Trouble Breathing in Scandinavia: An Investigation of Respiratory Health in Nordic Europe

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Abstract

Through the use of dual sociocultural and environmental lenses this research attempts to shed light on the most overlooked segment of archaeological collections, the 'oldest old', and their possibly linked relationship with non-specific respiratory diseases. Based on an in-depth review of the current literature that examines medieval to early modern Scandinavian skeletal collections, potential patterns and gaps within these data will be interpreted. The results showed that although current medical research demonstrates that older individuals are disproportionally affected by respiratory diseases due to their age-related decrease in immune response and nutritional status, as well as their age-related increased pathological load (Weiskopf et al. 2009; Plackett et al. 2004; Castelo-Branco & Soveral 2014; Grubeck-Loebenstein & Wick 2002), no such validating work has been undertaken within a medieval or early modern context. Research could not be found that focused solely on the respiratory health of the elderly within these specific time periods and regions. This is despite recent calls for an increased focus on the 'Archaeology of Old Age' (Appleby 2010), as well as research suggesting that the sociocultural, and environmental circumstances of medieval and early modern Scandinavia were continuously influx, especially during both the Little Ice Age (LIA) and the Medieval Climate Anomaly (MCA), which may have caused individuals to be more susceptible to chronic infections like sinusitis, otitis media or mastoiditis (Fagan 2000; Campbell 2016; Glaser 1997). This thesis hypothesizes that the gap in the literature is due to a complex interwoven series of factors including the built-in biases that many age-at-death estimation methods demonstrate and the historical legacy of leprosy and tuberculosis in Scandinavia. Differences between rural and urban settlements and their effects on respiratory disease could not be identified in the literature until the late medieval and post-medieval periods as rural and urban housing resembled each other closely up until the early modern period in Scandinavia (Jordan 1996; Roesdahl 1999). This research therefore proposes that it may be a conglomeration of fluctuating social, political, economical, and environmental circumstances all cumulatively experienced by the oldest old in medieval and early modern Scandinavia which dictated how effective their bodies were at maintaining a healthy immune system and respiratory health as relatively high rates of respiratory infections could be found throughout both periods with a slight increase seen in the late medieval period.

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Chapter 1-Introduction

Respiratory diseases are amongst the most common pathologies to have afflicted both past and present populations around the world. The non-specific nature of most respiratory diseases consequently leads to all age and sex categories being affected by both acute and chronic respiratory infections. In general, respiratory diseases impact the upper and lower respiratory tract as well as other related structures like the sinuses and auditory canals due to the interconnected nature of these systems (Bernofsky 2010; Krenz-Niedbala 2017a; Roberts & Lewis 2002). Although respiratory diseases have the potential to affect anyone, they can be mitigated or exacerbated by a plethora of internal and external factors. These include previous respiratory infections incurred during childhood, a decrease in immune system function, poor air quality, and occupational pollutants and their cumulative effects on the health and well-being of individuals (Grubeck-Loebentein & Wick 2002; Plackett et al. 2004; Collins 2019; Lewis 2002; Primeau et al. 2018).

This is especially true for the oldest members of society (hence referred to as the 'oldest old') who may have been disproportionally affected by respiratory diseases due to their age-related decrease in immune response, compromised immune function and nutritional status, as well as their age-related increased pathological load (Weiskopf et al. 2009; Plackett et al. 2004; Castelo-Branco & Soveral 2014; Grubeck-Loebenstein & Wick 2002; Ortner 2003; Mays 1998; Bernofsky 2010, Thane 2005). Even with this knowledge, many respiratory diseases, and how they affected archaeological populations, are not very well understood. This is due in large part to their predominant involvement with soft tissues rather than the skeletal system.

Previous respiratory research done throughout Scandinavia has largely focused on tuberculosis and leprosy (Kelmelis & Pederson 2019; Kelmelis et al. 2020; Pedersen et al. 2019; Boldsen 2001, 2005, 2009; Boldsen & Freund 2006; Møller-Christensen 1951, 1952, 1953, 1958, 1965, 1978), and although leprosy is not respiratory in nature, it does attack the upper respiratory tract (Boocock et al. 1995; Bruintjes 1990). It is only within the last twenty years that researchers have slowly begun exploring the less commonly studied aspects of respiratory diseases in Northern Europe. These include maxillary sinusitis, otitis media, and mastoiditis which are all non-specific osseous reactions to respiratory infections in the interconnected nasal and tympanic cavities.

Maxillary sinusitis is found, as its name suggests, in the maxillary sinus. It is the largest of the sinuses and extends through most of the maxilla infraorbitally. Osteological manifestations of sinusitis only occurs when the mucous membrane found within the nasal cavity is chronically inflamed (Roberts 2007). It is only with chronicity that osseous manifestations of the infection occur in the form of "pitting, spicule formation, or white pitted bone" (Boocock & Manchester 1995: 486). Chronic otitis media and mastoiditis, a consequence of untreated otitis media, occur after the chronic inflammation of the middle ear affects the ear ossicles (the malleus, incus, and stapes) (Krenz-Niedbala & Łukasik 2017b). The changes in ossicle morphology primarily present themselves as pitting and erosive lesions while mastoiditis itself is the changing of the air-cell patterns within the mastoid (Bruintjes 1990). This type of chronic infection ultimately transforms the patterns from normal pneumatization to either diploic (partial or no pneumatization) or sclerotic (air-cells developed into hard/dense bone) (Gregg & Steele 1982).

A precursory glance through the current bioarchaeological literature shows that although these diseases have been thoroughly analyzed in juvenile and adult populations the same cannot be said for the oldest members of those collections (Bruintjes 1990; Bernofsky 2010; Collins 2019; Qvist & Grøntved 2000/2001; Primeau et al. 2018; Bennike et al. 2005**;** Sundman & Kjellström 2013a/b; Eriksson 2019). The 'oldest old' should be given more consideration, not only in bioarchaeological work, but within respiratory research, due to their heightened susceptibility to respiratory infections and increased pathological load which could have been brought on, along with a myriad of previously discussed factors, by a change in sociocultural status (Weiskopf et al. 2009; Plackett et al. 2004; Castelo-Branco & Soveral 2014; Grubeck-Loebenstein & Wick 2002; Boldsen 2008). As an individual ages, their status and position in society undoubtedly shifts and changes along with their deteriorating health status. An individual who may have once enjoyed the comforts of an elevated social class may now find themselves cast out of their previous social groups due to a decline in health.

For example, a prominent weaver who once belonged to a thriving group of craftspeople, can no longer efficiently continue to weave due to loss of finger dexterity and vision. These physical hinderances force them out of their social circles as well as their socioeconomic group as they can no longer perform their work and provide for themselves. This loss of income may then lead to the individual losing the comforts once familiar to them and force them into unknown circumstances which are accompanied by increased rates of morbidity. An individual's increased risk of morbidity and deteriorating biological status are therefore intertwined with social and cultural circumstances (Appleby 2010).

The main goal of this thesis is to ascertain whether the oldest old of society would have been differentially affected by non-specific respiratory diseases in Scandinavia, as well as how these diseases have been researched within medieval/early modern Scandinavia. Data have also been collected and analyzed from England in order to provide perspective for work done in Scandinavia. Based on the in-depth review of the current literature, potential patterns within these data will be explored. The medieval and early modern periods were chosen as the periods of focus for this project due to the availability of comparable respiratory research and the perceived quantity of data that would be available to form such a literature review. As the reader will discover throughout this thesis, even with the focus remaining on these well researched eras of history a dearth of non-specific respiratory research was still an issue that needed to be circumnavigated.

This research will provide the most up to date, and only, significant literature review of non-specific respiratory research undertaken throughout the entirety of medieval/early modern Scandinavia, and its many medieval acquisitions. This study, therefore, can guide future researchers towards work that still needs to be done to fill in the gaps in the current bioarchaeological literature. Most importantly, this review will also attempt to shed some light on the most overlooked segment of any archaeological collection, the ‘oldest old’. Moreover, by conducting this research using sociocultural and environmental lenses, aetiological factors influencing the prevalence rates of non-specific respiratory diseases, such as urban vs. rural living, will be explored.

