to return to his duty" (227).

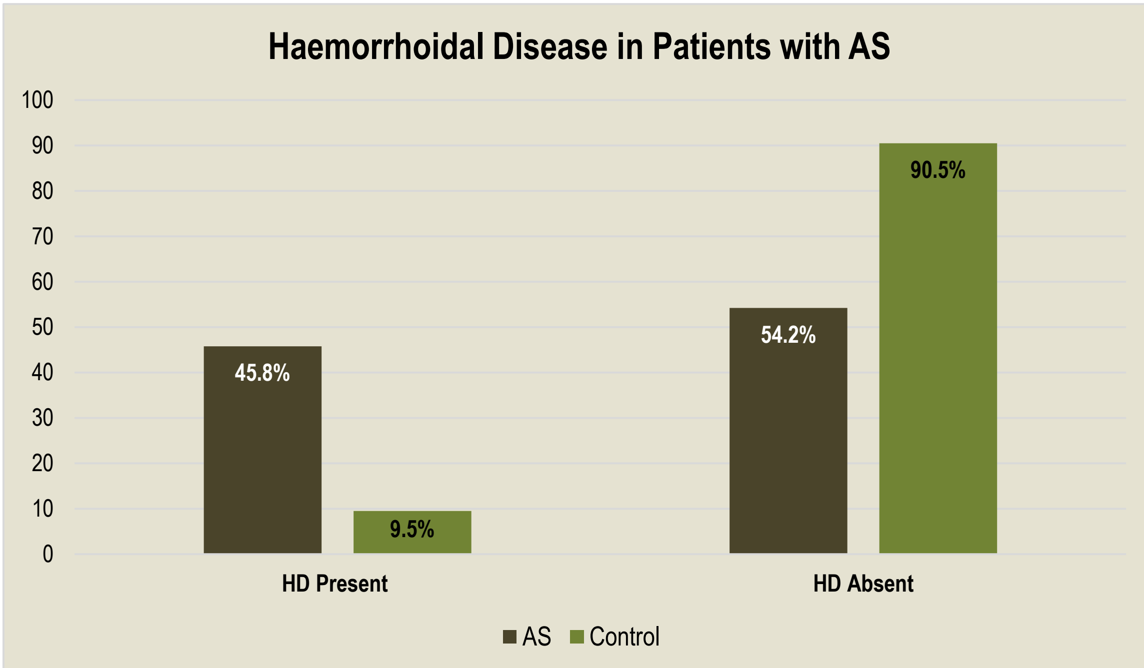
Despite talk of flushing out imposters, Marshall (1839) notes that rheumatism did account for many military discharges annually and acknowledged it was worthy of the action when proven legitimate. As mentioned in Chapter 7, many combatants were dismissed from service for rheumatism in the nineteenth century, especially during The Crimean War and American Civil War. Reactive arthropathies would have been among these rheumatic discharges and likely represented a sizable portion of these cases. This conclusion is based on physician's accounts which describe conditions like ReA as being "common" and statements indicating that many rheumatic discharges were the result of, "fluxes, fevers, or chronic diseases" (Great Britain, Army Medical Service 1858; Woodward 1863; US Surgeon General Office 1879). The case of Pvt. Peter Cluckey also serves as an example of reactive arthropathy leading to discharge, as he was granted honourable medical discharge with a certificate of disability in 1905.

As Marshall (1839) indicated in his work, military medical discharge for reactive arthropathies like SpA would have been justified. Once again, this was evident in the historical literature of Chapter 7, as several accounts mentioned the debilitating nature of these conditions; 'debilitating' meaning it hindered activities of daily living. For example, Dr. Woodward (1836) remarked that with 'pseudo-rheumatism' (ReA), "the patient becomes quite unfit for duty. Sometimes he is confined to his bed, but most frequently he hobbles about with the help of a stick" (319).

Though not pertaining to combatants, Bond's 1872 description of venereal induced reactive arthropathy (ReA) further illustrates the dire consequences of these conditions, as they caused, "constant dull, aching pain, causing complete loss of appetite and sleep, the patient frequently remaining bed-ridden for months, so that the limbs often become permanently contracted unless great skill and care be used in attending to the position of the limbs" (395). "Permanently contracted" indicates the limbs were likely rendered inoperable by the condition, which could certainly cause debility. For example, Pvt. Cluckey's limbs were rendered inoperable by ankylosis, causing him to lose the ability to perform basic functions like walking or feeding himself.

In addition to rapid debility, historical physicians also realized the potential for a chronic course, causing disablements over time. Thomson's 1836 description exemplifies this point. Thomson described the case of a patient who originally presented with the traditional ReA triad of symptoms, but continued to suffer from prolonged bouts of rheumatism; he was described as having four attacks in nine years, with one particular episode lasting nine months. Eventually, this patient could no longer stand upright and experienced troubles in relieving his bowels. This is an interesting point, as Pvt. Cluckey also underwent surgery after experiencing similar bowel issues (NMHM Archives). Modern clinical research indicates that there is a tendency for HLA-B27 positive individuals and SpA patients to have increased bowl troubles, including constipation (see **Table 43**) (Caglayan *et al.* 2015; Sonkar & Singh 2008).

Table 43: this chart displays the incidence of Haemorrhoidal Disease (HD) in AS patients, a condition often caused by constipation. AS patients show a significantly higher incidence of HD (p<0.001). Source: Table adapted from Caglayan *et al.* 2015, 513.



These historical descriptions of chronic pain and debility are further confirmed by modern clinical cases of SpA. Rohekar and Pope (2010) examined work disability in relation to SpA in a cross sectional study of 203 patients and concluded that, "WD [work disability] occurred in 18.5% of SpA, and work productivity (in those working) was reduced by 8.3%" (35). This finding has been reflected in many other studies. Kchir *et al.* (2009) conducted a study of AS in 103 patients and discover that, after a 12 year period of living with the disease, 20% were no longer able to work. Boonen *et al.* (2001) studied work withdrawal in AS patients and discovered it was 1.3 times higher than the general population: "of 529 patients with a paid job before diagnosis of AS, 5% had left the labour force within the first year after the diagnosis, 13% after 5 years, 21% after 10 years, 23% after 15 years, and 31% after 20 years" (1033). Fabreguet *et al.* (2012) studied work instability in relation to SpA and found this was also high; individuals with SpA face consequences of having impeded functional abilities that do not match their work demands, meaning retainment of employment is difficult.

With both modern and historical evidence of extensive SpA debility, military medical discharge must be considered a conceivable outcome for historical combatants. Assuming modern cases of work disability match the pattern of historical cases, some individuals may have been discharged rather quickly. As Boonen *et al.* (2001) stated, 5% of AS cases resulted in individuals leaving work within the first year after diagnosis. Pvt. Cluckey serves as a military example of this course, as his arthropathy caused immediate functional impediments that warranted medical discharge within the first year of disease onset.

As an alternative course, Boonen *et al.* (2001) illustrate that many SpA patients experience a slower progression of debility; for instance, the previously discussed Thomson (1836) example took a slow, but progressive, course. Combatants may have also experienced this pattern of increasing debility over time, but combatants often participate in strenuous activities, which may cause SpA to develop at a more rapid pace. This is suggested based on recent evidence which supports the possibility that inflammatory processes of microtrauma are a, “driving force for new bone formation leading to ankylosis” (Van Mechelen & Lories 2016, 179; Lories & Haroon 2014).

One must also consider the possibility that SpA disability occurred more rapidly and frequently in the past. Present day disability figures exist in spite of modern medical treatment. SpA treatments are far from perfect, but they have proven effective in eliminating or reducing the progress of SpA (Morris & Inman 2012; Poddubnyy 2013; Sieper 2012). Treatments involve the use of nonsteroidal anti-inflammatory drugs, anti-TNF drugs, and physiotherapy (Dagfinrud *et al.* 2005; Morris & Inman 2012; Poddubnyy 2013; Sieper 2012).

Medical treatments encountered during historical research included: bloodletting, aided movement/manipulation of the affected joints (and conversely, the use of splints to prevent movement), use of opiates for pain, bathing in hot water, abstinence from consumption of meat and alcohol, small doses of iodide of potassium, cleansing of the bowels, alkaline remedies (potash, liquor & cream of tartar), and Fowler's Solution (a tonic containing potassium arsenic, see **Fig. 74**) (Brodhurst 1866; Lawrence 1826; Thomson 1836; Woodward 1863). Of these remedies, bathing in hot water and the use of opiates would have aided pain management. Manipulation of joints may have also been beneficial, as modern research indicates physiotherapy and moderate exercise reduce pain, stiffness, and provides marginal improvement to mobility (Dagfinrud *et al.* 2005; Harper & Reveille 2009).

Though some treatments may have helped alleviate the painful symptoms of SpA, other remedies were highly unpleasant (cleansing of the bowels) and potentially harmful (bloodletting and the use of arsenic-laced Fowler's Solution). Furthermore, it is doubtful historical treatments reduced the progression of SpA to any great extent. Pvt. Cluckey serves as a rather apt example of virulent disease progression unhindered by historical medical treatments, which included the use of Fowler's Solution, injection of 0.5% solution of formalin in glycerine, hydrotherapy, sodium salicylate, potassium iodide, and quinine. Without effective medical treatments to reduce the progression of SpA, the prospects for quality of life (and mortality) were probably quite poor for historical cases of chronic SpA.

Evidence suggests there is little reason to doubt the probable occurrence of medical discharge in historical cases of military SpA, so what did this process involve? In the nineteenth century, military medical physicians were responsible for judging the fitness of combatants for service and suggesting discharge when necessary (Marshall 1839). It is easy to imagine that some historical physicians may have been baffled by cases of SpA, as its behaviour is quite abnormal compared to the rheumatic conditions in which they were most accustomed: age related rheumatism (osteoarthritis), gout, and (in the nineteenth century) ARF. Such confusion was indeed evident in military references discussed in Chapter 7; for example, Alfred Stillé (1864) wrote of dysenteric rheumatism, but was confused by its occurrence as the two conditions (dysentery and arthritis) did, “not form any proper union” (349). The early age of onset in SpA may have been further cause for confusion and could have led to suspicions of fraudulency. It is apparent from texts like Marshall (1839), Gavin (1843), and Ballingall (1844) that rheumatic complaints from young individuals (especially if eligible for a pension) were to be considered dishonest until proven otherwise. Though there may have been some pause over younger individuals with rheumatism, true cases of SpA were probably easy to validate due to common visible symptoms such as joint swelling (Szamocki *et al.* 2016).

Figure 74: the photo below shows a bottle of Fowler’s Solution, a tonic containing potassium arsenic. It was commonly used for medicinal purposes from 1786 to 1936. Source: Parascandola 2012.

Having the military physician evaluate and recommend a combatant for medical discharge was only the first step in a rather complicated process. From this point, nineteenth century British combatants would face further evaluations by government officials before *possibly* receiving a pension (Marshall 1839). If a pension was provided, the amount was dependent on matters such as the nature of the condition and their length of service (Marshall 1839). A similar process was used in the U.S. during the nineteenth century (Goler & Rhode 2012). If the combatant was granted medical discharge and provided a pension, they would then return to civilian life with a new social label: disabled veteran.

11.1.7 Life as a Disabled Veteran: What does it Entail?

The historical record pertaining to disabled veterans is fragmentary, which has made them a neglected figure in the narrative of war (Gerber 2012). Of the extant accounts, the narratives commonly detail the horrifically wounded, leaving those discharged for chronic ailments mostly undescribed. Nevertheless, a 'disabled veteran' is any combatant who's self-sufficiency and earning power was hindered by a wound or disease obtained during active service (Gerber 2012). Combatant's discharged for rheumatism fit this description despite their anonymity in historical documentation.

From around the sixteenth century onward, disabled veterans can be viewed as fortunate when compared to disabled civilians. As armies became more professional and increasingly controlled by governmental bodies, the sense of obligation toward disabled veteran increased (Gerber 2012). The disabled veteran was seen as someone who had earned assistance from the government (a reward for good service), but the civilian disabled were left to be cared for through acts of charity (Gerber 2012, 12). Governments were, "eager to contain costs by limiting especially generous assistance only to them [veterans]" (Gerber 2012,13). "Generous" is an overstatement, as pensions were often "meager and limited," but, nonetheless, made "the military profession special, since civilian occupations were still without these features" (Frey 2012, 53).

The first act providing official aid to British disabled veterans came about in the Elizabethan era, offering combatants with hearing disability an annual pension, the amount of which was determined by county officials. From this point, more disabilities were made worthy of a pension, but obtaining that pension was another matter. Laws of the sixteenth and seventeenth century were unstable, as they underwent numerous changes leading to discrepancies between law and actual practice (Frey 2012; Hudson 2012). Such problems included matters of one time or lifetime payments and limits to the number of pensions given (Hudson 2012). There was also emphasis placed on the ability to demonstrate one's disability to justices (Hudson 2007 [b]), which causes one to speculate where disabled veterans with rheumatism fit; did they have a weaker case than someone with very visual disabilities, such as a missing limb? There are accounts of men with "cold," "disease," and demonstration of "inoperative" limbs obtaining pensions, so rheumatic cases would not have been completely ignored. Nevertheless, in a system where pension amount was largely decided based on the opinions of evaluators, one has to wonder if there was bias.

No matter the cause of disability, it is clear that patience and a certain level of craftiness were necessary to obtain a pension in sixteenth and seventeenth century England (Hudson 2007 [b]). In addition to demonstrating their disability, disabled veterans had to provide evidence they had worked for as long as possible post-service (or had at least attempted to do so) and had exhausted all familial support available to them before a pension was granted (Hudson 2007 [b]; Hudson 2012). By all accounts, accumulating the evidence needed to prove this (letters from military officers, surgeons, employers, familial testimony, etc.) must have been a tiresome process, but veterans sought benefits with "zeal" via manipulation and negotiation (Hudson 2007 [b]). When a limited number of pensions were provided, veterans "were careful to watch for and act on pension vacancies, and informed on each other to create such vacancies" (Hudson 2007 [b], 110). When veterans were provided one-time payments, were denied pensions, or had pensions revoked, they relied on "magisterial amnesia" or lobbying to reappear before justices in pursuit of benefits (Hudson 2007 [b]). Veterans also began to ban together and demand change in legislation (Hudson 2007 [b]).

In addition to pensions, pensioner's hospitals were established in the seventeenth century, including the Royal Hospital Chelsea (for retired British soldiers) and the Royal Greenwich Hospital for Seamen (Frey 2012; Hudson 2012). Though not wholly unpleasant, in-pensioners lost certain freedoms that were available to out-pensioners. In-pensioners were often separated from their families, which received very little government support. In-pensioners could also be disciplined for misconduct and had to wear uniforms; Greenwich Hospital uniforms were blue with gold trim (see **Fig. 75**) (Boston *et al.* 2008; Frey 2012; Hudson 2012).

With the eighteenth and nineteenth century, the pension system became more stable. Pensions began to provide for disabled veterans as well as their families (Clark *et al.* 2003). The terms for obtaining a pension also improved, as the fine details (length of service, conditions that apply, process of evaluation, etc.) became more regulated (Clark *et al.* 2003; Marshall 1839).

Figure 75: this illustration shows a pensioner pointing across the river to the Royal Greenwich Hospital for Seamen. He is wearing the typical navy blue and gold uniform of in-pensioners. Source: Carpenter n.d., from Royal Museums Greenwich.

Though the current project has primarily focused on U.K. skeletal material, U.S. medical literature proved useful and Pvt. Peter Cluckey served in the U.S. Army. Did their experience differ from that of disabled British veterans? In many ways, much remained the same. Pensions were provided to encourage good service and obtaining a pension involved a bureaucratic process of evaluations and judgments (Goler & Rhode 2012). The first disabled veteran benefits in the U.S. were developed by Pilgrims during the seventeenth century. The Plymouth colony was at war with a local Native American tribe and, in 1636, they passed a law stating injured soldiers would be provided for by the colony (U.S. Department of Veteran Affairs [VA] 2015). During the American Revolutionary War, the Continental Congress promised pensions to disabled soldiers as a means of encouraging enlistment into the Continental Army (U.S. Department of VA 2015). The creation of domiciliary soldiers' homes came about in 1811, which were similar to the pensioner's hospitals in the U.K. (U.S. Department of VA 2015).