Chapter 2-Respiratory Diseases

Respiratory diseases, identified as upper and lower respiratory tract infections, are among the most common of ailments afflicting both past and present populations (Bernofsky 2010; Sundman & Kjellström 2013b; Roberts 2007). This may be due to the non-specific nature of respiratory diseases and the numerous possible aetiologies that may cause them, including congenital predispositions, poor dental health, asthma or chronic allergies, infectious diseases, as well as environmental and sociocultural factors (Lewis et al. 1995; Roberts 2007). Despite this long list of differing causal factors, bone can only react in a limited number of ways and patterns quickly emerge based on which bones are involved and the type of lesions present. Therefore, it is typical to find a correlation between chronic forms of respiratory diseases and manifestations of maxillary sinusitis, otitis media, and mastoiditis (Bernofsky 2010; Krenz-Niedbala 2017a; Roberts & Lewis 2002).

The maxillary sinus, or the Antrum of Highmore, is one of four pairs of paranasal sinuses, with the other three being the frontal sinuses, located above the eyes, the ethmoidal sinuses, located between the eyes, and the sphenoidal sinuses, located behind the eyes (Boocock et al. 1995). It is the largest of the paranasal sinuses, and although it does fluctuate in size and shape, it typically inhabits most of the maxilla and has four walls that are contained by the nasal (medial), orbital (superior), anterior (maxillary), and infratemporal (palatine/alveolar) portions of the maxilla (Roberts 2007; Richer 2015).

A normal, healthy sinus will be smooth in texture and have channels running along its walls for nerves and blood vessels (Lewis et al. 1995). It is also common for the infratemporal wall of the sinus to be remodelled because of the close relationship between this portion of the sinus and the roots of the maxillary molars (Lewis et al. 1995). Therefore, it is not out of the ordinary to have a marked sinus floor. The maxillary sinus' function as a mucous-lined air cell, acts as the body's first line of defence against any airborne particles or pathogens. The sinus uses the mucous it creates to trap foreign bodies and act as a barrier against factors such as infection and trauma (Brandtzaeg et al. 1996; Merrett & Pfeiffer 2000; Roberts 2007). The mucus is then carried against gravity by the cilia through the sinuses' only opening, the ostium, and into the middle meatus (the middle segment of the nasal opening) (Roberts 2007; Sundman & Kjellström 2013a; Merrett & Pfeiffer 2000). In a healthy host, the mucous will usually be replaced every twenty minutes, with the cilia removing upwards of "90% of particles that are roughly 2.5-9 μm in diameter every 6 hours" (Roberts 2007: 794). There are also many other systems in place to protect the host from respiratory infections, such as lysozymes and lactoferrin proteins which help remove bacteria from the upper respiratory tract and boost the hosts' natural immunity (Kaliner 1992).

The osseous manifestations of sinusitis, which are the result of chronic inflammation in the sinus tissues (Roberts 2007), only begin to occur when the ostium is blocked. This causes an inability for the fluid to drain and build up within the sinus which makes it possible for bacteria to multiply and cause damage to the fragile tissues (Merrett & Pfeiffer 2000; Roberts 2007). Examples of such bacteria include *Staphylococcus aureus, Streptococcus pneumoniae,* *Haemophilus influenza, Streptococci,* and *Pneumococci* (Lewis et al. 1995; Sundman & Kjellström 2013a; Wald et al. 1981). The bacteria then trigger inflammation to the mucous membrane and since the mucosa of the sinus is bonded to the periosteum, chronic inflammation can lead to bony changes (Sundman & Kjellström 2013a/b). A chain of events is then set into motion as sinusitis will disturb the fragile ecosystem within the paranasal sinus and may lead to permanent damage in function and a decreased host response (Merrett & Pfeiffer 2000: 304; Kaliner et al. 1997). These events may then lead to a decrease in host immunity and increase the chances of re-infection later in life.

Another avenue of infection is through an oroantral fistula, which is a small hole or ulcer, that is typically caused by abscesses, and opens the sinus to the bacteria commonly found within the mouth (Sundman & Kjellström 2013; Lewis et al. 1995). When the connection is made between the maxillary teeth and the sinus it then becomes much easier for any type of dental disease to cause a secondary infection within the maxillary sinusitis. For example, a lack of dental hygiene could result in increased rates of abscesses, caries, chronic periodontitis (a gum infection), and antemortem tooth lose which all have the potential to develop into maxillary sinusitis. Moreover, these factors increase drastically with age as cumulative episodes of poor dental health, and many decades worth of dental disease may limit the host's ability to fight infection and deteriorate the integrity of surrounding bone (Merrett & Pfeiffer 2000: 315). It may also mean that an odontogenic aetiology may have played a much larger role in sinus infections in comparison to modern first-world countries (Panhuysen et al. 1997; Boocock et al. 1995).

Although bacterial infections have been previously mentioned as an aetiological factor for respiratory diseases, they are not the only causal agent of sinusitis. Poor air quality in outdoor and indoor contexts, changes in climate, (in)organic gases like tobacco/fire smoke, and allergenic substances like pollen can all irritate the respiratory tract and cause sinusitis (Roberts 2007; Merrett & Pfeiffer 2000). These factors, among many others, would have all impacted archaeological populations with different levels of significance, especially when comparing rural and urban communities. In many circumstances it is expected that rural and urban living conditions differed drastically during the medieval period, but in actuality urban and rural housing resembled each other closely, but this will be further investigated in later sections.

There are several popular systems in place to aid researchers to classify the severity and type of osseous changes associated with maxillary sinusitis. There is none more popular than the system conceptualized by Boocock et al. (1995) who investigated the aforementioned pathology in individuals suffering from leprosy in medieval England. Their system is widely used as the standard descriptor for maxillary sinusitis and is referenced by most modern research papers. These authors describe maxillary sinusitis "as pitting and new bone formation caused by inflammation" (Boocock et al. 1995: 484). Their system, which is widely based on appearance, classifies the bony responses into one of four specific categories: "pitting, spicule-type bone formation, remodelled spicules, and white pitted bone" (Boocock et al. 1995: 486), which are more thoroughly described in Table 1.

Bony response	Comment
Pitting	Fine pits often seen in association with other types of bone change
Spicule-type bone formation	Thin spicules of bone that appear on the original bone surface with a honeycomb-like appearance
Remodelled spicules	Remodeled the walls of the sinus, merge and become wax or plaque-like
White pitted bone	Highly pitted, discrete areas of bone change

Table 1: Bony responses associated with Maxillary Sinusitis (Boocock et al. 1995: 486).

Although Boocock et al.'s (1995) system is indeed thorough, consideration for severity is largely omitted from their system. Sundman & Kjellström (2013a) provide this pertinent information in their own research on prevalence rates of maxillary sinusitis in a Swedish population. In an effort to further elaborate on Boocock et al.'s (1995) earlier work, this updated research utilized the previously established categories of "pitting, spicules, remodelled spicules, white pitted bone, and other" (Sundman & Kjellström 2013a: 450) and added severity scores to each type of bony change. These scores greatly depend on the proliferation of the lesions themselves and are scored on a scale from zero to three. Zero meaning there was no observable change seen on the bone while three signifies extreme change of the structural integrity of the bone (Sundman & Kjellström 2013a).

Other types of osseous lesions found within the maxillary sinus were described by Merrett & Pfeiffer (2000) who analyzed the Uxbridge skeletal collection. They began by describing three new lesion types: cysts, plaques, and lobules. These bony manifestations are typically used to describe pathognomonic changes seen in cases of periosteal new bone formation but were also found to represent the changes witnessed within cases of maxillary sinusitis.

Cysts are described as “hemispherical depressions in the bone, with a smooth interior surface and no bony projections” (Merrett & Pfeiffer 2000: 308). They are not to be confused with pits, which represent holes or indentations caused by bone resorption (Merrett & Pfeiffer 2000). Cysts are associated with an osteoblastic process which means that they are classified by the amount of bone that is deposited, while pits are purely resorptive in nature which means that they eat away or destroy the underlying periosteal bone. Pits are also variable in size and have the potential to morph into holes that can range anywhere from 1mm in diameter to upwards of 3-5mm (Merrett & Pfeiffer 2000). Plaques are also variable in nature and differ in their thickness and texture with some iterations presenting as smooth and dense while other manifestations are more porous. Generally, plaques are described as sheets or patches of osseous disturbance. Plaques will typically affect a larger area of bone in comparison to cysts or spicules, but this factor should not be taken as a proxy for a more serious infection. Lastly, lobules are curved accumulations of bone (Merrett & Pfeiffer 2000). These detailed descriptions on the appearance, severity and placement of these lesions will allow for positive diagnoses to be made.

Closely related to the nasal cavity is the tympanic cavity and the middle ear system, which is where chronic otitis media and mastoiditis, a consequence of untreated otitis media occur. These two structures, the nasal and tympanic cavities, are connected via the auditory tube, also known as the Eustachian tube, which is a small, angled tube roughly three to four centimeters in length and only a few millimeters in diameter (Daniel et al. 1988). The Eustachian tube “extends from the nasopharynx [which connects to the nasal cavity and is the upper part of the pharynx] to the anterior wall of the middle ear cleft” (Daniel et al. 1988: 144) and is the only canal that connects the two systems together. The tube itself is lined with mucous and helps to equalize the pressure in the middle ear, but its primary function is to drain the middle ear while also protecting the fragile structure from outside forces like fluctuations in pressure (Daniel et al. 1988; Todd 1983, 1986).

The Eustachian tube, and the mastoid process, are the two main culprits for infections in the middle ear. In terms of the former, it is the canal’s morphology that causes issues as proper draining of the middle ear is facilitated by the 45° angle of the tube but when that angle is decreased or completely omitted, drainage cannot be accomplished, and bacteria are allowed into the tympanic cavity (Flohr & Schultz 2009). This may contribute to increased rates of middle ear infections in children, since morphologically this structure in children is much shorter, wider, and situated more horizontally which makes aeration and drainage nearly impossible (Daniel et al. 1988). Although children are much more susceptible to inner ear infections, the effects of chronic inflammation do not appear as permanent osseous lesions until adulthood (Primeau et al. 2018). Adults are much more susceptible to inner ear infections if they have previously suffered damage through childhood manifestations. The connection between childhood infection, frequently occurring in the first four years of life, and adult expression of otitis media is thusly established (Gregg & Steele 1982).

Otitis media which begins as the chronic inflammation of the middle ear affects the ear ossicles, the malleus, incus, and stapes (Krenz-Niedbala & Łukasik 2017b). The inflammation is not limited to the mucous membrane though and can also spread to the mastoid process and attack the mucous membranes within this connected structure (Flohr & Schultz 2009). It is this chronic inflammation of the mucous membranes that ultimately cause alterations to the underlying bone in both the mastoid's air cells, and the ear ossicles in the middle ear. Middle ear pathologies are typically difficult to assess since the ear ossicles are one of the most commonly lost elements of the skeleton, in part, due to their size and fragility and it is even more rare to recover all six ossicles from both inner ear cavities.

The malleus, incus, and stapes, with the stapes being in the most medial position, form a chain in the middle ear cavity that aids in the "transmission of sound from the tympanic membrane to the cochlea" (Krenz-Niedbala & Łukasik 2017b: 375). The head of the malleus and the body of the incus are connected through a set of facets and both ossicles are located at the top of the eardrum cavity. While the lenticular process (a knoblike bone located at the distal end of the long process) of the incus articulates loosely to the head of the stapes which sits horizontally and at a right angle to the long process of the incus. The auditory ossicles, particularly the malleus and the incus, differ uniquely from any other bone in the human body as they virtually have no "marrow cavities [and are] suspended freely in the tympanic cavity by the ligaments enveloped only in a thin mucosal lining" (Qvist & Grøntved 2000: 83-84). This differs from other skeletal elements whose cartilage is typically replaced by bone during ossification, unlike the ossicles which retain their cartilaginous elements. This retention of cartilage may be an evolutionary response to the extreme wear and tear ossicles undergo throughout an individual's lifetime.

There is some disagreement in relation to how otitis media affects the ear ossicles as differing reports often tend to contradict each other. For example, according to Krenz-Niedbała & Lukasik (2017b: 379) the auditory ossicles are often disproportionately affected by infection with the "long process of the incus and the head of the malleus [being] most commonly effected". However, Qvist & Grøntved (2000) and Bruintjes (1990) state that it is actually the stapes that is most commonly affected as it is the most fragile of the ossicles and would be the first to show any type of lytic or proliferative lesions. Since a unanimous decision has not been reached on the subject of preferential effects of infection, all three ear ossicles should be analyzed thoroughly for any erosive or proliferative lesions.

Irregular lesions are rarely found to affect the ear ossicles, meaning any lesions found on these bony elements are typically associated with inner/middle ear infections, which are ultimately brought on by upper respiratory tract infections. Such lesions can vary widely and include changes in "morphology, pitting, and bone erosion" (Bruintjes 1990: 631) and are the result of osteitis and chronic inflammation of the middle ear. Any lesions that are found on the ossicles should also be examined with post-mortem environmental processes in mind since they are so fragile in nature, they are susceptible to damage caused by a number of environmental factors including soil pH or sun damage. More importantly, ossicles are also commonly damaged through human manipulation and excavation methods which may camouflage any pathological damage.

Reoccurring bouts of acute or chronic otitis media can ultimately cause the later development of mastoiditis, which is the altering of the air-cell patterns within the mastoid (Wittmaack, 1918, 1926). Anatomically speaking the middle ear cavity is connected to the "antrum above, and the pneumatized spaces (cells) in the mastoid, and the pyramid" (Flohr & Schultz 2009: 266). It is this connectivity that allows chronic middle ear infections to also result in a secondary infection of the mastoid process called mastoiditis. Due to infection, air cell patterns in the mastoid go from normal pneumatization to either diploic (partial or no pneumatization) or sclerotic (air-cells developed into hard/dense bone) (Gregg & Steele 1982; Wittmaack 1918; Wittmaack 1926). This can also lead to reoccurring bouts of infection in the mastoid since the mucous membrane has been compromised and can no longer efficiently fight off infection.

A pneumatized air cell pattern often represents a healthy mastoid which has not undergone reoccurring episodes of infection, or at least not at the time of air cell development during early childhood years (Gregg & Steele 1982). Healthy air cells will resemble a large and irregular honeycomb pattern (Gregg & Steele 1982). A diploic pattern signifies that no or only partial pneumatization occurred, meaning that the cavity in which the air cells are located is empty (Gregg & Steele 1982). This could be interpreted as the pathological process interrupting air cell development and completely halting the process, leading to an empty cavity. Sclerotic patterning is defined as "hard, dense bone in the vicinity of the middle ear, usually indicating the results of frequent or severe OM" (Gregg & Steele 1982: 460). To elaborate further, this also indicates that no pneumatization of the cavity occurred, rather it was entirely filled with bone instead of the typical air cells. Lastly, a mixed pneumatization could include variations of pneumatic, sclerotic, and diploic patterns and most likely occurred while pneumatization was in the process of occurring (Gregg & Steele 1982). Visually, this looks as if the pneumatization process had been paused and replaced with another as parts of the cavity will have healthy air cell patterns while other segments will be completely hollow or entirely filled in with bone. These changes in air cell structure are indicative of mastoiditis and will aid in the positive identification of not only this particular process but also a more general respiratory infection occurring.

While the ear ossicles are fully developed in prenatal life, and show little morphometric variation amongst individuals, (Krenz Niedbala & Lukasik 2017b) the air cell pattern within the mastoid itself only fully develops around puberty when pneumatization is complete in the petrous apex (Cinamon 2009). It is this prolonged development process that puts children at a greater risk for infection and ultimately, permanent osseous damage. Irregular or asymmetrical air cell development is highly unusual in the mastoid, which also makes mastoiditis along with otitis media an easy and reliable identifier of respiratory infection in any individual afflicted by these pathologies, including the oldest old (Primeau et al. 2018).

Chapter 3-Old Age

Introduction

The fundamental goal of any age estimation method is to use morphological variation in the human skeleton to determine biological age and to establish universally applicable criteria for such changes (Ortner 2003). Unlike age estimations that are applied to subadults, adult age estimations cannot be based on developmental changes. Therefore, age estimations must be based on the amount of degeneration seen, which has the potential to introduce error and bias into any methodology used (White & Folkens 2005; Milner & Boldsen 2012a; Buckberry 2015; Gowland 2007). Degeneration can be caused or swayed by an infinite amount of external and internal factors. These can include factors such as "activity, diet, disease and genetics, at both the individual and population levels" (Cave & Oxenham 2014: 613-614). This would result in immeasurable different ways that age can be expressed in each individual as they go through their unique life courses (Appleby 2011). These factors also have the ability to decrease the reliability of age estimations drastically after the age of 45-50 years (Cave & Oxenham 2014; Aykroyd et al. 1999). As it is now understood, the correlation between chronological age and biological age widens as an individual ages, with accelerated speed in the 50+ range as discrepancies begin to accumulate (Ortner 2003; Mays 1998).