Like the early U.K. system, the process of obtaining a fair pension could be difficult. In the nineteenth century, U.S. disabled veterans were frequently forced to make multiple appeals to increase their pensions. This was no easy task, as the U.S. system was purposefully designed to provide *partial* income replacement; the government saw this as a means of encouraging disabled veterans to reintegrate into civilian life (Goler & Rhode 2012). Disabled veterans living near the capital of Washington D.C. were fortunate, as the federal government frequently provided them with personalised employment. For example, some were sent to work at the newly established Army Medical Museum, now the National Museum of Health and Medicine (Goler & Rhode 2012, 174). Though the capital provided work for disabled veterans, many antebellum veterans outside of D.C. found it exceedingly difficult to find work and re-establish themselves in civilian life.

Finding work was especially difficult for the disabled Confederate veterans. At the end of the Civil War, the southern plantation economy had collapsed and major cities were physically destroyed (see **Fig. 76**), meaning southerners returned home to an environment where everyone needed work, disabled or not (McClurken 2009). In this demanding job market, disability would have further limited the veteran's employability, as strenuous work was often unfeasible. Wealthier Confederate veterans with education took positions as clerks or other forms of 'desk work,' but less educated disabled veterans were often forced to become beggars (McClurken 2009; Rosenburg 2012). As Confederate veterans, they were not eligible for federal funding and had to rely on the charity of private relief organizations and state governments, which were themselves starting from scratch post-Civil War (McClurken 2009; Rosenburg 2012). It was not until 1916 that the federal government passed a bill to provide Confederate soldiers' homes (Rosenburg 2012).

Figure 76: photo of Richmond, Virginia (Confederate Capitol) at the end of the American Civil War. Source: Russell 1865, Anon 1865, from the Library of Congress.

Early public imaging of soldier's homes displayed themselves as housing the greatly wounded. In reality, "most inmates were fully ambulatory. Yet they suffered from such chronic illnesses as arthritis or rheumatism, disease of the eye, exhaustion, or other painful conditions that inhibited their ability to live independently" (Marten 2012, 277). This false imagery is a direct demonstration of purposeful admittance of less 'glorified' veterans from history, which included those disabled by rheumatism (Nielsen 2012).

It was not uncommon for men to spend decades living in a soldiers' home, which (like the pensioner's hospitals of the U.K.) were able to regulate and discipline the men living within; punishments ranged from revoking of privileges to permanent eviction (Marten 2012). In the late nineteenth and early twentieth century, Elizabeth Corbett, who grew up in a soldiers' home in Milwaukee, described the nature of the inhabitants, comparing them "to Dickens's characters, in womb…'eccentricity ran riot.' They rarely bathed and frequently swore...their offbeat hobbies: collecting burned matches, manufacturing and wearing counterfeit medals, 'curing' deadly diseases, and proposing to women visitors" (Marten 2012, 278). Corbett also noted that drinking was common (Marten 2012).

Addiction, particularly to alcohol, was very common in soldiers' homes and lead to numerous problems (Marten 2011; Marten 2012). Men who left the house to do their drinking became the targets of robbery, but alcoholism also produced problems of discipline and health among the home's occupants (Marten 2011; Marten 2012). Many turned to the bottle to get over the daily monotony of looking at the same people and scenery day after day, others to escape the traumas of war and pain from old wounds/afflictions (Marten 2012).

It is here that Pvt. Peter Cluckey's case becomes the most poignant. Being highly immobilized by his condition, he lived in the U.S. Soldier's Home in Washington D.C. (see **Fig. 77**) for fifteen years. In spite of his extreme physical debility, Pvt. Cluckey became addicted to opiates originally prescribed for pain; as pointed out by

Gilmore and Stecher 1955, "his capacity for self entertainment and enjoyment of life was so limited that any attendant might easily have been tempted to accede to his wishes" (438). Though Pvt. Cluckey's autopsy did not reveal anything that could be directly attributed to his cause of death, it was concluded that opiates and poor nutrition were likely contributors to his death in 1925 (Gilmore & Stecher 1955). During life, it appears Pvt. Cluckey lived a very solitary existence. In preparation for their 1955 publication, Gilmore and Srecher inquired with Pvt. Cluckey's U.S. Army officers in hopes of discovering more about him, but found that the officers were completely unaware of any details regarding his friends, personality, or family relations (NMHM Archives).

Figure 77: this photo shows the main façade of the U.S. Soldiers' Home in Washington, D.C. Pvt. Cluckey lived in the home for 15 years. Source: Library of Congress, n.d.

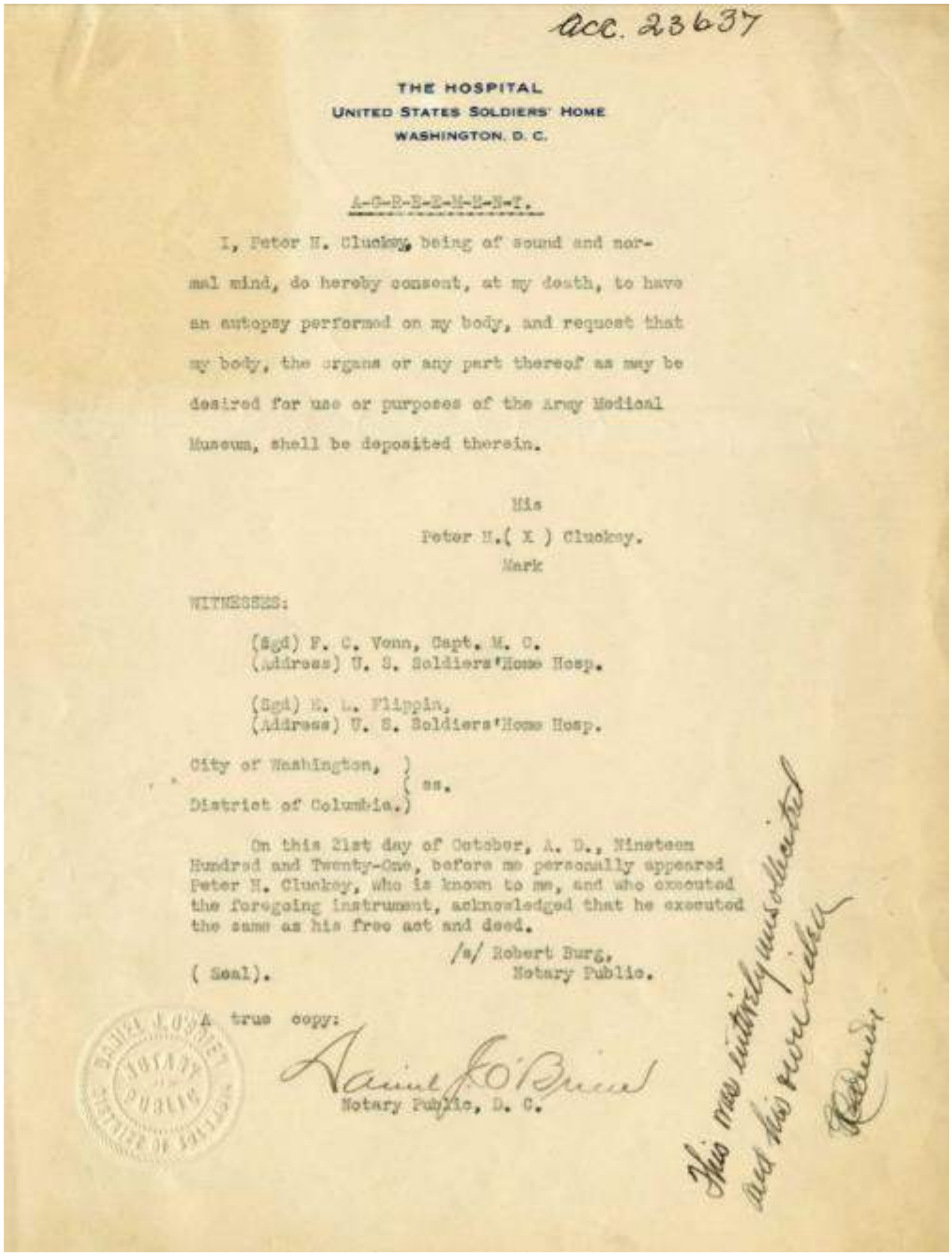
The NMHM records contain a statement about an interview with Henry Molock, an elderly man who lived at the U.S. Soldiers' Home and knew Pvt. Cluckey. This interview was conducted in 1954 by a Robert Walker Davis (background unknown), likely upon request by Gilmore and Stecher when seeking background information about Pvt. Cluckey for their 1955 publication. Mr. Molock was in his 60's at the time and Davis noted that his memory was suspect. Molock claimed that Pvt. Cluckey was a quiet, simple man, who had family, though Molock could never recall seeing them at the U.S. Soldier's Home (Davis 1954).

Molock also made a surprising statement:

> Cluckey, according to Molock, sold his body to the Army Medical Museum [NMHM] for fifty dollars, and Molock suspected that Cluckey also sold his body to other museums or institutions… Peter Cluckey made frequent trips to the Army Medical Museum, and quite often would borrow money from Molock to meet his expenses. But on his return he invariably had more money than when he left, and was able to repay what he owed. Moloch believes that Cluckey received money from "some lady at the Museum" on these trips (Davis 1954).

The suggestion that Pvt. Cluckey sold his remains to the museum is intriguing. Financial troubles were not uncommon among disabled veterans living in soldiers' homes, so the idea that he sold his body to interested museum curators is not completely outlandish. Nevertheless, Gilmore and Stecher state they did not find any evidence to support this claim. Indeed, Pvt. Cluckey's 1921 Will has a hand written note (with signature by G. P. Callender) stating his donation, "was entirely un-solicited and his own idea" (see **Fig. 78**) (NMHM Archaive); G.P. Callender was the Army Major who performed Pvt. Cluckey's autopsy. A further statement was made by Pvt. Cluckey's sister, Rose Rider, claiming he had verbally expressed his wishes for his body to be given to the museum for autopsy and scientific study as the museum saw fit (see **Fig. 79**) (NMHM Archives). With no physical documentation to suggest otherwise, Pvt. Cluckey's decision to donation his remains to the museum appears to have been motivated out of a desire for answers and to further scientific knowledge, but this could be true even if he did sell his remains.

Figure 78: The document below is a copy of Pvt. Cluckey's 1921 Will. One can see Major Callender's hand written note and signature along the lower right margin (the note states, "this was entirely un-solicited and his own idea"). There is no indication as to when this note was added. The following page shows a later version from 1924/1925. Source: NMHM Archives, acc. 23637 & Ancestry 2017.



acc. 23637

THE HOSPITAL
UNITED STATES SOLDIERS' HOME
WASHINGTON, D. C.

A-G-R-E-E-M-E-N-T.

I, Peter H. Cluckey, being of sound and normal mind, do hereby consent, at my death, to have an autopsy performed on my body, and request that my body, the organs or any part thereof as may be desired for use or purposes of the Army Medical Museum, shall be deposited therein.

His
Peter H.(X) Cluckey.
Mark

WITNESSES:

(Sgd) F. C. Venn, Capt. M. C.
(Address) U. S. Soldiers'Home Hosp.

(Sgd) E. L. Flippin,
(Address) U. S. Soldiers'Home Hosp.

City of Washington,)
) ss.
District of Columbia.)

On this 21st day of October, A. D., Nineteen Hundred and Twenty-One, before me personally appeared Peter H. Cluckey, who is known to me, and who executed the foregoing instrument, acknowledged that he executed the same as his free act and deed.

/s/ Robert Burg,
Notary Public.

(Seal).

A true copy:

Daniel J. O'Brien
Notary Public, D. C.

This was entirely unsolicited and his own idea
Callender

I, Peter H. Cluckey of Washington, D. C., being of sound mind, memory and understandi ng, do make this my last will and testament hereby revoking and making void all former wills at anytime heretofore made by me.

FILED
OCT -1 19
James Tanner
REGISTER OF WILLS, D. C.
Clerk of Probate Court

Cluckey, Peter H.

Item #1. I direct that after my decease that my body be given to the Curator Army Medical Museum of Washington, D. C.

Item #2. I give, devise and bequeath to my beloved brother Frank Cluckey of Detroit, Mich.and to my beloved sisters, Marie Hayes and Rose Rider, both of Toledo, Ohio. share and share alike all money that I may have at the time of my death deposited in the Soldiers Home Tresury of Washington, D. C. and all other property real, personal or mixed of every nature and description of which I am now possessed or may hereafter acquire, prior to my death , to have and to hold the same their heirs and assigns forever.

I nominate and appoint my beloved brother Frank. Cluckey, of 275 Holden, Ave. Detroit, Mich.my sole executor of this my last will and testament without bond.

in witness whereof I, peter.H.Cluckey, the testator, have to this my last will and teatament set my hand and seal this 9th day of June A.D. 1916.

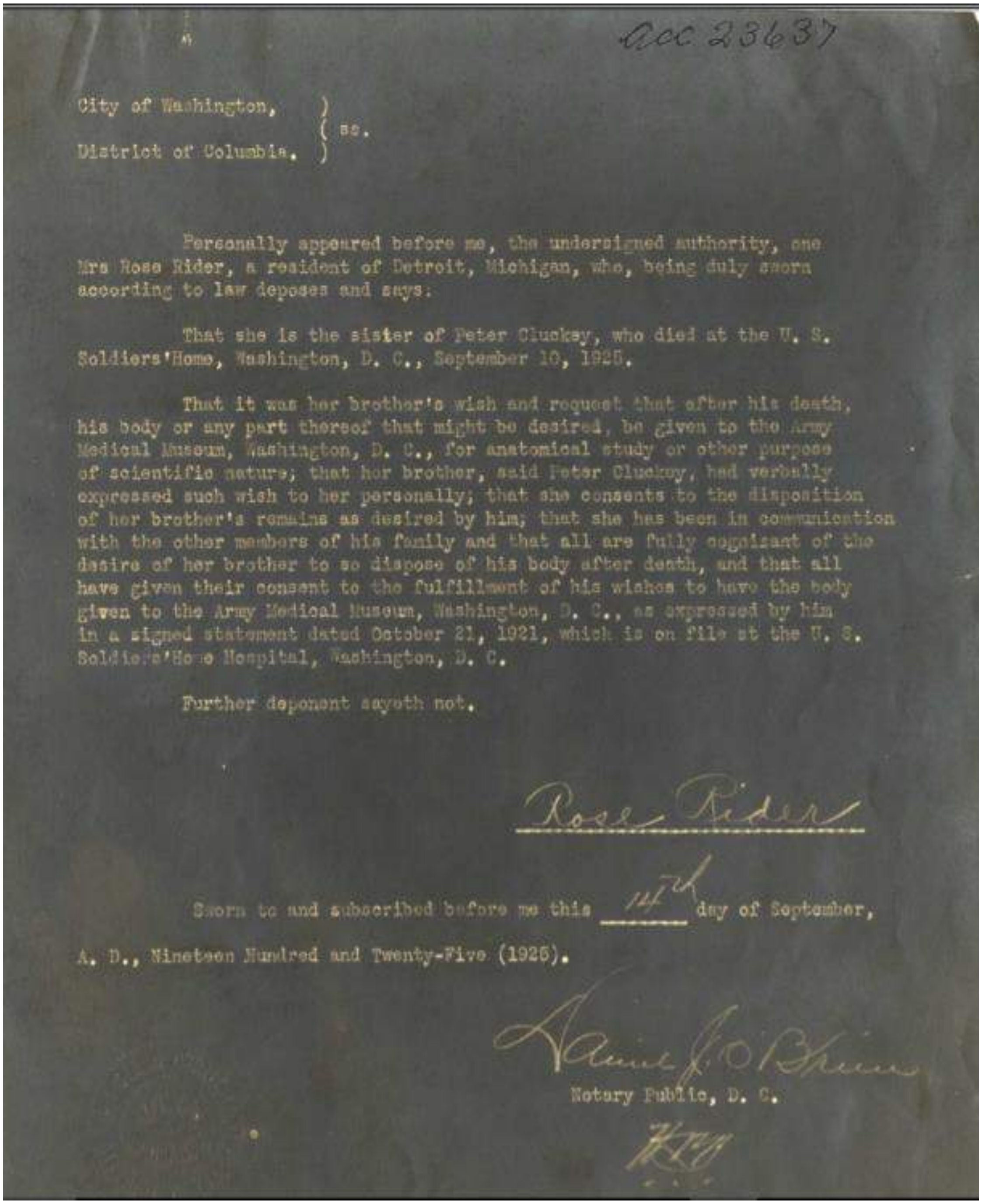
His
Peter H. × Cluckey
mark

Signed, sealed, published and declared by Peter H. Cluckey, the aboved named testator, as and for his last will and Testament, in our presence, who at his request, and in his presence, and in the presence of each other, have hereunto subscribed our names as attesting witnesses.

J. M. Gissinger
address U. S. Soldiers Home, D.C.

A. R. Tuttle Capt U.S.A.
address U. S. Soldiers Home, D.C.

Figure 79: The document below is a letter stating that Pvt. Cluckey's sister (Rose Rider) was knowledgeable of his wishes for autopsy and bodily donation to the Army Medical Museum. Source: NMHM Archives, acc. 23637.



acc 23637

City of Washington,)
(ss.
District of Columbia.)

Personally appeared before me, the undersigned authority, one Mrs Rose Rider, a resident of Detroit, Michigan, who, being duly sworn according to law deposes and says:

That she is the sister of Peter Cluckey, who died at the U. S. Soldiers'Home, Washington, D. C., September 10, 1925.

That it was her brother's wish and request that after his death, his body or any part thereof that might be desired, be given to the Army Medical Museum, Washington, D. C., for anatomical study or other purpose of scientific nature; that her brother, said Peter Cluckey, had verbally expressed such wish to her personally; that she consents to the disposition of her brother's remains as desired by him; that she has been in communication with the other members of his family and that all are fully cognizant of the desire of her brother to so dispose of his body after death, and that all have given their consent to the fulfillment of his wishes to have the body given to the Army Medical Museum, Washington, D. C., as expressed by him in a signed statement dated October 21, 1921, which is on file at the U. S. Soldiers'Home Hospital, Washington, D. C.

Further deponent sayeth not.

Rose Rider

Sworn to and subscribed before me this 14th day of September,

A. D., Nineteen Hundred and Twenty-Five (1925).

Daniel J. O'Brien
Notary Public, D. C.

Ultimately, life as a disabled veteran presented many challenges to historical combatants. Though benefits were provided to disabled veterans from the sixteenth century, obtaining them was no easy process. Furthermore, early systems were not applied consistently, as laws were often open to interpretation. To acquire benefits, veterans had to display their disability to justices for evaluation, sometimes on multiple occasions, as appeal was often necessary to obtain adequate compensation.

Once dismissed from service, disabled veterans had to reintegrate into civilian life. Finding employment was often necessary, but not easily achieved. Unemployment or lack of familial support resulted in homelessness or confinement to a sterile, government-run living facility (pensioner's hospitals or soldiers' homes). Disabled veterans confined to these facilities were prone to drug abuse (primarily alcohol and opiates).

Outside of military medical documents noting the number of rheumatic discharges, accounts of rheumatically disabled veterans are largely absent from history. In some instances, this exclusion appears to have been deliberate, as disabled veterans with ghastly war wounds were favoured for public presentation (Nielsen 2012). Though amputated limbs and other major disfigurements are the iconic imagery representing 'disabled veterans,' the historical and skeletal investigations of this research leave little doubt that historical disabled veterans included individuals afflicted by reactive arthropathies.

11.1.8 Summary

Section 11.1 discussed the secondary research questions produced after confirming reactive arthropathies were an occupational hazard to historical combatants. Some of these questions have addressed issues directly related to bioarcheology, while others have focused on interpreting how reactive arthropathies may have influenced the lives of past combatants. Interpretations about the experience of historical combatants with SpA were made using historical references, modern clinical cases of SpA, and the case study of Pvt. Cluckey. All lines of inquiry suggest that reactive arthropathies were capable of greatly altering the lives of the afflicted.

In researching modern cases of SpA debility and work disability to aid interpretation of historical cases of military SpA, one final question was raised. As the present project has illustrated, reactive arthropathies were an occupation hazard to past combatants due to their increased exposure and susceptibility to arthritogenic bacteria. As pointed out in Chapter 2, issues with weakened immune systems and infectious diseases associated with overcrowding and poor sanitation remain a problem for modern combatants, albeit a less deadly problem.

With infectious diseases remaining a military problem in the present, is it incorrect to think of reactive arthropathies as a problem specific to historical combatants? Could reactive arthropathies also be a problem for modern military combatants? The following section explores this idea with the intent of making further comparisons between past and present cases of military SpA.

11.2 Reactive Arthropathy as an Occupational Hazard to Modern Combatants

To explore whether reactive arthropathies are a persisting problem to military combatants, an examination of 'modern' (post 1916) clinical research was conducted, focusing on ARF and SpA. ARF is a relatively rare condition in developed societies with clean sanitation and access to antibiotic treatments, but ARF remains the leading cause of cardiovascular death in developing countries (Chakravarty 2014, 893). Though ARF is not a major concern to most of the developed world, some groups are considered exceptions. For example, streptococcal infections favour crowded environments and are commonly noted in modern military personnel (Chakravarty 2014). In the 1980's there were numerous outbreaks of Streptococcal infections (attributed to a particular outbreaks of a mucoid strains of S. pyogenes, type *emm*18.1) which lead to a dramatic increase in the number of ARF cases occurring in all branches of the U.S. Military (Esposito *et al.* 2015; Gray *et al.* 1999; Gunzenhauser *et al.* 1995; Kaplan 1989; Wong & Yuen 2012). Though this clearly illustrated the potential for ARF to occur in modern military combatants, a large outbreak of ARF has not occurred since. Nevertheless, military personnel are still considered a high-risk group and several articles warn that precautionary measures should be taken to ensure the continued prevention of ARF (Chakravarty 2014; Gerber *et al.* 2009; Peterson 2013).

ReA has also made several military appearances since 1916. In 1945, an article published in *The Journal of the American Medical Association* reported 25 cases of 'Reiter's Syndrome' in U.S. military personnel (Hollander *et al.* 1945). It was noted that many of the cases did not test positive for gonorrhoea, but some men reported having diarrhoea in the weeks preceding their arthritic symptoms (Hollander *et al.* 1945). In 1953, another article was published in the *Annals of Internal Medicine* that reported 23 cases of 'Reiter's Syndrome' at the Minneapolis Veterans Administration Hospital (Hall & Finegold 1953).

In 1966, there was a military 'outbreak' of ReA. Noer (1966) states that 602 men on a U.S. Navy vessel developed symptoms of bacillary dysentery from a *Shigellosis* outbreak. The dysenteric outbreak resulted from a celebration of the ship's anniversary. Two cooks with dysentery (described as being mildly ill) concealed their illness and continued to work in food preparation in fear of being hospitalized; being their last night in port, they did not want to lose their privileges ashore (Nore 1966). Two weeks following the outbreak of dysentery, 9 cases of 'Reiter's Syndrome' were reported and attributed to the preceding dysenteric outbreak (Nore 1966). Of the 9 observed cases, 3 resulted in damaging long-term effects; 2 sailors were invalided out of the navy and another returned to duty but continued to suffer from residual effects.

More recent reports of SpA in military individuals or groups have also been noted. In 2005, Sulit and Clarke reported on a case of PsA developing in a U.S Marine. In 2014, Eslami *et al.* described a case of AS in a military aviator. In 2012, Martin *et al.* published an article about a military outbreak of bacillary dysentery (*Shigella)* that resulted in 2 U.S. Marines developing ReA. The frequent referral to modern military cases of SpA suggests that its affinity for military groups has been persistent and remains an occupational hazard. Further investigation was conducted to evaluate the awareness of modern military SpA.

11.2.1 Epidemiological Research into Military SpA

It appears a handful of researchers are aware of the affinity between SpA and military personnel. Military outbreaks of infectious disease remain common, especially gastrointestinal infections (Curry *et al.* 2010; Martin *et al.* 2012; Riddle *et al.* 2008). For this reason, Riddle *et al.* (2008), Porter *et al.* (2011), and Martin *et al.* (2012) have all suggested that ReA is a potential consequence of military outbreaks of dysenteric diseases. The bioarchaeological data of this research provides credit to their suspicions, as cases with the ReA pattern of expression were identified in military skeletal assemblages. Though this adds a mark in favour of their argument, modern epidemiological research is ultimately needed to validate their claims. This has only been attempted on a few occasions.

In 2010, Curry *et al.* conducted a matched case-control study of ReA following infectious gastroenteritis in U.S. military personnel. They identified 506 cases of ReA between 1999 and 2007. They also looked at nonspecific arthritis after reports of infectious gastroenteritis and identified 16,365 cases for the same time period. Their calculated incidence for ReA was 4.1 (95% CI: 3.7, 4.5) per 100,000 and their nonspecific incidence was 132.0 (95% CI, 130.0-134.0) per 100,000 (Curry *et al.* 2010). Ultimately, they conclude that, "reactive arthritis may be more common in military populations than previously described. The burden of ReA and strong association with antecedent IGE [infectious gastroenteritis] warrants continued IGE prevention efforts" (Curry *et al.* 2010, 1).

The findings of Curry *et al.* (2010) were further supported by DeYoung *et al.* (2013). They conducted a study to assess the association between rheumatological diagnoses and self-reported cases of diarrhoea and vomiting in the U.S. Military after deployment to Iraq or Afghanistan. They found that the odds ratio (2.67, 95% CI 1.11 - 6.47) indicated a threefold increased risk for rheumatological conditions after being exposed to diarrhoeal diseases during deployment. They concluded that: "rheumatological conditions, even those classified as 'non-specific,' are significantly associated with prior severe diarrhoea in previously deployed military personnel, potentially indicating ReA and need for preventive measures to reduce diarrhoeagenic bacterial exposures in military personnel" (DeYoung *et al.* 2013, 1). Their findings, along with Curry *et al.* (2010), suggest there is a legitimate modern military affinity for reactive arthropathies. Though their findings suggest an association exists, epidemiology is a field largely reliant on observational study, which frequently requires multiple replications before results are considered with any certainly (Peng 2016). For this reasons, it is suspected further epidemiological research is needed. Though the current project has researched the historical (rather than modern) military affinity for SpA, it provides further credence to the findings of Curry *et al.* (2010) and DeYoung *et al.* (2013) and illustrates that this is a longstanding issue within military groups.

Less epidemiological research appears to have been conducted in relation to the British Armed Services. Bennett *et al.* (2013) state that, "the Armed Services have many patients with inflammatory rheumatological conditions with approximately 150–200 new cases being diagnosed each year and the predominant inflammatory conditions are the SpAs" (8). They also made an estimate of the current number of SpA cases in the Armed Services: 1,500 current patients. This figure was calculated from the normal population's prevalence (1%), so Bennett *et al.* (2013) state that the true figure is probably higher due to the nature and demographics of the Armed Services. No reports on incidence or odds ratios have been uncovered in relation to British Armed Services.

11.2.2 Efforts in Prevention of Military SpA

People respond differently to SpA treatments, resulting in differing durations of disease expression (Kavanaugh & McHugh 2007; Keat & Hamdulay 2007). For example, traditional treatments for ReA result in about 50% of cases recovering in a 6 month period, but 4% - 19% will experience a course lasting longer than a year (Morris & Inman 2012, 392). No matter the condition's ultimate duration, while in an active state, SpA can hinder daily functions leading to temporary (and sometimes permanent) suspension from military duties. This recently occurred in the case of AS reported in a military aviator:

> Before the onset of disease [AS], the patient led an active, healthy lifestyle, exercising regularly 3 to 5 times a week. It also became more difficult to exercise for prolonged periods; perform high- impact exercises (eg, jogging); and play sports because of pain, stiffness, and discomfort. Once the symptoms began, he was unable to continue his active lifestyle and soon stopped exercising altogether (Eslami *et al*. 2014, 115).

For this case, the aviator favourably responded to treatments and was able to continue his career as a military aviator, but it took 18 months of treatment before he was granted a waiver (Eslami *et al.* 2014). Some continue to have residual effects years after initial diagnosis (see **Table 44**). Any condition this debilitating and lasting over a *minimum* course of months should be a concern for military commanders.

The best means of preventing the occurrence of SpA in military populations is to reduce the occurrence of their infectious triggers. For instance, outbreaks of diarrhoeal diseases are common among modern combatants and have become a subject of great concern to some researchers (Curry *et al.* 2010; Porter *et al.* 2011; Riddle *et al.* 2008). In 2008, some members of the U.S. Department of Defense were objectionable to the use of government research funds for diarrhoeal disease prevention; since diarrhoeal diseases are rarely fatal in modern combatants, it raised the question 'how much is an ounce of prevention really worth?' (Riddle *et al.* 2008). Riddle *et al.* (2008) and Porter *et al.* (2011) have both countered this argument, stating that funding for diarrhoeal preventative research is not a simple matter of preventing diarrhoeal diseases. Instead, it is about preventing the conditions that follow these infections, including inflammatory bowel disease, Guillian Barre syndrome, and ReA, which are costly and difficult to manage (review **Table 44**): "these sequelae can result in severe morbidity, as well as increased healthcare utilization costs" (Riddle *et al.* 2008, 2498). Publications like that of Riddle *et al.* (2008) resulted in a diarrhoeal disease research program funded by the U.S. Department of Defense (Connor & Gutierrez 2013).

Table 44: this table was presented in Curry *et al.* (2010) and illustrates that the, "duration of ReA symptoms was prolonged after initial diagnosis. Among specific ReA cases that remained on active duty, 35.5% (89/251) were still receiving ReA-related medical care for a minimum of 2 years after initial presentation" (4). Prolonged treatment implies there would be increased health costs for the U.S. Military as a result of ReA cases. Source: Curry et al. 2010, 6.

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Though U.S. clinicians have successfully made their argument, the U.K. has faced the same objections more recently. Connor and Gutierrez (2013) detailed troubles in gaining funding, stating: "in the Defence Medical Services we have a fledgling Military Enteric Disease Group, with plentiful support yet little funding and comprising a few well- intentioned personnel" (136). They too mention the importance of such programs in preventing the occurrence of conditions like ReA. The current author could find no evidence that this argument changed the status of their funding.

11.2.3 Modern Veterans Living with SpA: A Nightmare

Prevention is not the only matter that needs to be addressed. Considering the affinity between military combatants and SpA, it is important that military organisations have an appropriate response for cases of SpA. Though policies for treatment of military SpA are in place, problems were identified. For example, the British Armed Services specify how cases of SpA should be addressed in the Joint Medical Employment Standard (JMES), but there is some debate over present standards. Combatants with inflammatory arthropathies treated with anti-TNF drugs were once universally counted as medically non-deployable, but this has begun to loosen (Bennett *et al.* 2013). Bennett *et al.* (2013) state that patients who have a positive response to anti-TNF treatments should be allowed to maintain their deployable status with appropriate limitations. As people react differently to treatments, a universal standard is difficult to make, so questions now pertain to assessment and fair judgment of exceptions and limitations (Bennett *et al.* 2013).