Concept of Age

Age itself is a somewhat ambiguous term and can be difficult to quantify through the analysis of archaeological remains. This is due to the misunderstanding of the basic term as well as its socially constructed nature. Age is not an all-encompassing status; rather there are several different types of age which heavily fluctuate in use and relevance between time periods and cultures. These can include chronological, biological, and social age.

Chronological age "refers merely to age in years, defined according to the calendar… it is an unchanging measurement of the passing of time according to regular, scientifically defined principles" (Appleby 2010: 149). This specific concept of age is wholly a human construct, and a fairly recent one at that with numerical ages only being recorded in Scandinavia starting in the 17^{th} century (Welinder 2001; Kertzer & Laslett 1995). It is one modern societies use to keep track of the progression of an individual's age (Appleby 2017). Although the measurement of chronological age is an anthropocentric idea, it has regularly been applied to other nonhuman entities in order to measure their age, including animals, plants, and most significantly, archaeological material (Appleby 2010; Ginn & Arber 1995). It is also not a concept thought to hold as much weight in past societies as other models, such as social age. Its added value to an individual's sociocultural significance was largely limited to certain classes of society or situations, such as marriage or other legal affairs (Appleby 2017). This is not to say that past individuals did not know or care about their chronological ages, it is merely to say that their social or biological ages, may have held more importance as it dictated larger aspects of their everyday lives and how they were perceived within their social groups. As chronological age is a human construct, it is also therefore an arbitrary and ever-changing concept that shifts meaning and significance within every culture.

For clarification, if present ideals of age are created using social principles, then it can be assumed that they were thusly perceived as such in the past as well (Lucy 2005: 43). It is crucial for present day researchers to recognize that the concept of age is not fundamental to human existence, but rather an idea that is constantly in flux. Chronological age has also been wrongly mistaken for biological age, but there is a clear distinction between the two. For example, two individuals with the same chronological age will have drastically different signs of skeletal degeneration due to their unique life experiences and will thusly be given different biological ages (Appleby 2010: 148). Furthermore, it has been shown that "less than half (Nawrocki 2010) or ~30% (Jackes, 2000) of the variability in age indicators are associated with chronological age" (Mays 2015: 333). This may explain in part why a discrepancy is present between the chronological age most current ageing methods produce and the individual's true biological age (Fortes 1984; Gowland 2007). Therefore, biological age and not chronological, should be the basis for any age-estimation method.

Biological or social age would have held more weight in past societies as these types of ages would have affected an individual's ability to function in their day-to-day life and would have determined their place within their communities. In terms of biological, or physiological age, conceptually this type of ageing can be described by examining the degenerative processes found on the skeleton (Appleby 2010). It is this degeneration that researchers measure when estimating age in adults as they do not have the information needed to determine chronological age (Welinder 2001). A caveat to this statement would be that although the relationship between skeletal 'age indicators' and chronological age is quite close in younger individuals the divide between the two progressively grows as individuals age (Appleby 2017). It is the condition of the body's internal systems including skeletal, immune, muscular, and many more that determine an individual's biological age. More specifically it is the system's level of degeneration, or senescence, that helps to quantify biological age. Therefore, in order to create a whole picture of an individual's age, it is necessary to consider all categories of ageing including chronological, social, and biological in order to properly understand the ageing process and correlate it to physical appearance and physiological function.

Due to the highly social nature of ageing, social identity must be taken into consideration when examining an individual's skeletal remains. A certain age identity is not a static characteristic but is rather very fluid as old age is a social idea and is constantly being renegotiated (Appleby 2011). This makes the distinction between the 'young old' and the 'oldest old' so important to archaeologists because it would have been just as equally, or perhaps more, important to the society itself and to the lived experience of the individuals being studied. For example, the distinction between the 'decrepit' oldest old and the 'young' old becomes culturally significant when productivity becomes affected (Thane 2005). One category is still able to contribute valuably to the group, while the former needs to be taken care of which further takes away an able-bodied individual from continuing on their normal everyday tasks, ultimately losing the work and contributions of two or more people depending on the amount of care the elderly individual needs. This is not to say that the oldest old could not have still contributed to the group in valuable ways, it is simply to say that their contributions are culturally variable in and of itself (Sofaer 2011).

An individual's social age is not determined as a specific number at all but rather, how an individual sees and portrays themselves as well as how they are variably depicted in their sociocultural circle (Ginn & Arber 1995; Agarwal & Beauchesne 2011). Social age is also dependent on the individual's life experiences and the development that subsequently occurs (Sofaer 2011). Therefore, development is just as much defined by biological growth as it is the cultural experiences an individual partakes in (Sofaer 2011). For example, some cultures base social age on body modification rituals, which are largely centred on the cultural and development progress experienced by the individual. Therefore, social age can be interpreted through the major events and rites of passage (marriage, menstruation) that occur throughout an individual's lifespan (Sofaer 2011). Perhaps social age best explains the notion that aging cannot be categorized nor labeled in definite terms, rather it is an ever-evolving process, one that spans much longer than biological or chronological age.

The development and maintenance of the human skeleton is not only formed by biological process but rather it is largely shaped by the social and cultural activities that the individual undertook while they were alive. In other words, the skeleton is highly malleable and is largely the product of the cumulative biological and sociocultural influences experienced throughout a lifetime (Agarwal & Beauchesne 2011). Age is not a singular identity but is inextricably intertwined with other characteristics such as "gender, kinship, social status, rank, ethnic and religious affiliation" (Appleby 2010: 152). It is a status an individual achieves with the experiences they undergo throughout their lives and is unique to every individual (Welinder 2001; Sofaer 2011). It is also believed that an individual's social life spans past their biological or personal lives as their memory will live on within their community after they have died (Sofaer 2011).

This last categorization of age would have played a heavy role in past societies as social age would have depicted, and been used as proxy for, an individual's worth to their own community (Thane 2005). In today's society social age is not the principal way in which individuals are aged, but it does still hold importance in society's judgement of them. It is also important to recognize that although age can be categorized in several different ways, and each play an important role in determining an individual's identity, they are all experienced together and should therefore be studied as such (Appleby 2017).

Social age is also often judged based on societal opinions of physical or biological changes (Sofaer 2011). For example, age can be interpreted through an individual's "appearance, bodily functions, age-related disease, and skill" (Appleby 2017: 145). A change in physical appearance is often one of the most visible signs that an individual has undergone ageing. These changes can come in several different forms including, changes to the hair (colour and fullness), skin (wrinkles, age spots), loss of vision or antemortem tooth loss, and/or a degeneration of fine motor skills and dexterity (Appleby 2017). Archaeologists can thus learn valuable information through the way past societies depicted older individuals in their writings or paintings/drawings and can decipher that society's attitude towards certain age-related physical changes through which characteristics they chose to highlight in their material recordings (Appleby 2017). As every individual will experience degenerative changes in a unique way, this creates heterogeneity amongst the oldest adults. This ultimately leads to individuals reaching certain chronological milestones at different times throughout their lives which increases the interpretive gap between chronological and biological age.

Overall, the concept of age has changed and evolved throughout time with different interpretations of the term holding and losing prevalence throughout the centuries. During the Middle Ages, in England (approx. 5th-15th c.), it was thought rare to survive to be 'old' as it was previously estimated that the elderly represented no more than 8% of society, with this number fluctuating during periods of disease (for example, plague) (Shahar 2005; Thane 2000). This estimate is based on the work of local historians who in the mid-1960s investigated and recorded hundreds of baptismal, burials, and marriages from English parish registers (Wrigley & Schofield 1989). These records, in the form of monthly tallies of births, deaths, and marriages were then used to recreate the English population history from 1541-1871 by using the back projection method of reconstructing population data like population size and life expectancy at time of birth (Wrigley & Schofield 1989). These types of estimations should be used apprehensively though, rather than as an accurate representation of the demographics of medieval society. In many cases, these estimations are based on medieval records which are limited or incomplete in nature. This is especially true of primary records from medieval kingdoms like Denmark, as primary sources that discuss demographics are few and far between and could be biased due to a lack of thorough population representation, inefficient/incomplete recording methods, and the historian's own interpretation of the oldest old. Therefore, the applicability of this estimation to medieval Denmark and its overall accuracy should not be taken as fact, but rather a limited approximation.