Problems in U.S. policies were identified in relation to cases necessitating military retirement. These issues were made evident by Lieutenant Colonel Michael Parker of the United States Army. After being diagnosed with SpA, he spent five years struggling to obtain an appropriate rating for his disability through Veteran Affairs (VA), a process that ultimately took numerous evaluations, appraisals, and appeals to achieve. He began to write a blog post about his experience, which clearly illustrates the challenges; for example, one of Lt. Col. Parker's blogs reveals that his AS was not even considered in his initial VA rating:

> My initial 60% VA rating came to me in December 2006, just a couple of months after I retired. They did not provide any rating for my spondyloarthropathy in this initial rating despite the fact it was the first condition listed and the reason I had to undergo medical and physical evaluation boards by the Army. It was by far my most documented medical condition yet the initial VA rating decision didn't even discuss the condition (Parker 2004).

Lt. Col. Parker's posts got the attention of the *Military Times* newspaper in 2006. The newspaper conducted an investigation that uncovered, "systemic problems in how injured troops from each branch of the service were receiving different disability retirement ratings for the same injuries or were being told they didn't qualify for benefits because their condition pre-existed their military service" (Spondylitis Association of America [SAA] 2009).

In order to get disability retirement from the U.S. military, one must go through a very involved process comprised of assessment and review by several medical and physical evaluation boards. Ultimately, the result of this process is a percentage rating for disability (SAA 2009). For a rating of 30% or higher, the individual gets disability retirement with lifelong benefits (see **Table 45**). A rating under 30% can be denied disability retirement and given a one-time severance payment. If the evaluation board rules that the condition pre-existed military service, all potential benefits can be completely denied. The problem in obtaining an appropriate SpA rating is the result of two problems.

Table 45: the information in the table below is from the VA webpage. As one can see from the table, the percentage rating given for disability can greatly affect the benefits provided. The rates given are monthly. Source: U.S. Department of Veteran Affairs 2016.

U.S. Military VA Rating & Benefits				
Background	Percentage Rating			
	30%	50%	70%	90%
Veteran Alone	$407.75	$836.13	$1,334.71	$1,743.48
Veteran + Spouse	$455.75	$917.13	$1,447.71	$1,888.48
Veteran + Spouse + Child	$491.75	$976.13	$1,530.71	$1,995.48

The first problem is quite basic, evaluators are unfamiliar with SpA conditions. This leads to the second problem. Lack of awareness of the progressive and debilitating nature of SpA leads evaluators to use the wrong criteria when rating the condition. By policy, SpA conditions should be rated with other inflammatory arthropathies such as RA, which "are well suited for these conditions, as they cover both active disease process and the impact of residual damage when the disease is not active" (Spondylitis Association of America 2009). Nevertheless, without proper knowledge of the condition, SpA often gets evaluated as general spondylitis, which is rated based on the amount of change it causes to the spine without consideration of other disease features, leading to a lower percentage rating (Spondylitis Association of America 2009). Lt. Col. Parker has become an advocate for such cases and has helped to bring about change in the system, as in 2008 the U.S. House of Representatives added information into a defense authorization bill in order to "help expedite soldiers' claims and bring some consistency to how the VA and DOD [Department of Defense] rate similar medical conditions" (Spondylitis Association of America 2009).

In spite of some progress, these issues have continued within the U.S. military. In 2012, NBC News published an article about Daniel Kinberg, a U.S. Marine. Not long after a deployment to Afghanistan, he was diagnosed with AS, which caused his deployable status to be indefinitely retracted; not long after, he was also diagnosed with Post-Traumatic Stress Disorder (PTSD). Kinberg attempted to retire with disability and medical benefits, but, like so many others, found the road difficult, "at first, the military denied him a retirement with full benefits, arguing that the PTSD and ankylosing spondylitis pre-existed his service" (Ruiz & Miller 2012). Lt. Col. Parker aided Kinberg with his case and was able to successfully argue that his AS was not pre-existing; however, the process of getting an appropriate rating was a long and stressful journey, one that Kinberg and others have described as a "nightmare" (Ruiz & Miller 2012). Lt. Col. Parker still receives questions on his blog from veterans seeking his advice in relation to VA SpA ratings and other medical conditions, clearly indicating that policy issue persists (Physical Evaluation Board Forum 2016).

11.3 The Crossroad between Past & Present: Similar or Different?

Combatants, past and present, were affected by the same bacterial infections, meaning SpA is a historical and current military occupational hazard. The similarities between modern and historical cases of military SpA stretch well beyond this point (see **Table 46**). Historical accounts and the case of Pvt. Cluckey reveal that military SpA could be debilitating and cause for medical discharge from service. Modern cases reveal this is still a possible outcome, though modern combatants have the advantage of effective treatment options. Disease altering therapies mean modern combatants can often return to duty after several months of treatment, but prolonged affects have been reported, leading to retirement or changes to deployment status. Though modern medical treatments for SpA are far from perfect, modern combatants likely experience more favourable outcomes than their historical counterparts.

Historical combatants discharged from service faced several challenges. For example, numerous evaluations and judgments had to be faced before *potentially* receiving a pension from government offices. When pensions were obtained, appeals frequently had to be made, as the amount provided was not the equivalent of a living wage. After evaluating modern cases of military SpA, like that of Lt. Col. Parker and Daniel Kinberg, similar challenges remain apparent. Failure to understand the nature of SpA leads to inaccurate disability ratings and miscalculation of benefits. To rectify these errors, modern combatants must make an appeal and again enter the evaluation process. Such matters make it apparent that parallels exist between past and present. The topic of military SpA is a novel means of bioarchaeologically and historically exploring the impact of military infectious diseases, but it is also a topic of modern relevance.

Table 46: this table compares modern and historical cases of military SpA. Source: created by the author.

Comparison of Modern & Historical Military SpA		
Feature	**Historical Combatants**	**Modern Combatants**
Gastrointestinal Diseases Common	Yes	Yes (Curry *et al*. 2010)
Venereal Disease Common	Yes	Yes (Gaydos *et al.* 2015)
Streptococcal Tonsillitis Common	Yes	Yes (Chakravarty 2014)
ReA Common	Yes	Yes (U.S. Military) (Curry *et al*. 2010; DeYoung *et al*. 2013)
Debility	Yes	Yes
Treatment Options	Some pain management, no disease altering treatments apparent in medical literature.	Disease altering treatments available, success varies.
Awareness	Some general understanding of ReA pre-1916, but wide medical awareness came post-1916.	Rheumatologists are well informed, but SpA awareness needs improvement in administrative military roles related to medical assessment. Confusion leads to incorrect disability ratings.
Discharge from Service	Yes	Yes
Pensions/Benefits	Obtainable through complex evaluation process; policy issues suspected (bias in early evaluations systems?).	Obtainable through complex evaluation process; policy issues evident.
Quality of Life	Best evidence suggests it was reduced (troubles with employment and debility).	Reduced by SpA (Singh & Strand 2009)

CHAPTER 12:
Conclusions & Future Research

12.1 Conclusions on Military Reactive Arthropathy

12.1.1 Primary Findings & Contributions

Dysentery, diarrhoea, streptococcal tonsillopharyngitis, gonorrhoea, and undoubtedly other venereal diseases like chlamydia were common among historical combatants. These diseases thrived as a result of the unsanitary and overcrowded conditions historical combatants frequently inhabited; these environments allowed pathogenic bacteria to thrive and overcrowding meant contagion was unavoidable. Past combatants were also highly susceptible to these pathogenic bacteria, as poor diet/nutritional deficiencies, strenuous activity/physical exhaustion, and mental strain would hinder immune system efficiency. These circumstances have made epidemics of infectious disease a common component in historical accounts of war. Many of the pathogenic bacteria behind these common military diseases were also arthritogenic, meaning they are capable of triggering the development of reactive arthropathies like SpA or ARF.

The military connection to infectious disease has not been commonly explored in bioarchaeology, as most infectious diseases do not directly affect bone. On the other hand, some of the reactive arthropathies that could result from these infections do cause skeletal changes. As such, a study design focused on historical and bioarchaeological research methods was created to investigate whether reactive arthropathies were a frequent enough occurrence to be considered an occupation hazard to historical combatants.

The literary investigation revealed a sizable number of ReA references in military documents, several of which indicated this condition was common. The palaeoepidemiological investigation also provided positive results. Reactive pathology was more prevalent in military skeletal assemblages. A nested case control study reviled the odds for the occurrence of reactive pathology significantly increased when exposed to the military lifestyle. This evidence was used to conclude reactive arthropathies were an occupational hazard to historical combatants.

Military infectious diseases caused high fatalities and disruptions to military campaigns, but the findings of this research indicate there were other consequences. If a combatant survived their illness, they could potentially develop reactive arthropathies like SpA or ARF. For cases of ARF, one faced potential death due to heart complications, but debilitating arthritis was not a likely outcome for survivors. Combatants with SpA related arthropathies faced less potential for immediate death, but could suffer from debility. The prospects for historical combatants with debilitating SpA were less than ideal. Without disease altering treatments, medical discharge from service was a plausible outcome. Pvt. Cluckey's case serves as a rather harrowing example illustrating some of the challenges rheumatically disabled veterans faced: debility, inability to work, assisted living, pain, and potential drug addiction.

In summary, the present research has made the following primary contributions:

1. It provided further bioarchaeological insight into the consequences of the military lifestyle's connection to infectious disease (development of reactive arthropathies).

2. It has quantitatively confirmed suggestions of a historical affinity between reactive arthropathies and military combatants, illustrating that reactive arthropathies were an occupational hazard to historical combatants.

3. These findings led to new interpretations about the experience of historical combatants afflicted by reactive arthropathy.

12.1.2 Secondary Findings & Contributions

Primary findings of this research revolved around the commonalty and effects of military SpA on historical combatants, but secondary contributions have also been made. Bioarchaeologically, this project represents an investigation of military skeletal assemblages which is not focused on trauma or cause-of-death analysis. Studies focused outside of these areas are relatively few, so this project has contributed to this body of data. Furthermore, this project has contributed to SpA prevalence research, which is another area of infrequent bioarchaeological focus.

Lack of SpA prevalence research may be due to difficulties in diagnosing SpA in skeletal material, but this research, along with the work of Martin-Dupont *et al.* (2006) and Arriaza (1993), has demonstrated it is possible to obtain useful results when broader diagnostic criteria and statistical methods are employed. Additionally, by working in an opposing direction of previous research, this project confirmed SpA prevalence can be used to make general conclusions about sanitation practices and rates of infectious diseases.

In conducting the literature investigation, it became apparent that much is excluded from the historical narrative of ReA. Brodie's 1818 description is occasionally given due credit for the discovery of the ReA triad, but this research found an older description by Yvan in 1806. Though Yvan described the condition first, Brodie appears to have had the better comprehensive understanding of the condition. The literature investigation also made it apparent that ReA was well understood by some physicians before 1916, as many descriptions of ReA and the ReA triad were noted in the eighteenth and nineteenth century. This information conclusively confirms that Reiter, Fiessinger, and Leroy should not be given credit for the discovery of ReA; however, they can be given credit as the first physicians to understand the role of bacteria in the pathogenesis of this condition. This was no small contribution, as it clarified long held confusion over the question of 'how' rheumatism could possibly be linked to infectious diseases of the bowels and genitals.

Finally, this research has illustrated how bioarchaeological research is relevant to modern pathology. Though limited, epidemiological research suggests SpA is more prevalent in modern military groups. Diarrhoeal disease research programs could help reduce the occurrence of costly and debilitating conditions like SpA, but obtaining funding for these programs appears to be a common problem (Curry et al. 2010; Connor & Gutierrez 2013; Porter et al. 2015; Riddle et al. 2008; Tallant et al. 2014). This research clarifies the link between infectious disease, conflict, and the potential consequences (development of arthritis). Past was compared to present and it was concluded that the experience of modern combatants has striking similarity with the experience of historical combatants. This strongly illustrates that military SpA is an enduring problem worth more consideration by military official. Many of the infectious diseases that affect modern military combatants may not be deadly, but there are logistic, social, and medical issues that could be improved to reduce their occurrence; as illustrated, these infections carry serious medical concequences, including reactive arthropathies that affect mortality and quality of life, so an "ounce of prevention" should carry more worth than presently provided (Riddle *et al.* 2008). Measures to reduce the infections that cause SpA would be ideal, but policy issues surrounding extant cases (treatment, deployment status, and disability retirement) also need thorough addressal.

12.2 Future Research

12.2.1 Epidemiological Research into Modern Military SpA

Modern issues pertaining to military SpA have begun to receive attention, but problems are far from eliminated. This suggests more research would be beneficial, epidemiological research in particular (prevalence, incidence, odds ratios, disease burden, and quality of life assessment). This is especially true for the U.K Armed Services, as present data has been specific to the U.S. Military. After debate, a well-funded diarrhoeal disease research program was established on behalf of the U.S. Department of Defense, but a similar U.K. program has expressed troubles in obtaining funding. Further epidemiological research specific to the U.K. Armed Services could gain the attention necessary for research funding.

12.2.2 Testing Skeletal Assemblages with Low HLA-B27 Prevalence

As mentioned in Chapter 11, the genetic component of SpA is something to be considered when questioning whether reactive arthropathies affected all military groups. The prevalence of HLA-B27 reflects upon the prevalence of SpA, so comparing military skeletal assemblages across populations will likely present different results. Nevertheless, it is plausible to suggest military skeletal assemblages may consistently present more cases of reactive pathology when compared to genetically and chronologically appropriate non-military (control) skeletal assemblages. As present research stands, reactive arthropathies can only be confidently confirmed as an occupational hazard for historical combatants of western European decent. To determine if reactive arthropathies were a consistent problem for military groups in spite of HLA-B27 prevalence, current research methods would need to be applied to military and non-military assemblages from populations known to have a low HLA-B27 prevalence. Japanese and Chinese assemblages would be ideal for this investigation.

12.2.3 Probable N & Possible N

It was proposed that the Possible N measure may be useful when researching reactive pathology prevalence in poorly preserved skeletal assemblages. As the skeletal assemblages examined over the course of this project were relatively well preserved, this proposed use has yet to be confirmed. To assess if the proposed use of the Possible N measure is valid, both the Probable N and Possible N measures should be tested on assemblages with poor preservation. The difference between the reported prevalence of these measures can then be assessed to determine if the Possible N measure is useful.

12.2.4 Medieval & Ancient Military Remains

Common soldiers of medieval armies were often exposed to the military lifestyle for shorter durations than the standing armies of more recent history. The Towton assemblage provided results that suggest reactive arthropathies were more common among military combatants than civilians of the late medieval period. Though reactive pathology occurred in medieval armies, duration of exposure may have remained important, as 42.9% of the Towton erosive pathology cases fit skeletal profiles suggestive of professional military status (Boylston *et al.* 2007; Novak 2007 [a]). As the Towton assemblage was quite small, other medieval military assemblages could be examined to determine if reactive pathology and skeletal profiles show any patterns suggestive that professional combatants were more or less affected.

It would also prove interesting to look further into older military assemblages. Due to time and financial constraints, the present research chose to focus primarily on conflicts of the early modern era and nineteenth century. Nevertheless, examination of ancient assemblages would undoubtedly prove useful. Less is known about the medical history of many ancient armies, but what is known is exceedingly interesting (Gabriel 2012). In particular, it would be interesting to examine Roman military skeletal remains postdating the Roman Civil War (40s B.C.). As mentioned in chapter 2, after this point, the Roman army had an efficient medical system that is estimated to have reduced the occurrence of disease due to the sanitation regulations they enforced (Gabriel 2007). This prediction could be confirmed through a palaeoepidemiological study comparing the prevalence and odds ratios of reactive arthropathy in Roman and other ancient military assemblages.