Old age and its relationship with social identity has constantly evolved through time and has been difficult for historians to ascertain based on the limited sources they have. The next few paragraphs in particular discuss, in general terms, how some elderly people would have been treated in Christian societies. These are not meant to be taken as proxy for how every society treated their elderly but merely to be an example of how these historians chose to interpret the information collected from specific primary sources. In general, the way the elderly were treated differed greatly depending on the period and the prevailing social views of the time. For example, due to the perceived lack of older individuals (50+) throughout Western Europe in the medieval period those that did survive into late adulthood were thought to become closer to God and live a more quiet and spiritual life (Shahar 2005). The negative impacts that came with old age were meant to be seen as inevitable and accepted with gratuity (Shahar 2005).

This tie to religion permeated through to the 17th century as the elder of any Christian household was to be revered and treated with the utmost respect (Botelho 2005). It was a Christian's duty to help and give alms to the elderly and destitute. This was heavily dependant on the person's occupation, social status, wealth, religion, and sex as these factors determined how they were treated by mainstream society (Botelho 2005). It was also a time in which Scandinavia's population was greatly patriarchal, which meant that certain individuals, especially poor women, were not granted the same amenities in their old age compared to their male counterparts (Botelho 2005). It seems that these evolving views on old age may have been linked to the steady climb in population numbers which continued into the 18th century. More people were surviving into adulthood in this period and attaining old age was therefore not something to be revered anymore.

In the 18th century older individuals lived in a proto-industrial society that fully embraced urbanization (Troyansky 2005). The elderly were therefore expected to live more independent and autonomous lives as old age became a state that was more manageable. The 18th c. was also a time of great developments in the welfare of the elderly as public service pensions and social welfare programs were made popular in this period (Troyansky 2005). Medical developments took root within the 18th century that improved the quality of life for the elderly and focused less on preventing old age and more on how to manage it (disease, diet, health) (Troyansky 2005).

As shown throughout this section, age is a very complex and multifaceted concept. It is not a single identity but rather several that converge together to create part of an individual's distinct persona. Due to the many ways of quantifying age, if one were to only look at one of the previously mentioned aspects of age it would create a very narrow image of that individual which would not have very much archaeological value because of the missing context. Age should be investigated collaboratively with other sub-disciplines in archaeology, history, sociology, and the biological sciences, as they can all help to form a clearer and more detailed picture of 'age' as it was thought of throughout the past (Hoppa 2002). Archaeologists therefore have a unique obligation to portray age, and other such aspects of a person's identity in an accurate manner; one which ensures that present biases are not thrust upon past societies and instead examined impartially. The culture one lives within ages them as significantly as time

(Arber & Ginn 1991). No truer statement exists as biological and osteological age are only as important as the society they exist within allows them to be.

Correlation Between Older Age and Increased Risk of Morbidity

One connection that has yet to be made is the one between older adults and their increased vulnerability to respiratory diseases. The potential impact of respiratory diseases on an older individual's health will also be discussed in order to identify any potential connections between age and increased morbidity/mortality rates. A necessary factor that affects morbidity and mortality within any at-risk group is the amount of exposure to the causal agent. This is often greatly dependent on human culture and the circumstances that certain individuals experience throughout their lifetimes. For example, it was once believed that individuals who predominantly spent their time indoors, like women and the elderly, were spending more time being exposed to the harmful effects of smoke (Ortner 1998). This is no longer the prevalent theory though, as women and the elderly were not always forced to work indoors, but rather they spent much of their time outdoors, working around the farm and contributing to its daily upkeep (Shapland et al. 2016).

Biological factors also influence morbidity rates in older individuals and such factors can include a weakened immune system and compromised immune function. These factors would have severely diminished their body's ability to fight off reoccurring or long-lasting infections. There are several processes and systems within the human body that are set up to protect the individual from an increased pathogen load and associated infection process. Many of these systems are significantly compromised in the elderly which heavily contribute to the process of immunosenescence and increased levels of infections (Castelo-Branco & Soveral 2014). Immunosenescene is the process of age-related decline in immune function which makes older individuals more vulnerable to infections and diseases (Appleby 2017). For example, T and B cells are part of the body's immune system and help protect it from infection. In the elderly the number and diversity of these cells drastically reduce and those that are produced are often functionally defective, meaning the cell's ability to properly respond to new or chronic infections is hindered (Weiskopf et al. 2009; Castelo-Branco & Soveral 2014; Grubeck-Lobenstein & Wick 2002).

The decrease in immune function in the oldest old may also make these individuals more susceptible to secondary or reoccurring infections (Grubeck-Lobenstein & Wick 2002). Macrophages, the cells responsible for inflammatory responses against antigens, are functionally compromised in the elderly, meaning infections are more likely to become chronic which further burdens the aged immune system (Weiskopf et al. 2009; Plackett et al. 2004; Castelo-Branco & Soveral 2014). Furthermore, the first line of defence against infections are the epithelial barriers in the skin, lungs, and gastrointestinal tracts; many of these barriers are functionally deficient in the elderly (Weiskopf et al. 2009).

It is oftentimes the accumulation of previous assaults on the immune system interwoven with the age-related breakdown of the components of these systems that leads to the increased susceptibility of the oldest old to new pathogens and poorer responses to chronic infections (Castelo-Branco & Soveral 2014; Weston 2008; Roberts & Manchester 1997; Appleby 2010; Gowland 2016). This increased risk of morbidity is also intertwined with social and cultural circumstances as lower-class individuals who lived in more vulnerable sociocultural circumstances could have been exposed to higher pathological loads than their higher-class counterparts. These individuals were also more likely to be under severe stress during childhood, which contributes heavily to the decline of adult health.

When one looks specifically at respiratory diseases, patterns within the published data point to a correlation between increased levels of infection within the ‘oldest old’ and earlier bouts of childhood sickness (Primeau et al. 2018; Boldsen 2007). For example, in relation to otitis media and subsequently mastoiditis, these disease processes alter the patterns of pneumatization of the mastoid air cell system, which is a process that typically only occurs in the first four years of life (Collins 2019; Qvist & Grøntved 2000/2001; Flohr & Schultz 2009; Bruintjes 1990). Although otitis media is most prevalent in infants and children, its chronicity is what ultimately leaves permanent damage visible later in life (Qvist & Grøntved 2000/2001; Flohr & Schultz 2009). Therefore, it is the chronic version of otitis media and mastoiditis, that results in the skeletal changes seen in older adults, but it is the original bout of infection that leaves the individual more susceptible to inner ear and respiratory infections because of the compromised air cell patterns (Daniel et al., 1988; Gregg & Steele 1982). Hence creating a connection between original infection and continued susceptibility and increased morbidity.

Chronicity is a major contributor to the breakdown of health and immunity seen in older individuals as the constant stress put on the individual may lead to the collapse of the body's many systems including its immune response (Goodman et al 1988: 173). The total breakdown of an individual's immune system is heavily dependent on the stress load experienced by that individual and its interactions with factors such as genetic susceptibility, age, and sex (Goodman et al. 1988; Appleby 2011; Bernofsky 2010; Weiskopf et al. 2009). Having said this, increased susceptibility and morbidity is not only influenced by an individual's biological state, but external factors like unstable socioeconomic conditions will also heavily influence the way older individuals are able to adapt and adjust to their surroundings, perceived stress, and any pathological threats. It is the individual circumstances someone lives in, which will dictate how effective their bodies are at maintaining a healthy immune system, good respiratory health, and will lead them to being less susceptible to chronic pathological infections (Lee 2012). Therefore, it is crucial for researchers, when looking at any demographic patterns concerning a pathological condition, to consider the sociocultural context in which that individual may have resided. It is these types of external stressors (i.e., persistent poverty as a constraint) and their "biological costs" (Goodman et al. 1988: 192) that will ultimately determine the health status of an individual. Therefore, increased prevalence rates of respiratory diseases are not an overarching development that accompanies older age but are heavily dependent on the sociocultural circumstances of the particular individual or population.

Although not abundant, there are a few studies that have found correlations between old age and increased infection rates of respiratory diseases in the medieval period. For example, Panhuysen et al. (1997: 612) found that "statistical analysis showed a strong correlation between an increase in age and dental pathology and associated sinusitis." While Flohr & Schultz (2009) found much the same results when they studied the prevalence of mastoiditis in two early medieval cemeteries in Germany. They found that the relationship between altered pneumatized air cells and biological age increased significantly (Flohr & Schultz 2009).