12.2.5 Urban Centres

Militaries are not the only assemblages where one can expect higher prevalence of reactive arthropathies due to increased exposure and susceptibility to bacterial infectious diseases. Many of the poorest individuals occupying cities would have also had compromised immune systems and been exposed to crowd diseases. In fact, these individuals contributed to the detriment of military populations, as poor urban recruits often introduced diseases like mumps and measles to rural recruits. Though urban poor were attracted to the military, so too were rural poor and some middling class individuals. The control assemblages for this research were selected to reflect this dynamic, so assemblages were mixed rather than segregated by socioeconomic status, but, it is suspected that comparison of assemblages defined specifically by socioeconomic status could illustrate significant differences in reactive arthropathy prevalence and odds due to differing environmental and behavioural backgrounds.

One suggested assemblage for examination would be the Crossbones assemblage from Southwark, London. This cemetery was in use from the seventeenth to mid-nineteenth century. The cemetery is believed to have begun as a single women's (prostitute's) cemetery before becoming a pauper's cemetery for the poorest individuals of London (Mikulski 2007). This background, along with evidence of venereal diseases (6.1% prevalence), make Crossbones ideal for comparison with more affluent assemblages (for example, Chelsea Old Church) (Mikulski 2007).

12.2.6 HLA-B27 Testing for Pvt. Peter Cluckey

A proposal for a project to test Pvt. Cluckey's remains for HLA-B27, HLA-DRB1 (related to RA), and rheumatoid factor is currently underway. The present project has already provided a much-needed reassessment of his case and has determined that SpA is the most likely explanation for his arthropathy, but his genetic profile would be useful in further understanding his case. Furthermore, as best evidence suggests Pvt. Cluckey donated his remains for answers and scientific advancement, this genetics project is a modern means of continuing to honour his final wishes.

There are two methods which can be used for genetic testing. The first method involves testing a bone sample. HLA-B27 testing has been successfully carried out on archaeological skeletal remains to support diagnosis of AS (Haak et al. 2005; Leden et al. 2009). This method requires a section of the femur be cut, enough to produce 20mg of bone powder (Anzai *et al.* 1999). Working in consultation with one of the curators at the National Museum of Health and Medicine (NMHM), this method had already been established as the unfavoured option. First, Pvt. Cluckey's skeleton is an important part of the museum's permanent display, so destructive sampling of his skeletal remains is not ideal. Pvt. Cluckey's skeletal remains have also been subjected to chemical treatments that could interfere with the test results. Finally, as much genetic information as possible is desired from these tests, but rheumatoid factor has not been successfully extracted from bone (Waldron 2009).

The current method being investigated will make use of Pvt. Cluckey's preserved liver tissue, which is a sizable specimen that has never been used by the museum (the specimen was housed in off-site storage until very recently). Pvt. Cluckey's liver was preserved in formalin, which is problematic. Long-term storage in formalin is not ideal for DNA testing and Pvt. Cluckey's liver has been preserved in this chemical for 91 years (Paireder *et al.* 2013; Rodríguez 2002; Sengüven *et al*. 2014). Until recently, this would have been very unpromising. Nevertheless, Niland *et al.* 2012 reported a method of treating specimens that produced DNA samples from tissues stored in formalin at room temperature for 70+ years: "usable DNA can be extracted from tissue fixed in formalin and embedded in celloidin or paraffin from the early 1900's to present, and may be amplified through PCR and used for clinical and experimental studies" (199). Paireder *et al.* 2013 have also demonstrated similar success in testing long term preserved formalin tissues.

Though successful DNA extraction cannot be guaranteed with such an old specimen, only a small sample is needed; 1 cm X 1cm. This size sample would leave the majority of the specimen untouched and available for future research. With this in mind, the potential to provide new information about Pvt. Cluckey's case (and continue to fulfil his final wishes) appears to outweigh the potential for failure. The best course of action and necessary resources are currently being discussed between the author, Dr. Sandusky (participant of the Niland *et al.* 2012 study), and Brian Spatola (the Anatomical Collections Manager at the NMHM). This information will be included in a proposal presented to the Museum Director of the NMHM in the Fall/Winter of 2016/2017 for approval.

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APPENDIX A:
Operational Definitions

INTRODUCTION:

Some of the Erosive Arthropathies (EAs) share similar characteristics, which can complicate diagnosis. Furthermore, EAs share features with other non-erosive conditions in the form of bone destruction and/or bone proliferation. In an attempt to reduce difficulties in distinguishing between these conditions, the following manual provides operational definitions for erosive arthropathies and other conditions of potential confusion. The basis of all operational definitions has come from the widely referenced Waldron 2009 publication *Palaeopathology*; notes on additional characteristic have also been provided. Aside from Waldron (2009), the information is largely based on clinical and palaeopathological documentation, which have been listed as Suggested Reading at the end of the manual.

BREAKDOWN OF RELATIONSHIPS:

The following section summarizes the relationship between erosive arthropathies and non-erosive conditions of possible confusion. Since this manual was generated for Banton 2016, labels of 'non-reactive' 'possibly reactive' or 'reactive' have been provided.

Erosive Arthropathies (EAs):

Non-Reactive

1. Erosive Osteoarthritis
2. Gout

Possibly Reactive

3. Rheumatoid Arthritis

Reactive

4. Spondyloarthropathy
    a. Reactive Arthritis
    b. Psoriatic Arthritis
    c. Ankylosing Spondylitis
    d. Enteropathic Arthritis
    e. Undifferentiated Spondyloarthropathy

Non-Erosive Conditions Involving Spinal Fusion

- Diffuse Idiopathic Skeletal Hyperostosis (DISH)
- Spinal Trauma
- Deformity

Non-Erosive Conditions Involving Sacroiliac Joint Fusion

- Rickets Deformity of the Pelvis
- DISH
- Trauma

Non-Erosive Conditions Involving Destructive Bone Lesions

- Lytic Lesions (Tuberculosis, Metastatic Cancer, and Fungal Infections)
- Infections (Osteomyelitis)
- Leprosy
- Hallux Valgus

GENERAL DEFINITIONS:

Enthesopathy: a condition affecting the insertion points of tendons and ligaments (entheses); in skeletal material, enthesopathy is made evident through bone formation at the entheses.

Sacroiliitis:

Sacroiliac joint (SIJ) erosions

OR

1. abnormal bone growth on the SIJ articular surface(s) AND
2. ossification within the anterior sacroiliac ligament

Skip Lesion of the Spine: unfused vertebrae separating areas of fused vertebrae; non-continuous fusion.

True Erosions: erosions associated with erosive arthropathies can differ from destructive lesions observed in other conditions.

True erosions involve:

- cortical destruction
- undercut edges
- exposed trabecular bone
- scalloped ridges
- scooped out floors.

EROSIVE ARTHROPATHY DEFINITIONS:

Erosive Arthropathy (EA):

A general classification including the Spondyloarthropathies (Psoriatic Arthritis, Reactive Arthritis, Ankylosing Spondylitis, Enteropathic Arthritis, and Undifferentiated Spondyloarthropathy), Rheumatoid Arthritis, Gout, and Erosive Osteoarthritis.

EA can be defined as:

The presence of true erosions found in association with a joint(s)

Additional Observed Characteristics:

- Erosions may be peripheral, para-articular, articular, symmetrical, and/or asymmetrical

Erosive Osteoarthritis (EOA): Non-Reactive

A subcategory of EA

Meets all of the following:

1. Presence of eburnation in any of the joints of the hand
2. Asymmetrical, central erosions of the proximal-interphalangeal (PIP) and/or distal-interpalangeal (DID) joints of the hands; this may produce the '**Gull-Wing'** sign (see **Fig. 1**)
3. Lack of SIJ or spinal involvement

Gout: Non-Reactive

A subcategory of EA

Meets all of the following:

1. Asymmetric erosions in articular or para-articular tissues
2. Overhanging margins (Martel hook)
3. Absence of osteoporosis in the affected joint(s)

Additional Observed Characteristics:

- Often monoarticular
- Ankylosis is not a characteristic feature
- Erosions are usually round and may have sclerotic (thickened/dense) edges
- Common locations include the feet, ankle, knee, hands, and wrists

Rheumatoid Arthritis (RA): Possibly Reactive

A subcategory of EA

Meets all of the following:

1. Symmetrical, marginal erosions in the small joints of the hands and/or feet
2. Minimal new bone formation
3. Absence of SIJ or spinal involvement

Additional Observed Characteristics:

- Osteoporosis may be evident in affected joints.
- See **Figure 2** for distribution of affected joints.

<u>Spondyloarthropathy (SpA): Reactive</u>

A subcategory of EA that encompasses the specific conditions of Psoriatic Arthritis, Reactive Arthritis, Ankylosing Spondylitis, and Enteropathic Arthritis; Undifferentiated Spondyloarthropathy is often considered as well.

SpA can be identified by the presence of <u>three</u> of the following:

1. SIJ involvement in the form of fusion or sacroiliitis
2. Syndesmophyte spinal bone formation and/or fusion in 3 or more vertebrae (see **Fig. 3**)
3. Enthesopathy expressed through bone formation at the entheses; must be in a minimum of 3 locations, but ideally enthesopathy should be extensive and/or diagnostic (see **Table 1**).
4. Marginal joint erosions; asymmetric erosions are most common

<u>Ankylosing Spondylitis (AS): Reactive</u>

A form of SpA

Meets all of the following:

1. Symmetrical fusion of both SIJs, <u>AND</u>
2. Continuous spinal fusion (lacks skip lesions) extending up from the base of the spinal column (see **Fig. 3**)

Additional Observed Characteristics:

- In early development, syndesmophytes target the anterior and posterior corners of the vertebral bodies; over time the entire body margin may be affected (see **Fig. 3**).

- Fusion expands upward from the lumbar or lower thoracic vertebrae; frequently extends from the lumbosacral region.

- **Bamboo Spine** is characteristic of advanced AS: when syndesmophyte formation creates an undulating contour, the spine may resemble a stalk of bamboo.

- Facet joints may become ankylosed, especially the costovertebral joints.

- Erosions may be present in the spine, but are often difficult to observe without radiography due to the extensive bone formation of advanced AS.

- AS is focused in the axial skeleton, but when extra-spinal erosions do occur, there is a preference for large joints like the shoulder or hip (see **Fig. 2**).

- Osteoporosis of the spine can be a feature of AS.

Psoriatic Arthritis (PsA): Reactive

A form of SpA

1. SIJ involvement; fusion or sacroiliitis (more common) AND
2. Paravertebral spinal fusion with skip lesions (see **Fig. 3**), AND
3. Marginal erosions that show preference for the distal interphalangeal joints of hands and/or feet with lysis of the distal tufts

Additional Observed Characteristics:

- Erosions may be asymmetric or symmetric.

- Entheses are more likely to occur in the upper extremities (see **Fig. 2**).

- **Arthritis mutilans** may be observed: osteolysis (bone resorption) resulting in digit shortening, sometimes causing 'telescoping digits.'

- The '**cup in pencil**' deformity may be observed: in joints, the proximal bone is affected by erosions and the articulating distal bone is widened by bone formation (see **Fig. 1**).

- The '**licked candy stick**' is sometimes observed; where erosions cause tapering in bones like the metacarpals, metatarsals, phalanges, or clavicles (see **Fig. 1**).

- Only 20-40% of modern clinical cases have axial involvement, meaning peripheral erosions and bone formation are often the primary features.

- Periostitis may be observed in locations affected by erosions.

- When spinal involvement occurs, fusion is in the form of paravertebral syndesmophyte formation that is not limited to the right side; bony extension may occur across the disk space (see **Fig 3**).

- Involvement of the cervical spine has been recorded; erosion of the odontoid peg in the cervical spine may occur, as may ankylosis or syndesmophytes in the cervical spine.

Reactive Arthritis (ReA): Reactive

A form of SpA

Meets all of the following:

1. Asymmetric fusion of one or both sacroiliac joints, AND
2. Characteristic paravertebral spinal fusion with skip lesions (see **Fig.3**), AND
3. Asymmetric marginal erosions of the small joints of the feet

Additional Observed Characteristics:

- In general, lower extremities are more likely to be involved than upper extremities.

- Entheses in the lower limbs and feet support the diagnosis of ReA; calcaneal spurs are particularly common.

- Though erosions in the small joints of the feet is characteristics, clinical data suggests erosions in large joints of the lower extremities, such as the knee, may also be observed (see **Fig. 2**).

- Periostitis may be observed in locations affected by erosions.

- Spinal fusion is in the form of paravertebral syndesmophyte formation that is not limited to the right side; there is a preference for the lumbar and lower thoracic vertebrae; bony extension may occur across the disk space (see **Fig 3**).

Enteropathic Arthritis (EnA): Reactive

A form of SpA that cannot be specifically identified in skeletal material, as it frequently imitates the changes seen in AS, meaning it has continuous spinal fusion, symmetrical SIJ involvement, a tendency for spinal erosions, and when extra-spinal erosions occur (rare) there is a preference for large joints.

Undifferentiated SpA (USpA): Reactive

A form of SpA that cannot be specifically identified in skeletal material. USpA is a categorization often used to delineate cases with abnormal patterns of expression, though the basic features of SpA are still expressed.

FOR DIFFERENTIAL DIAGNOSIS:

Diffuse Idiopathic Skeletal Hyperostosis (DISH):

DISH is associated with many of the same features as SpA, but the expression of these features typically differ.

Meets all of the following

1. Fusion of four contiguous vertebrae; no skip lesions
2. Fusion is confined to the right side in the thoracic region (see **Fig. 3**)

Additional Observed Characteristics:

- Entheses and ligamentous growth may be observed in the pelvis and shoulder, with feathering or whiskering on the iliac crests being especially common.

- Spinal fusion (and SIJ fusion when it occurs) is limited to the ligament; fusion does not extend across the joint spaces and inflammatory changes are not typical (erosions, resorption, or abnormal bone growth on joint surfaces).

- Costovertebral and other facet joints of the spine are rarely involved.

- Erosions should not be present; if erosions are present, close observation is necessary to determine if SpA or a concomitant EA is responsible; some clinical cases have reported DISH coinciding with gout and (occasionally) SpA (Kiss *et al.* 2002; Littlejohn & Hall 1982; Olivieri *et al.* 2013;).

Hallux Valgus:

Abnormal lateral deviation of the great toe (Mays 2005).

Destructive lesion of hallux valgus (bunions) often:

- Occur on the medial surface of the distal 1st metatarsal
- Are para-articular
- Are groove shaped (elongated depression)
- Have a smoother appearance than true erosions (thickened/remodeled trabecular bone)
- Is accompanied by exostosis at the medial epicondyle of the 1st metatarsal

Infection:

Infectious bone changes are often highly irregular. Extensive infections are not characteristic of EAs, so one must consider differential diagnosis for destructive lesions found in relation to conditions like osteomyelitis.

Bone infections can be indicated by:

- Increase in bone size/volume due to periosteal bone formation (in osteomyelitis, it may be extensive, creating a shell of bone known as an involucrum)
- Presence of cloaca (openings in an involucrum, created for pus drainage)
- Avascular necrosis may be observed due to extensive new bone formation

Leprosy:

Destructive bone changes in leprosy may be confused with EAs, though advanced cases are rather distinct.

Leprosy can be identified by:

1. The presence of **Rhinomaxillary syndrome** (resorption of the maxillary and nasal bones)

OR

2. Concentric osteolysis of bone in the phalanges of the hands or feet, working distal to proximal.

Additional Observed Characteristics:

- It is not uncommon for osteomyelitis to accompany osteolysis in the feet.
- The '**licked candy stick**' deformity may be observed (See **Fig. 1** and 'PsA' for definition)
- Bone destruction in leprosy is resorptive and changes are not limited to the joints (see **Fig. 1**).
- Charcot's joints may occur.

Lytic Lesions

Lesions of bone destruction observed in several diseases.

Typically, lytic lesions:

- Are areas of bone destruction surrounded by bone of normal density
- May or may not be associated with new bone formation, but if so, it is usually irregular/disorganized bone
- May occur anywhere; they are not limited to joints

Metastatic Cancer:

Often causes bone destruction due to lytic lesions.

General characteristics include:

- Lesions at lytic
- May affect any bone surface; this is in contrast to EAs, as bone destruction must be associated with the joints.
- Often affect particular locations determined by the type of cancer (breast, prostate, etc.)
- Frequently have a ‘moth-eaten’ appearance
- If bone formation is associated, it is usually irregular/disorganized

Mycotic Infections:

May causes bone destruction due to lytic lesions.

General characteristics include:

- Lesions are lytic
- May affect any bone surface; this is in contrast to EAs, as bone destruction must be associated with the joints.
- Expression is random in regards to location, new bone formation (present or absent), symmetry, and laterality; this is in contrast to EAs, which often follow particular patterns of expression.
- Though plenty of mycotic infections can cause skeletal changes, they are rare except for certain geographical locations within in North and South America. As such, this is not the most likely explanation for lytic lesions in European assemblages.

Tuberculosis (TB):

Destructive bone changes in TB may be confused with EA.

TB lesions are normally:

- Lytic
- Unifocal
- Involve little or no new bone formation

Additional Observed Characteristics:

- The spine is most commonly affected and, in extreme cases, Pott's disease (vertebral collapse) or Kyphosis (excessive curvature) may be apparent.
- In the spine, the vertebral bodies are primarily involved, sparing the posterior elements.
- Lesions are sometimes cystic in appearance, especially if they occur in the hands.

Trauma/Deformity Induced Spinal Fusion:

Anytime trauma or deformity is found in association with fusion or bone formation, it must be considered as a plausible explanation for this pathology.

Some Examples Include:

- Compression fractures (or any fracture that is directly associated with fusion)
- Slipped (misaligned) vertebrae
- Deformities such as Klippel-Feil Syndrome or Block Vertebrae

Trauma/Deformity Induced Sacroiliac Joint Fusion:

Anytime trauma or deformity is found in association with fusion or bone formation, it must be considered as a plausible explanation for this pathology.

Some Examples Include:

- Congenital or Rickets deformity
- DISH (see operational definition for DISH features)
- Fractures

Figure 1: Erosions

The images below display different types of erosion.

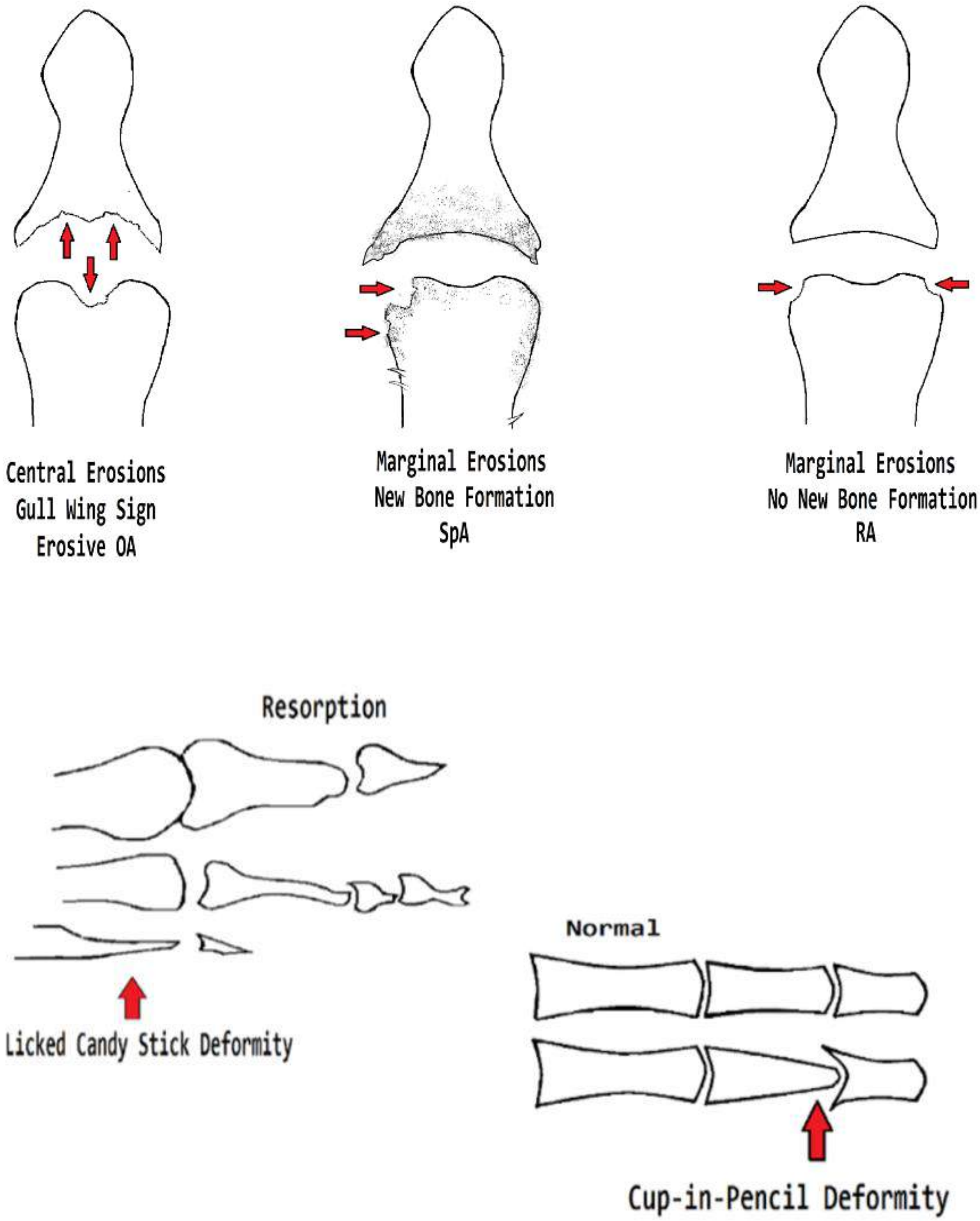


FIGURE 2: Distribution of Pathology (adapted from Arriaza 1993)

For PsA, ReA & AS: the **rectangles filled in red** represent joints more commonly involved; in the spine and sacroiliac joints this indicates fusion, elsewhere it represents erosion and/or enthesopathy. **Unfilled rectangles** represent joints that are involved with erosions and/or enthesopathy, but are less common.

For RA: **rectangles filled in red** represent erosions only; bone formation is uncommon in RA.

NOTE: PsA displays the asymmetrical variant, not the symmetrical variant (the symmetrical variant would resemble the RA distribution for hand, wrists, feet, and ankles, involving both erosions and new bone formation).

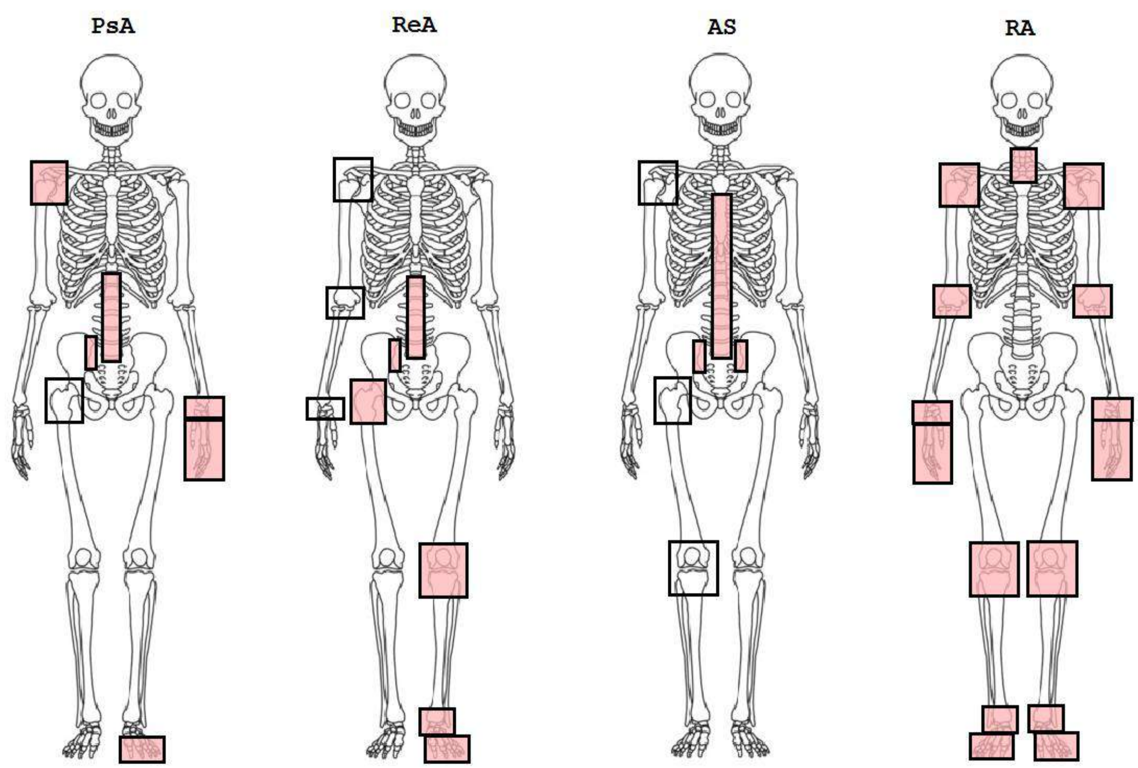


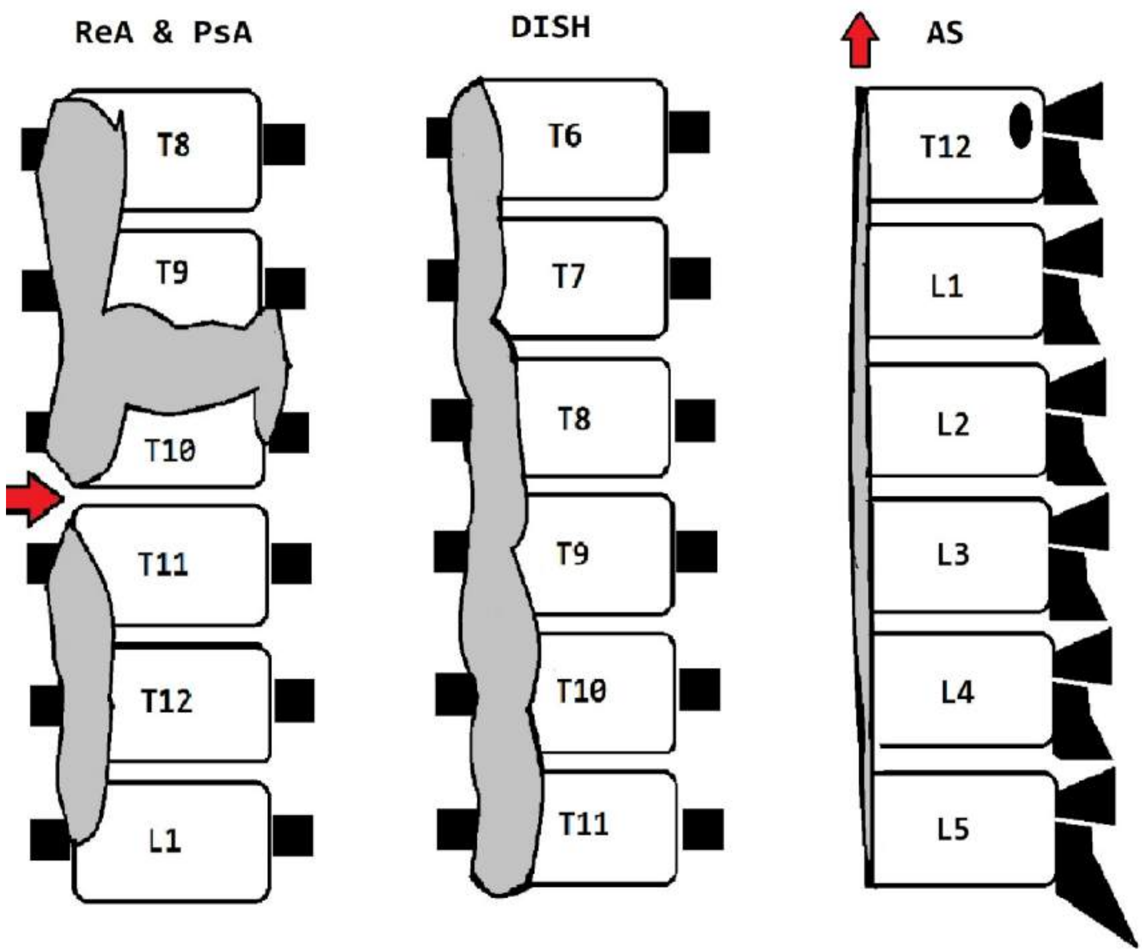
FIGURE 3: Spinal Bone Formation

In **PsA** and **ReA**, spinal bone growth: **1)** primarily takes the paravertebral position (right and/or left) **2)** often follows along the ligament, but may extend across the disk space **3)** in well-developed cases, skip lesions are present (shown by red arrow) **4)** syndesmophytes are often chunky.

In **AS**, spinal bone growth: **1)** involves the lateral and anterior aspects of the vertebrae, but bone formation is typically smoother/less bulky than seen in other conditions, especially the anterior formation **2)** it is not uncommon for the costovertebral joints or other spinal facets to ankylose, **3)** changes are continuous without skip lesions **4)** fusion expands upward from the lumbar or lower thoracic vertebrae (shown by red arrow).

In **DISH**, spinal bone growth: **1)** occurs within the ligament and is limited to the ligament; it does not invade the disk space **2)** is confined to the right paravertebral position within the thoracic vertebrae **3)** is continuous without skip lesions **4)** has a flowing, dripped candle wax appearance.

Source: created by the author.



Blue Arrows = changes over time

In **ReA and PsA** fusion is caused by ossification of the paravertebral connective tissues. Bone formation takes on the appearance of chunky, comma shaped syndesmophytes that bridge together in the paravertebral position(s). Bone formation does not generally start from the joint margin. Early in formation, there may be space preserved between the bridging bone and vertebral body, but this will disappear over time (shown by the red arrow).

AS targets the annulus fibrosus. Compared to ReA and PsA, syndesmophytes of AS occur close to the joint margins, are smoother, smaller, and less bulky. Eventually, fusion may involve all points of the vertebral body margin, but, in early development, the anterior and posterior corners of the vertebral body are favoured positions for syndesmophyte formation.

In **DISH**, fusion occurs as a result of ossification of the anterior longitudinal ligament. Bone formation is bulky, but flowing, frequently taking an undulating appearance of dripped candle wax. Unlike the SpAs, the disk space is spared and only the right side is involved in the thoracic region.

Source: created by the author.