The 'Invisible Elderly'

There are several prevailing theories as to why the oldest segments of any archaeological sample have been systematically overlooked within the bioarchaeological literature. In part, this may be due to the methods used to age skeletal remains; if these methods are fundamentally biased, then it comes to reason that their results would also reflect this bias. It may also be due to the false assumption that individuals could not have survived without the current level of medical care and sanitation that is available today (Cave & Oxenham 2014: 164). The negative stereotype that accompanies old age as a "period of increasing incompetence and dependency" has also greatly biased current attitudes towards the elderly (Appleby 2011: 233). These reasons help to explain why, even though it has been demonstrated time and again that individuals could have survived into their elderly years during the medieval period, older individuals are seldomly visible within the demographics of archaeological populations, and if they are, they are spoken of as great anomalies (Welinder 2001; Cave & Oxenham 2014; Appleby 2017; Appleby 2010).

There are many reasons why the elderly have become invisible in the archaeological record. The first is the misinterpretation of the term 'average age at death' (Cave & Oxenham 2014; Smith et al. 2017; Appleby 2017). Although many cemetery collections may be classified as having a 'low' average age at death, it does not mean that there were no older individuals in that archaeological population; it simply means that high levels of child mortality greatly reduced the collection's average age at death (Shahar 2005; Gurven & Kaplan 2007). Infancy was the period in which an individual had the greatest risk of dying simply because of the child's vulnerability and lack of immune response to the world around them. If that infant survived and reached adulthood, they had a good chance of surviving into their elderly years (Smith et al. 2017; Mays 1998; Shahar 2005). Therefore, although more infants and children died compared to any other demographic category, this should not be interpreted as there being no older individuals living in the archaeological past. Older individuals would have represented an integral segment of past societies, albeit much less frequently (Thane 2005, Shahar 2005, Appleby 2017, Appleby 2010).

Another factor leading to the omission of the elderly in the archaeological record would be the methodological problems in age estimation techniques which tend to underestimate age based on the skeletal evidence (Cave & Oxenham 2014; Boddington 1987; Chamberlain 2000). Due to this issue, past researchers may have assumed that individuals would not have survived into advanced years and perhaps did not pay the necessary attention to the older age category and the obvious biases within them (Cox 2000). This is evidenced by the single age categories that typically represents 50+ that is used as the general limit of any age estimation methodology.

One of the earliest age estimation methods utilized cranial sutures and their closure rates as proxies for age (Vesale 1542; Welcker 1866; Feraz deMacedo 1892; Frédéric 1906; Todd 1924). Meindl & Lovejoy (1985) as well as Todd (1924, 1925) observed that cranial sutures gradually close and will eventually become obliterated as the individual keeps aging and the cranial bones fuse completely. The foremost problem with this methodology was determined early on in its development, and it is the inconsistency in closure rate (Singer 1953; Brooks 1955; Powers 1962; Chamberlain 2006). Although the process is indeed linear, it is different for every individual as it is possible for the sutures to never fully close or to close fully at a young age (Meindl & Lovejoy 1985; Todd 1924; Chamberlain 2006; Cox 2000).

Other methodologies include Todd's (1920), Suchey-Brooks' (1998, 1990), and McKern & Stewart's (1957) methods for ageing the pubic symphysis, which is the fibrocartilaginous joint that connects the hip bones together at the front of the pelvis (Chamberlain 2006). This skeletal element is less affected by the everyday or typical stresses put onto the body through walking, running, jumping, and even giving birth. It has been widely known as the most reliable skeletal indicator for age estimation and has therefore had several methods based upon the changes seen within it. Even though the morphological changes are well understood in this specific osseous structure, the age ranges produced using the pubic symphysis are often so broad and overlapping that the results given are sometimes meaningless (Cox 2000). Other methodologies using the pelvis include the alternative method presented by Lovejoy et al. (1985) for estimating age-at-death based on the auricular surface. Although these changes closely resemble those seen in the pubic symphysis, how they transition from one stage to another is not yet fully understood.

Past methodologies have also been found to lack accuracy and precision, while also consistently underestimating the age of individuals in their 50's or onward (Milner & Boldsen 2012a; Chamberlain 2000). It does not seem to matter whether a macroscopic or histological approach is taken when ageing skeletal remains, the results are much the same, and are both biased (Aykroyd et al. 1999). This ill-understood bias in age estimation was not brought to the attention of anthropologists until the early 1980's and 1990s' when Bocquet-Appel & Masset published their research in 1982, 1985, and 1996 which shocked the archaeological community by bringing attention to the many preidentified problems surrounding age estimation methods (Cox 2000). Adult age estimation is not a straightforward process and has been a lingering problem even for experienced biological anthropologists. Having said this, up to date age estimation methods, specifically the new transition analysis program, have allowed researchers to calculate accurate age intervals for the oldest of adult remains, by using a combination of anatomical features to attribute age to skeletal remains and creating more compatible statistical frameworks (Boldsen et al. 2002; Milner & Boldsen 2012a, b, c).

Many of the issues of inaccuracy and bias towards age-at-death estimation methods originate in the reference sample used to create the methodology. More specifically, if the reference sample used is biased then it stands to reason that the resulting methodology will also hold those same biases (Buckberry 2015). This phenomenon is known as age mimicry and is the theory that age estimates tend to mimic the age structure of the known-age reference sample(s) that was used to develop the methodology (Boldsen et al. 2002: 73; Bocquet-Appel & Masset 1982, Hoppa & Vaupel 2002; Konigsberg & Frankenberg 1992; Usher 2002). These biases can result in an oversaturation of a certain age bracket while leaving other age ranges sparsely represented (Buckberry 2015).

Another issue with some age-at-death estimations are the wide age ranges used to try and account for the high variability between individuals, this results in so much overlap between age ranges that they become meaningless (Buckberry 2015). Creating wide age ranges also forces individuals with a unique set of characteristics to conform to a broad category which may result in data about their unique ageing patterns becoming lost (Buckberry 2015). Thusly, it is important to disaggregate that common and obsolete terminal category of 45 or 50+ that each ‘elderly’ individual is classified as. Researchers must take into consideration the innumerable factors that have the potential to change an individual’s already unique ageing patterns.

Ultimately, even though researchers have encountered the ‘oldest of old’ in most, if not all, archaeological collections they would not have had the framework to classify them as such, with the closest category available to them often being the 45 or 50+, which is too broad to be of any significant use. Historians themselves depend on a plethora of primary sources like tax or marriage records, death certificates, and paintings to decipher valuable information through the way past societies depicted older individuals in their writings or illustrations. They can use that information to decipher the varying attitudes societies have had towards the elderly. For example, historians can learn how some groups view certain age-related physical changes through which characteristics they chose to highlight in their material recordings. Or society’s differing opinions on the young-old and the old-old and how this influenced the elderly’s position in society through their physical abilities or personal appearances (Appleby 2017). This historical context can then help to inform osteological analysis and build a basis for their interpretations of the skeletal data. As stated by Cave and Oxenham; "if the oldest age category in a sample is determined to be 45+ years then it follows that the mean age at death will be significantly lower than 45 years" (2014: 2). It was therefore made easy to ignore older individuals as their age was often underestimated in a phenomenon called the 'attraction of the middle'. This is an event in which the youngest and oldest segments of the entire population are both over and underaged respectively (Aykroyd et al. 1997). This phenomenon is commonly seen in traditional ageing methods and results in average of age-at-death estimations around 35 years (Gowland 2007).

Chapter 4-Sociocultural Changes

Denmark

Introduction

The medieval period in Scandinavia ranges roughly from the early 11th c. to the early 16th c. (A.D. 1050-1536), while the early modern period is the short span between Reformation and when Denmark lost large holdings of land to Sweden in the mid 17th c. (A.D. 1536-1660) (Hybel & Poulsen 2007; Yoder 2010; Oakley 1972; Scott 2015). Within this period Denmark experienced socioeconomic hardship, population fluctuations, agricultural changes, and village desertion which may have all played a role in influencing individual and population respiratory health (Gamble 2014; Yoder 2006; Lamb 1995; Dybdahl 2012; Vahtola 2003). It is therefore with these factors in mind that rural vs. urban characteristics were compared in the hopes of determining the contextual features of each sociocultural environment that may have had the most detrimental effects on respiratory health. By determining the sociocultural and historical contexts experienced by medieval populations, it will hopefully help to explain any patterns seen in the osteological data.