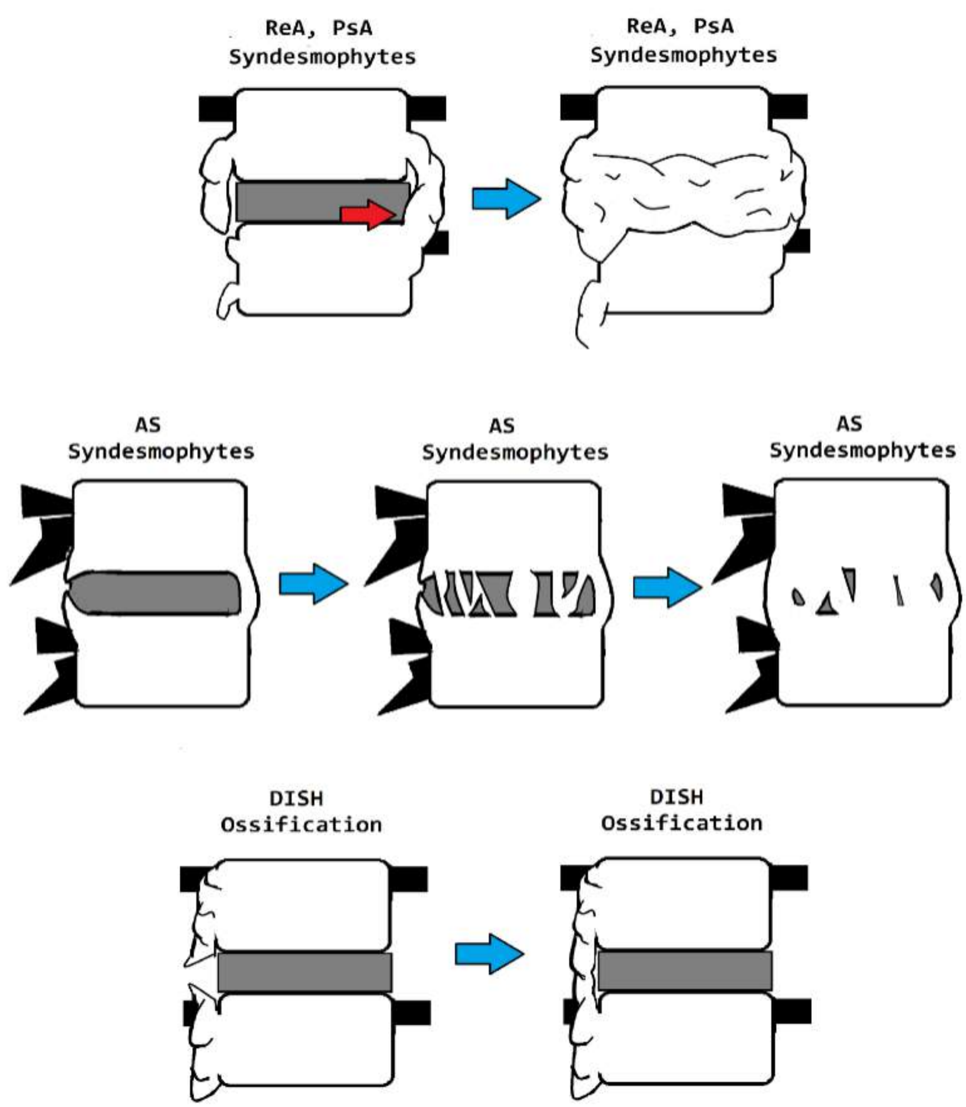


Table 1: The following table lists pathology commonly noted in cases of SpA. This information is compiled from both palaeopathological and clinical literature (see Suggested Reading). Source: created by author.

Bone Formation in SpA	
Cranium & Mandible	Occipital Protuberance (Enthesopathy)
	Nuchal Lines (Enthesopathy)
	Temporomandibular Joint (fibrocartilaginous proliferation)
	Musculus Temporalis Insertion, Coronoid Process (Periostitis)
Spine	Interspinal Ligaments (Enthesopathy)
	Supraspinal Ligaments (Enthesopathy)
	Anterior Longitudinal Ligament (Syndesmophytes or Ankylosis)
	Intervertebral Fibrocartilage (Ankylosis)
	Costovertebral Joints (Ankylosis)
	5th Lumbar Spinous Process (Enthesopathy)
Pelvis	Anterior Sacroiliac Ligament (Enthesopathy or Ankylosis)
	Iliac Crest (Enthesopathy)
	Anterior Superior Iliac Spine (Enthesopathy)
	Posterior Superior Iliac Spine (Enthesopathy)
	Ischial Tuberosity (Enthesopathy)
	Superior Pubic Ligament (Enthesopathy)
	Inferior Pubic Ligament (Enthesopathy)
Thorax	Sternocostal Ligaments (Enthesopathy)
	Intercostal Muscles (Enthesopathy)
Pectoral Girdle	Acromioclavicular Joint (Enthesopathy, Ankylosis, or Erosion)
	Musculus Deltoideus Insertion, Acromion (Enthesopathy)
	Musculus Levator Scapulae Insertion, Scapula (Enthesopathy)
	Coracoclavicular Ligament (Enthesopathy)
	Ischiopubic Rami (Enthesopathy)

Upper Limb	Medial Humeral Epicondyle (Enthesopathy)
	Lateral Humeral Epicondyle (Enthesopathy)
	Supraspinate Tendon Insertion, Humerus (Enthesopathy)
	Flexor Carpi Ulnaris Insertion, Pisiform (Enthesopathy)
	Flexor Carpi Radialis Insertion, Metacarpals II & III (Enthesopathy)
	Extensor Carpi Ulnaris Tendon (Enthesopathy)
	Wrist & Metacarpals (Periostitis)
	General: Metacarp als (Enthesopathy)
Lower Limb	Greater Femoral Trochanter (Enthesopathy)
	Medial Femoral Condyle (Enthesopathy)
	Lateral Femoral Condyle (Enthesopathy)
	Linea Aspera (Enthesopathy or Bone Proliferation)
	Intertrochanteric Crest (Enthesopathy or Bone Proliferation)
	Patella (Enthesopathy)
	Tibia Tuberosity (Enthesopathy)
	Achilles tendon (Enthesopathy)
	Plantar Fascia (Enthesopathy)
	Fifth Metatarsal Tuberosity (Enthesopathy)
	Ligamentum Teres Insertion, Femur (Enthesopathy)
	Musculus Gastrocnemius Insertion, Femur (Enthesopathy)
	Musculus Semimembranosus Insertion, Tibia (Enthesopathy)
	Popliteus Insertion, Tibia (Enthesopathy)
	Occipital Protuberance (Enthesopathy)
	Nuchal Lines (Enthesopathy)
	Temporomandibular Joint (fibrocartilaginous proliferation or erosions)
	Musculus Temporalis Insertion, Coronoid Process (Periostitis)
	Interspinal Ligaments (Enthesopathy)

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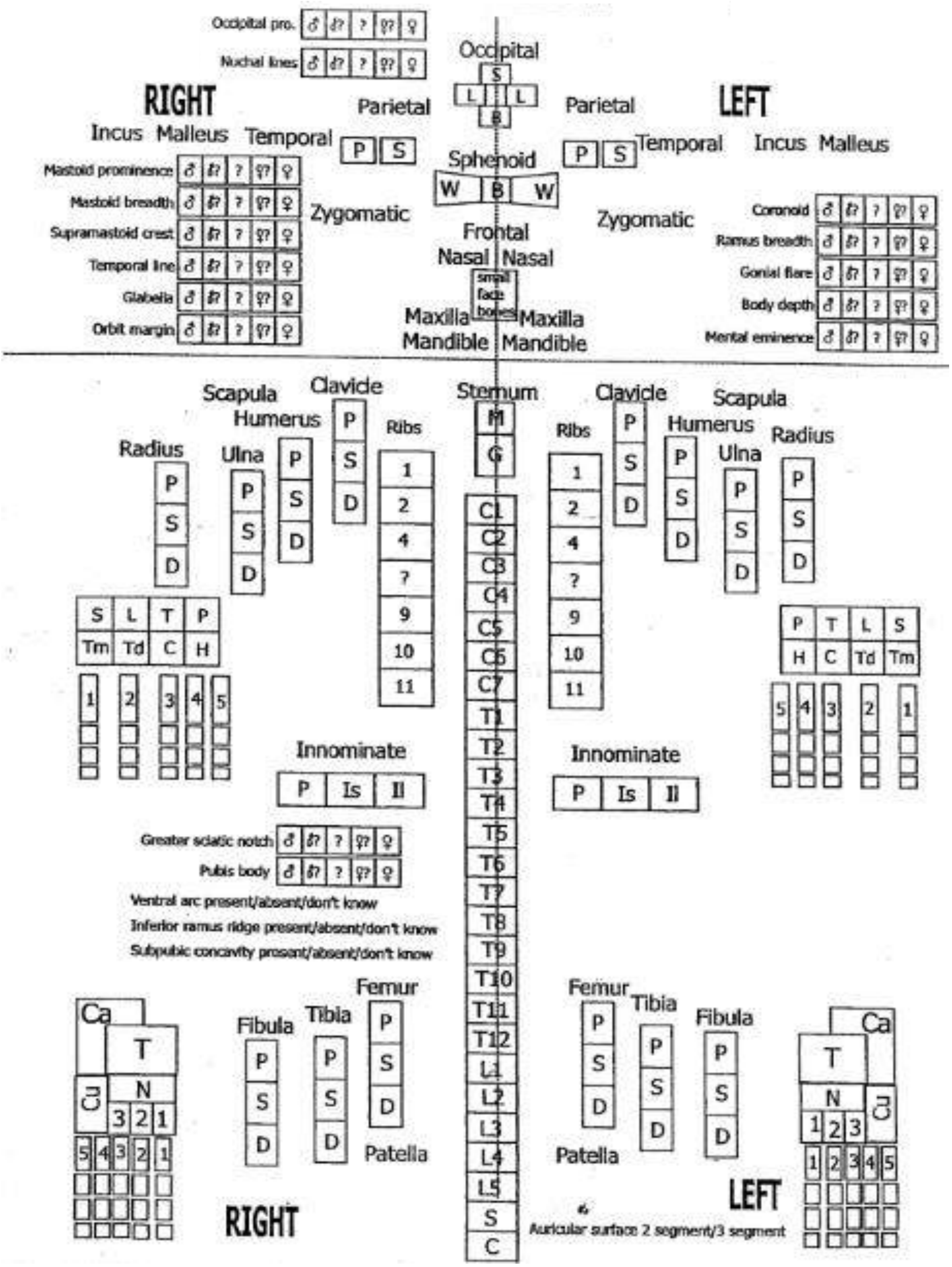
APPENDIX B:
Skeletal Recording Form

Site: Specimen Number:



General Condition of Remains:

Measurements for Height or Sex:

FEMUR
FeL1: Right _______ Left_______
FHD1: Right _______ Left_______

HUMERUS
HuD1: Right _______ Left_______

SCAPULA
GIL1: Right _______ Left_______

CLAVICLE
CIL1: Right _______ Left_______

Using Pelvis & Skull Morphology from *Standards* (1994) and Metric Measurements:

SEX:

AGE:

Spinal Elements & Pathology

Key: 1 Present/Yes, 2 Absent/No, Not Observable 0

	Present	Erosions	Fusion
C1			
C2			
C3			
C4			
C5			
C6			
C7			
T1			
T2			
T3			
T4			
T5			
T6			
T7			
T8			
T9			
T10			
T11			
T12			
L1			
L2			
L3			
L4			
L5			
L6 (?)			
S1			

Spinal Pathology Continued

Skip Lesions: yes/no, where?

Vertebral Fusions: Paravertebral, Anterior, Posterior, Mixed/Describe

SIJ/Pelvis Pathology

Key: 1 Present/Yes, 2 Absent/No, Not Observable 0

	Present/Absent?	Fusion?
Left		
Right		

Describe Fusion: (asymmetric or symmetric; if symmetric, are fusion points within the two joints symmetric or asymmetric; any signs of it being congenital or trauma related?)

Sites of Entheses/New Bone Growth & Erosions

Key: 1 Present, 2 Absent, Not Observable 0

	Entheses/New Bone	Entheses/New Bone	Erosions	Erosions
	Right	Left	Right	Left
Scapula				
Humerus Proximal Distal				
Radius Proximal Distal				
Ulna Proximal Distal				

Carpals Scaphoid Lunate Triquetral Pisiform Trapezium Trapezoid Capitate Hamate				
Metacarpals 1 2 3 4 5				

Proximal Phalanges 1 2 3 4 5				
Intermediate Phalanges 2 3 4 5				
Distal Phalanges 1 2 3				

4 5				
Pelvis Iliac Crest Ischium Sacrum				
Femur Proximal Distal Greater Trochanter Lesser Trochanter Linea Aspera				
Tibia Proximal				

Tubercle Soleal Line Distal				
Fibula Proximal Distal				
Patella				
Calcaneus Posterior Inferior				
Other Tarsals Talus Navicular Cuboid				

Cuni. Medial Cuni. Intermediate Cuni. Lateral				
Metatarsals 1 2 3 4 5				
Proximal Phalanges 1 2 3 4				

5				
Intermediate Phalanges 2 3 4 5				
Distal Phalanges 1 2 3 4 5				

Other Locations Noted:

Pathology Summary Chart

Key: 1 Present, 2 Absent, Not Observable 0

Fusion of SIJ	1 2 0 **Which**: Right, Left, Both
Sacroiliitis	1 2 0
Spinal Fusion	1 2 0 **Type:** Continuous or Skip Lesions Associated with Trauma or Other Pathology? Yes No
Asymmetrical & Marginal Erosions in Feet and/or Lower Extremities	1 2 0
Asymmetrical & Marginal Erosions in Hands and/or Upper Extremities	1 2 0
Tuftal Resorption and/or 'Cup & Pencil'	1 2 0
Symmetrical Marginal Erosion in Hands and/or Upper Extremities	1 2 0
Symmetrical Marginal Erosion in Feet and/or Lower Extremities	1 2 0
Articular and/or Para-Articular erosions	1 2 0
Central Erosions in the Hands with Osteoarthritis Present	1 2 0
Infection Related Erosions	1 2 0
Enthesopathy/New Bone Formation	1 2 0 **Where:** Upper Extremities, Lower Extremities, Both **Number of Locations:**
Other Relevant Pathology/Notes:	

General Pathology Notes:

APPENDIX C:
Skeletal Diagnoses

The table below provides the diagnoses made with a brief description of pathology. Age categories are abbreviated as found in-text. For sex, M = Male and M? = Questionable Male. For classification, Reactive Suspect has been abbreviated to RS.

Skeletal Data				
Skeleton	**Age Category**	**Sex**	**Classification**	**Criterion/Pathology**
All Saints Church (York)				
2705	LMA	M	Reactive, Plausible	Criterion 2. Spinal fusion with skip lesions and chucky syndesmophytes.
3114	MA	M	Unidentified, RS	Criterion 1. Degeneration could not be excluded from differential diagnosis. Changes suggestive of infection were noted with the right acetabula. Spinal bone formation, takes the form of DISH. 1 gout-like erosion in right 5th metatarsal (articular and punched out appearance). Most likely DISH, Gout, and degenerative Sacroiliitis, but was given benefit of the doubt as a RS. This course was also applied to KWK 3182 for similar reasons.
3554	MA	M	Nonreactive	Erosion on the inferior facet of L3, associated with complete spondylolysis of L4.
Chelsea Old Church (OCU00)				
713	MA	M	Reactive, SpA	Criterion 1, 2, 3, & 4; The changes were highly characteristic of AS, fulfilling criterion as described in Chapter 6. Figure 8, Chapter 1 shows spinal pathology.
593	MA	M	Unidentified, RS	Criterion 5 (irregular); some tufla resorption was noted in the distal phalanges of the right foot. This can be a feature of PsA, but no other pathology was noted.

35	MA	M	Nonreactive	Gout? Para-articular erosion on the mediodistal surface of the right 1st metatarsal and the proximal-medial surface of the articulating 1st proximal phalanx.
668	MA	M	Nonreactive	Gout? Para-articular erosions with a deep, rounded appearance. Pathology occurred on the mediodistal surface of both 1st metatarsals and the mediodistal surface of the left 3rd metacarpal. Degenerative changes also present.
St. Brides Lower (FAO90)				
1680	MA	M	Unidentified, RS	Erosive pathology was observed in both feet. Erosions were articular, affecting the entire joint surface, but were not lesions associated with gout, as the erosions were small, porous, and associated with new bone formation. Tarsometatarsal joints affected. Septic Arthritis suspected, but given the association with new bone formation, the case was counted as a Reactive Suspect for benefit of the doubt.
1500	MA	M	Nonreactive	Very small, round erosive lesions were observed on the para-articular locations of both 1st metatarsals (mediodistal surface). No other pathology relevant to EAs was observed. Given the locations affected, the case was considered nonreactive.
1521	MA	M	Nonreactive	Bilateral, round/oval lesions observed in the para-articular location of both 1st metatarsals (mediodistal surface). No other pathology relevant to EAs was observed. Given the locations affected, the case was considered nonreactive.
1558	UMA	M	Nonreactive	Small sclerotic lesions on the distal right 5th metatarsal. The lesion was solitary and articular surface, which is most indicative of gout. Degenerative changes were observed, so osteoclast activity of osteoarthritis is also possible.
1825	UMA	M	Nonreactive	Bilateral lesions observed in the para-articular location of both 1st metatarsals (mediodistal surface). The lesions were small and generally round/oval in

				appearance. No other pathology relevant to EAs was observed. Given the locations affected, the case was considered nonreactive.
2193	MA	M	Nonreactive	Bilateral lesions in the para-articular location of both 1st metatarsals (mediodistal surface). Though trabecular bone was exposed, it was thickened, giving the interior of the lesions a smooth appearance. The locations affected are characteristic of gout, so the lesion was categorized as being nonreactive; however, this may be a case of hallux valgus. This alternative diagnosis is supported by evidence of lateral deviation and tubercle exostosis.
2253	MA	M	Nonreactive	Gout. A large para-articular erosion on the distal end of the left 1st metatarsal. The erosion strongly undercut the joint margin, creating an overhanging projection of bone (a Martel Hook). A large and deeply lesion was noted on the styloid process of the right ulna. Possibly related to gout.
Towton				
8	UMA	M	Reactive, SpA	Criterion 1, 4, & 5. Changes occurred mostly in the feet and lower extremities, which is most characteristic of ReA, but the case did not fully meet the operational definition, so this is a speculative suggestion.
9	UMA	M	Reactive, SpA	Criterion 1, 3, 4, & 5. Some enthesopathy was noted in the upper extremities, but the vast majority of enthesopathy and all erosions were noted in the lower extremities. This is most characteristic of ReA, but the case did not fully meet the operational definition, so this is a speculative suggestion. Note on spinal fusion (T6, T7, and T8) and bone formation in T4 &5: this was clearly ligamentous growth and did not

				appear related to the osteophytosis apparent in the rest of the lower spine.
13	UMA	M	Reactive, SpA	Criterion 3, 4, & 5. Some enthesopathy was noted in the upper extremities, but the vast majority of enthesopathy and all erosions were noted in the lower extremities. This is most characteristic of ReA, but the case did not fully meet the operational definition, so this is a speculative suggestion. Enthesopathy was very extensive and characteristic of SpA. Spinal bone formation consisted of ligamentous growth in the left and right para-vertebral position from T7 to T12.
50	?	M?	Reactive, Plausible	Criterion 4 & 5 (noted 3X) Very incomplete skeleton. Enthesopathy was in characteristic locations. Four erosions noted in the feet, but one was para-articular. The rest were marginal and some were associated with new bone formation.
22	LMA	M	Unidentified, RS	Criterion 5 (noted < 3X) Erosions were characteristic of reactive arthropathy. One of these erosions occurred on the margin of the right sacral articulation and was associated with some new bone formation (thin, flake-like appearance) on the joint surface.
25	UMA	M	Unidentified, RS	Criterion 4 & 5 (noted < 3X) Erosions were observed in two locations: One was para-articular and occurred on the distal end of the right 1st metatarsal. The erosion is quite round, deep, and smooth walled. This is likely a pressure lesion (bunion). The second erosion was observed on the margin of the radial articulation of the right scaphoid.

				Enthesopathy was in characteristic location for SpA (posterior calcanei, iliac crests, left ischium, foot phalanges)
41	LMA	M	Unidentified, RS	Criterion 5 (noted < 3X) One erosion occurred on the distal end of the right 5th proximal foot phalanx. It caused marginal destruction to both the medial and lateral surface. Reactive bone formation (periosteal bone formation) was also noted.
York Mass Grave (YMG)				
3864	YA	M	Reactive, Probable	Criterion 1 & 5 (3X) Marginal erosions were noted in the feet. Sacroiliitis was noted based on scalloped erosion on the auricular surface of the left SIJ and bone growth inferior to the auricular surface suggestive of ligamentous ossification.
2407	UMA	M	Unidentified, RS	Criterion 5 (noted < 3X) Though 3 or more characteristic erosions can be counted as a potential 'Plausible Reactive' case, one of the three erosions observed in YMG 2407 was not considered characteristic, as it affected the articular surface only. Nevertheless, the other erosions were asymmetric and marginal, rising suspicion of a potentially reactive nature behind this pathology. Periosteal bone formation was observed on the neck of the left talus, though no erosions were present in this location.
3007	UMA	M	Unidentified, RS	Criterion 5 (noted < 3X) An extensive erosion was observed in the 2nd metacarpophalangeal joint of the right hand and was accompanied by reactive bone formation. On the distal end of the 2nd metacarpal, the changes were marginal and cylindrical (affecting all surfaces and working inward onto the articular surface). Small true erosions were observed in addition to resorptive

				changes. There was also thickening of the distal shaft due to periosteal bone formation. The erosive and periosteal changes observed in the articulating 2nd proximal phalanx were of the same variety.
3092	YA	M	Unidentified	Criterion 3 This was a young individual with some ligamentous growth in the spine. No evidence of trauma or degeneration was evident. The age and lack of clear cause for the bone formation made the case worth note, but the case was not counted a Reactive Suspect. No true erosive changes were noted and the amount of bone formation was not highly characteristic of any particular pathology.
3089	LMA	M	Nonreactive	One para-articular erosion was observed on the distal end of the left 1st metacarpal. The lesion was very round and deep. No other pathology relevant to EAs was observed. Given the location affected, the case was considered nonreactive.
Plymouth Royal Naval Hospital (EA)				
569	LMA	M	Unidentified, RS	Criterion 5 (noted <3X) Erosions were observed in the left radius (radio-ulnar joint). These erosions were marginal and spread onto the articular surface. Lesions were also observed on the proximal end of the right 2nd intermediate hand phalanx. The changes affected the dorsal portion of the articular surface and were resorptive in nature, creating a roughened appearance. True erosions were observed along the dorsal joint margin. The radio-ulnar joint can be involved in some forms of SpA and more commonly RA. It was not excluded from the

				Reactive Suspect to provide benefit of the doubt.
544	LMA	M?	Unidentified, RS	Criterion 5 (noted <3X) Erosive changes were observed on the distal end of the right 1st metacarpal. True erosions marginally affected the palmar-lateral surface of the distal articulation. Para-articular to these marginal erosions, resorptive changes were noted and were accompanied by irregular periosteal bone formation. It was not excluded from the reactive suspect count due to the presence of new bone formation and the marginal nature of the true erosions.
547	UMA	M	Unidentified	Erosive lesions were observed on the mediodistal surface of the left 1st intermediate foot phalanx. The largest erosion undercut the joint margin from the para-articular location, while smaller lesions affected the inferior-medial margin.
551	UMA	M	Nonreactive	The distal end of the right 5th metatarsal had a round, deeply-set lesion on the articular surface. The edges of the lesion were clearly defined and the surrounding bone appeared normal. The lesion was atypical. It is suspected this lesions is related to tuberculosis, which was diagnosed based on the presence of lytic lesions in L3.
674	UMA	M	Nonreactive	The distal ends of the right 1st metacarpal and the right 1st metatarsal had para-articular lesions. The lesion on the 1st metatarsal was on the medial surface. The lesion was characterized as being deep and somewhat elongated, with smooth interior walls of thickened trabecular bone. The lesion lacked the round, scalloped, and roughened appearance of true erosions. The erosion observed on the right 1st metacarpal was similar, with a round,

				deep-set, and smooth walled appearance. The lesions were not typical of gout, but their location was characteristic. The smooth walls within the lesions may be more indicative of pressure lesions like bunions or cysts. Without skeletal pathology to indicate otherwise, the lesions were counted as having Nonreactive Pathology.
702	Adult	M?	Nonreactive	Erosive pathology was observed in two right foot tarsals, the navicular and the intermediate cuneiform. The articular joint surfaces were affected. The lesions were subcortical and resorptive in nature, but were also accompanied by irregular periosteal new bone formation. Septic Arthritis is suspected. Unlike FAO90 1680, osteomyelitis was observed in the lower leg, supporting this conclusion, so it was not counted as a Reactive Suspect.
Greenwich Royal Naval Hospital (KWK)				
3044	MA	M	Reactive, SpA (ReA)	Criterion 1, 2, 3 (part two), 4, & 5 All but one erosion was observed in the feet and most enthesopathy occurred in the lower extremities. This case fit the criterion to meet the Operational Definition for ReA. Case discussed in-text in Chapter 11, section 11.1.2.
3177	MA	M	Reactive, SpA	Criterion 1, 4, & 5 Though fulfilment of any three criterion is enough for a 'SpA' classification, the amount of changes observed were somewhat limited due to issues of preservation. No spinal elements were present and only one SIJ was available for observation. Left SIJ fusion was observed.

				Extensive enthesopathy was observed in the lower extremities, with several characteristic locations involved. Several marginal erosions were noted in the right foot. The lower extremity involvement is most characteristic of ReA, but the case did not fully meet the operational definition, so this is a speculative suggestion.
6113	MA	M	Reactive, SpA (ReA)	Criterion 1, 2, 3 (part 2), 4, 5 Erosion were observed in the feet and most enthesopathy was in the lower extremities. This case fit the criterion to meet the Operational Definition for ReA. Case discussed in-text in Chapter 11, section 11.1.2.
3253	MA	M	Reactive, Probable	Criterion 2 & 4 Syndesmophyte fusion was observed between C6 and C7, between T8 and T9, and between T12 and L1. Skip lesions were between T7 and T8 and between T9 and T12. Some spinal bone formation was also observed on the posterior spinal processes. Skip lesions and chunky syndesmophyte formation is most characteristic of the ReA and PsA varieties of SpA. Enthesopathy included characteristic locations, but involved the upper and lower extremities.
6103	UMA	M	Reactive, Probable	Criterion 3 & 5 (noted >3X) Marginal foot erosions. Interlocking bridges of bone formation were observed on the anterior bodies of C3 through C7. Fusion occurred between C6 and C7. Though evidence of degeneration was present, it was not extensive. Further interlocking bridges of bone formation were observed in the

				right paravertebral position of L3, L4, and L5.
3143	MA	M	Reactive, Probable	Criterion 4 & 5 (noted 3X) Most enthesopathy was noted in the lower extremities, 2 erosions occurred in the feet, and 1 in the left hand.
3068	MA	M	Reactive, Plausible	Criterion 4 & 5 (noted 3X) Extensive and characteristic enthesopathy was noted in the lower extremities and two characteristic erosions were noted in the feet (marginal involvement). A 3rd marginal erosion was noted, but it was found in association with osteoarthritic changes and hallux valgus. For this reason the cause was considered Plausible rather than Probable.
3106	MA	M	Reactive, Plausible	Criterion 1, 3, & 5 (abnormal) Though erosions were observed, the case was marked as a Plausible Reactive case rather than a Probable Reactive case due to the abnormal nature of the erosions observed; they did not fully meet criterion 5, but their presence with criterion 1 (sacroiliitis) and 3 (spinal bone formation) is highly suspect.
6078	UMA	M	Reactive, Plausible	Criterion 4 & 5 (noted >3X) This case had 3 marginal erosions noted in the feet, though one was marginal and para-articular and associated with advanced degenerative changes. For this reason the case was considered Plausible rather than Probable. Characteristic enthesopathy was present in the lower extremities. Bone formation was especially noteworthy in the tarsal bones, which had periosteal new bone formation on their dorsal surfaces.

6017	MA	M	Reactive, Plausible	Criterion 5 (noted 3X) Marginal, asymmetric erosions were noted in the 3 locations in the left foot (1st metatarsal, 1st proximal phalanx, 2nd proximal phalanx)
3265	MA	M	Unidentified, RS	Criterion 4 & 5 (noted > 3X) with reactive bone formation. This was a complicated case of extensive and highly symmetrical erosive arthropathy affecting the hands and feet. Normally this would be attributed to RA (which may be the case), but some features were not characteristic of RA: – Enthesopathy and periosteal bone formation associated with erosive pathology – Extensive DIP involvement – Spinal erosions in the lumbar region No convincing axial bone formation was present, with the exception on one small, but distinctive (comma shaped), syndesmophyte. Only one SIJ articulation was observable, no pathology was evident. Though a case can be strongly made for RA, it was counted as an Unidentified case and Reactive Suspect based on the uncharacteristic features noted and the fact that PsA (which has a symmetrical variant) only affects the axial skeletal on 20 to 40% of cases. Case discussed in-text in Chapter 11, section 11.1.2.
3103	MA	M	Unidentified, RS	Criterion 5 (noted < 3X) Both para-articular and marginal asymmetric lesions were observed. Some lesions were represented by true marginal erosions. A para-articular

				lesion was also noted, but is most likely a pressure lesion (likely unrelated to the other marginal erosive pathology observed).
6096	MA	M	Unidentified, RS	KWK 6096 was a poorly preserved (few hands, feet, and spinal elements were preserved), but tufla resorption was observed in the 1st distal phalanx of the left foot. As tufla resorption can be a feature of SpA, the case was not excluded from the Reactive Suspect Count.
3272	UMA	M	Unidentified, RS	Criterion 5 (noted < 3X) A true marginal erosions was observed on the proximal articulation of the right 2nd metacarpal. The remaining lesions observed in KWK 3272 occurred in the feet. These were not true erosions, but areas with resorptive changes that followed along the joint margins (some bled onto the para-articular surfaces). The observed pathology of KWK 3272 was not characteristic enough for diagnosis, but was not excluded from the Reactive Suspect Count to provide benefit of the doubt.
3039	MA	M	Unidentified, RS	Criterion 4 & erosion The lesion on the left pisiform was noted. No other lesions were present in the extant elements of the feet and hands. Spinal preservation was very poor, so pathology could not be observed. Enthesopathy was present in both calcanei, affecting the posterior (insertion for the Achilles tendon) and inferior (insertion for the plantar fascia) aspects.
3182			Unidentified, RS	Criterion 1 & 4 DISH was diagnosed based on the spinal changes. Right SIJ fusion was observed, involving the inferior portion of the joint. The joint

				space was involved, which is not a normal feature of DISH. It is also possible the changes were degenerative. Extensive enthesopathy, with some characteristic locations were noted, but these locations can also be part of DISH. Para-articular erosion was observed in the right 1st metatarsophalangeal joint. Though this is not likely SpA, it was included in the Reactive Suspects to provide benefit of the doubt (similar action was taken in the control remains for York 3114).
3032	MA	M	Unidentified	Several erosions were noted in the right hand of KWK 3032, but many were associated with extensive degenerative changes, bringing the nature of the erosions into question.
3119	MA	M	Nonreactive	A porous, para-articular erosion was noted on the mediodistal surface of the left 1st metatarsal. The distal ends of both 1st proximal foot phalanges also displayed deep, round lesions on their articular surfaces. These erosions were not overly characteristic of gout, but their para-articular and articular expression make a nonreactive nature likely. For alternative diagnosis, degenerative changes could be responsible for the changes in the proximal foot phalanges.
3269	MA	M	Nonreactive	A lesion was observed on the articular surface of the distal right 5th metatarsal. The lesion was very round and deeply set, with smooth walls. Its location make Nonreactive Pathology likely, but it is suspected this is a pressure lesion.
3176	UMA	M?	Nonreactive	Gout? A para-articular erosions on the distal articulation of the left 1st metatarsal. The primary lesion had a punched out appearance. No other erosive pathology was observed. This is likely gout.

3168	MA	M	Nonreactive	A lesion was observed on the distal articulation of the right 1st metatarsal. The lesion occurred on the medial surface and was para-articular, deep, and somewhat elongated (groove-like) in appearance. Though the trabecular bone was exposed, the interior of the lesion was quite smooth. Gout could be one potential explanation, but the general shape of the lesions is more suggestive of a pressure lesion (bunion).