Although Denmark achieved some level of peace when the country was united in A.D. 1157 by Valdemar I, this unification was by no means achieved easily as the centuries preceding it were fraught with tumultuous vies for the Danish throne (Hybel & Poulsen 2007). Unfortunately, this relative peace did not last long as it was quickly disrupted by a number of events, including the plague, which ran rampant in Northern Europe during the second half of the 14th c. The Protestant Reformation in A.D. 1536, also drastically changed how land and wealth were distributed among the inhabitants of Denmark; with the crown seizing all land once owned by the Church (Hybel & Poulsen 2007). While these changes were occurring, ever-evolving climatic conditions periodically bombarded Danish communities and allowed individuals little reprieve from harsh living conditions that altogether may have worsened the effects of the above-mentioned events while simultaneously causing fluctuations in respiratory health.

Population Demographics

Before the 12th c. there is a great dearth of written sources from Denmark that discuss population demographics. This greatly limits the ability of bioarchaeologists to give their work historical context as there are not many sources available to aggregate information (Hybel & Poulsen 2007). The literary sources that do exist however, are not from native writers but are from foreign kingdoms, like Germany, England, and Frankia (Skovgaard-Petersen 2003b). The few native Danish texts that were written before the 12th c. often concerned themselves with the lives and activities of Danish kings. For example, the *Roskilde Chronicle* that was written in the 1140s depicts the ever-evolving relationship amongst kings and the church between the 9th-12th centuries (Skovgaard-Petersen 2003b). There are only a few well-known Danish chronicles that expand their writing to incorporate more than just the lives of the upper tiers of society. This short list includes the work of Adam of Bremen, a German chronicler who lived in the 11th c. (Skovgaard-Petersen 2003b). His chronicles offer a wealth of information on early medieval Germany as well as the history and geography of medieval Denmark. Having said this, the works of a few chroniclers are simply not enough to reconstruct demographic patterns for early medieval Denmark and thus information regarding this time period is sparse.

An increase in Danish literary sources took place in the 12th c. which helped to determine that Denmark experienced an extensive population boom that brought the kingdom's population in A.D. 1100 from half a million to 1.5 million in the mid-13th c. (Thomas 2003; Christensen & Mikkelsen 2006; Bøgh 1999). This increase in population occurred gradually and varied across Denmark, as growth was most prevalent in fringe areas with low population density. Town populations experienced much slower growth and was largely kept in check by a deepening of the social class system and increased taxes which may have been beneficial to the health of urban populations as it would have kept them from experiencing the same increase in density as other regions in the country (Gamble 2020). Later in the 14th c. Europe's inflated population experienced several environmental and biological disasters that forever changed Europe's demographics (Malthus 1798; Hybel & Poulsen 2007). These disasters pushed the nation's population into stagnation and decline. One such catastrophe was the Great Famine that killed an approximate 10% of the European population (Hybel & Poulsen 2007).

Life expectancy would remain relatively low until the mid-18th c. It was only in the early modern period that the majority of individuals could be expected to live for 40 years, despite previous improvements in diet and socioeconomic circumstances (Scott 2015; Benedictow 2003; Benedictow 2012). Throughout the medieval period, life expectancy at birth would range between 18 and 23 with the average being in the early 20s (Vahtola 2003; Benedictow 2012). This average included even the wealthier noble classes of Danish society as everyone was susceptible to long-lasting famine and disease. When only the lower classes are considered then life expectancy at birth drops even lower, ranging from 15-18 years (Vahtola 2003).

These numbers are largely based on the, somewhat biased, 1966 work of Ohlin who wrote a critical review of previous statistical studies concerning English medieval populations and their demographic patterns. Through his work, Ohlin concluded that in the 14th c. mean life expectancy at birth, for the baronial class, would have a maximum range between 22 and 28. Ohlin then states that this is quite a conservative range and was based on "cautious assumptions of infant mortality of two hundred and fifty per thousand" (Ohlin 1966: 76-77). Higher and more realistic infant mortality rates would instead produce a life expectancy at birth range of 20-25 (Ohlin 1966; Wrigley & Schofield 1989), 22-28 for individuals belonging to the noble class (Miller & Hatcher 1978). Moreover, children belonging to lower classes, like the peasantry, would have likely experienced higher mortality rates and thus shorter life expectancies compared to their higher-class counterparts. Members of the peasantry would have landed in the lower echelons of the 20-25 range and even perhaps fallen below it in times of sociocultural, environmental, or political stress (Benedictow 2004). This life expectancy range is roughly ten years less than the generally accepted life expectancy range for the early modern period and suggests that the two periods had separate and unique demographic systems (Benedictow 2012).

Ohlin largely based his work on Princeton Life Tables and centered these calculations on levels of infant mortality, parish records, and marriage records. Although useful, these model life tables are limited by the source data used, which in this case is largely incomplete. Firstly, these life tables assume some level of population homogeneity, but medieval Scandinavia was not a stagnant society and would have experienced some cultural intermixing with other European kingdoms. Life tables also assume that survival, birth, death, and migration rates were constant during the relevant time period, which is difficult to assume with older collections when such circumstances are difficult to accurately ascertain. This is especially true during times of war, environmental crises, or political upheaval when large numbers of people were displaced or killed by non-demographic factors. Moreover, Ohlin's use of infant mortality levels as well as parish and marriage records is problematic as it is unlikely that these records were complete as several years would have gone unrecorded due to factors like extenuating environmental crises or wartime disturbances. Therefore, basing life expectancy ranges on incomplete or heterogenic data that has been substituted with information from neighboring countries, or altered due to non-demographic factors like political upheaval, war, or mass migrations, could largely skew the results.

These numbers are further misleading as they make it appear as if everyone died young and no one survived into old age. This phenomenon is caused by the high infant mortality rates experienced during the medieval period, which drastically skew data towards lower life expectancy estimates. If that infant survived into adulthood though, they had a good chance of surviving into their elderly years (Smith et al. 2017; Mays 1998; Shahar 2005). Therefore, although more infants and children died compared to any other demographic category, this should not be taken as a lack of older adults in any given society. It simply means that older individuals would have represented an integral, but small, segment of past societies (Thane 2005, Shahar 2005, Appleby 2017, Appleby 2010).

Overall, this drop in population speaks to the root causes of low life expectancy which are permanent poverty, poor housing, disease outbreaks, substandard hygiene, and malnutrition (Scott 2015; Hybel & Poulsen 2007). These characteristics are all the mainstays of lower class and peasant life, and coincidentally they are also the characteristics that increase the incidence of diseases such as the ones discussed in this thesis. It is therefore made clear that even if not extending a life by decades an individual's health and longevity seems to be heavily influenced by their place in the social hierarchy of their community (Madsen 1999). Although this is a general rule, it may have fluctuated and reversed in times of war and political conflicts, which occurred with regularity throughout the medieval period. It is therefore evident that like so many periods before it, the medieval period was characterized by a "population pyramid that placed the young on the bottom and the old at the top" (Madsen 1999: 327).

Urbanization and State Formation

The late Iron and Viking Ages saw the earliest indications of state formation and urbanization in Denmark which marked the beginning of the country's slow ascent as Scandinavia's most developed and urbanized kingdom. The beginning of urbanization in Denmark also brought much sociocultural change to the country that could have negatively impacted the respiratory health of the kingdom's population. Factors like the appropriation of craft specialization, commercialization, and large-scale trade are all precursors to urban centers becoming densely populated settlements with a penchant for increased disease prevalence. This comes in the form of 'proto towns' being established in Southern Scandinavia (Runge & Henriksen 2018). These early towns started out small, with populations of only 100-1000 individuals and were the earliest examples of 'urban towns' but without the distinct centralization and population density that later medieval urban centers would boast. When compared to England, Denmark lacked significant urbanization, but it was still the most urbanized country in Scandinavia (Dahlbäck 2003). Virtually all towns in Scandinavia were established in the southern regions of the kingdom, with exceptions being made to the northern mining towns (Andrén 1989). Hence why Denmark was the most urbanized kingdom in the Nordic Union as it was also the most southernly located.

Throughout the medieval period these proto towns expanded and were eventually replaced with towns, in their own right. These early towns are characterized as such based on their population density, size, and whether or not the majority of its population was subsiding by trade and craft activities (Runge & Henriksen 2018; Yoder 2006). There were approximately 100 towns that were established throughout the medieval period in Denmark, with 70 of those towns being founded by the 14th century (Hybel & Poulsen 2007). These towns functioned as densely populated trading, administrative, and ecclesiastical centers which were demarcated fiscally (meaning they had their own self-sustained economies) and joined in networks that linked the whole country as well as foreign lands (Whited et al. 2005; Yoder 2006). Although towns at this time still closely resembled their rural counterparts, this increase in population density and focus on speciality trades would have begun the marked increase in disease exposure and environmental pollutants that urban dwellers would continually experience for the next few hundred years.

These factors increased significantly in the late 12th- early 13th century when Danish urbanization was further revolutionized. Despite the constant growth, urban towns and the people inhabiting them (nobles, lords, kings, and wealthy merchants) only made up roughly 10% of the kingdom's population (Scott 2015; Yoder 2006). Northern Europe's population was overwhelmingly rural (almost 90%) (Whited et al. 2005; Thomas 2003) and would remain so for several hundred years. Towns increasingly supported larger populations that carried out progressively specialized occupations and increased division of labour (Whited et al. 2005; Hybel & Poulsen 2007). Such occupations included working in tanneries or with kilns which would have further exposed those workers to harmful chemicals and pollutants that could lead to respiratory problems. Although these sophisticated skills first developed in medieval farms they quickly moved to the towns where they continued to flourish (Whited et al. 2005).

Although councils were the governing bodies of these early towns, their focus resided in the promotion of their administrative laws rather than the regulating of health code policies that could have mitigated the detrimental health effects of these budding industries (Hybel & Poulsen 2007; Andrén 1989). Separate town councils with crown representatives present at meetings also oversaw the health and administration of the town inhabitants (Bernofsky 2010; Lewis 2002; Roberts et al. 1998; Andrén 1989; Dahlbäck 2003). Despite the early appearance of towns in Denmark, it was not until the early modern period that urban centers began taking on a truly individualistic form with laws and boundaries marking them as distinct entities separate from their rural contemporaries.

While early urban housing often resembled their rural counterparts, they were sometimes intermixed with houses made of stone or brick walls, which helped in the prevention of fires. This was a concern as most buildings were narrow and compact and often located one on top of another (Kristensen 1999). Most urban housing had tiled or slated roofs, which may have actually trapped smoke inside and increased respiratory problems (Roberts & Lewis 2002; Whited et al. 2005; Kristensen 1999). Nevertheless, timbered or wattle and daub homes, like those seen in rural hamlets, were still popular and more cost efficient in urban centers, and therefore popularly used by all classes of individuals even those belonging to the upper middle class.

Altogether with the higher population density and the increased outdoor pollution, town inhabitants are often speculated to have been exposed to a higher degree of risk factors for respiratory diseases. Although early urban and rural settlements largely boasted the same risk factors for disease, the increased density of these factors in late medieval urban towns may have led to a higher rate of exposure, especially to those most vulnerable. Having said this occupational diseases are a largely under-studied areas of medieval health (Lee 2012). Although it can be speculated that the oldest echelons of society may have spent more cumulative time exposed to these detrimental health factors, and thus experienced greater rates of disease, it is very difficult to verify these claims. Moreover, it is impossible to know archaeologically how much pollution may have been present in a home or how much time a family spent exposed to it, even if researchers know what materials medieval homes were made from. It is mere speculation, which greatly limits any research that can be done on the topic (Bernofsky 2010).

Rural Life

Rural villages and early urban towns were not that dissimilar in this period as houses and occupations resembled each other closely (Jordan 1996; Roesdahl 1999). This complicates the question of which settlement type was more detrimental to an individual's respiratory health as both rural and urban settlements shared many of the same characteristics. As previously mentioned, rural houses were often wattle and daub or timbered buildings with thatched roofs, with even earlier examples taking the form of rectangular houses sunken into the ground. One difference that marked rural housing from its urban counterpart was that both humans and animals often lived together within these houses especially in the colder winter months; and although this could have also occurred in urban centers across Denmark, no record of this could be found (Whited et al. 2005; Kristensen 1999). Despite this particular lack of evidence, it has been shown in other circumstances that humans and animals came into regular contact in urban towns due to the crowdedness of towns (Sundman & Kjellström 2013a/b). Therefore, both rural and urban circumstances could have exposed their populations to zoonotic diseases as infected fleas or flies would make contact with humans. Animal feces would have also been prevalent indoors which would have made the living situation unhygienic. Moreover, bringing farm animals into the home could have caused the air in the house to become increasingly putrid (due to the feces) and humid (due to the extra heat from wet animals). These circumstances would have decreased the air quality inside the home and may have aggravated those with pre-existing respiratory problems and caused infections like sinusitis.

Rural living was diverse across medieval Denmark as the organization of a rural village varied depending on settlement size and subsistence style, which was regionally dependant and will be discussed in more detail later in this section (Hybel & Poulsen 2007). Not all regions of Denmark were suitable for agriculture with many settlements being forced to depend on alternative avenues of subsistence which resulted in villages across Scandinavia varying substantially. The sociocultural and economic circumstances that would affect respiratory health within one regional were therefore most likely unique onto itself (Hybel & Poulson 2007). This could have drastically impacted how well certain villages and hamlets managed environmental, economic, or sociocultural stressors that could negatively impact health. Some villages would have been better equipped for some circumstances while others would have suffered and vice versa. Although these variables could have also allowed smaller rural populations to be self sufficient and retain their autonomy from larger urban towns this diversity is difficult to ascertain bioarchaeologically without excavating the material culture associated with rural villages across different regions of Denmark.

The diversified nature of rural settlements across Denmark is made apparent through the difference in farm sizes across the kingdom, with some towns ranging from less than 10 to others as many as 20-30 farms (Yoder 2006). A village's structure and location were rarely static though, and it was common for larger villages to relocate or split into several smaller hamlets especially in times of hardship or overpopulation (Hybel & Poulsen 2007). Rural villages across medieval Denmark were often made up of a small "community of free landowners and tenant farmers along with their servants and farmhand slaves" (Hybel & Poulsen 2013: 144). The individualistic use of property with a communal interest in the overall crop's well being, often seen in rural villages of this time period, would have mitigated the affects of food shortages and the subsequent deterioration of health caused by malnutrition and prolonged periods of food stress. This changed somewhat when villages grew along with population density and put a strain on resources, therefore aggravating these circumstances. Consolidated farming thus became the more popular choice so resources could be more readily shared (Hybel & Poulsen 2007).

Another important settlement system that gained popularity in the 12th c. was the manorial system (Poulsen 1997; Yoder 2006). The manor, or estate, and the large tracts of land surrounding it were owned by a wealthy lord or nobleman and the land itself was worked by a wide range of individuals including peasants, servants, wage-labourers or landboers, renters and leaseholders (Poulsen 1997; Yoder 2006; Bøgh 1999; Whited et al. 2005). The central element to this system was the peasant farm as the manor itself was merely the administrative center that collected the farm's rent and dues (Hybel & Poulsen 2007). Landboers, were a class of semi-free tenants that lived on the estate and worked the leased land, these individuals quickly became the largest group in rural society by the end of the period (Poulsen 1997; Yoder 2006).

Much like the dynamic nature of the medieval village structure, subsistence was also highly diversified across medieval Denmark and was largely influenced by location. For villages located on premium land, agriculture was their main form of subsistence. The most important crop to Danish agriculture was wheat and remains so even in recent times (Scott 2015; Jordan 1996).

Not all parts of Denmark were suitable for largescale agriculture and in these incompatible areas, other avenues of subsistence were explored. Western Jutland, for example, is characterized by sandy soils which are inconducive to farming (Poulsen 1997; Hybel & Poulsen 2007). Livestock, such as cattle and oxen therefore quickly became very important in that area. Eastern Jutland was itself covered by large, forested areas which resulted in pigs becoming a popular farm animal as they were capable of roaming the heavily wooded areas and feed on acorns (Poulsen 1997; Hybel & Poulsen 2007; Orrman 2003). Cattle and oxen increasingly became important in all areas of Denmark especially after the plague (A.D. 1349/50) cut the workforce in half. It was much easier to tend to a herd of cattle rather than farm several hectares of land (Poulsen 1997; Gough 2013; Orrman 2003).

In other areas of Denmark, agriculture was replaced altogether with other trades. For example, the fishing industry grew in importance among the southern and eastern coastal regions of Denmark, as did, in smaller proportions, iron and salt production. Herring fishing in the Baltic Sea became the most important industry in medieval Denmark from the 12th century onwards (Hoffman 2014). Large fisheries were established on the South coasts due to the high demand for herring in Germany, and their southern position would greatly facilitate exportation to Northern Germany. The fisheries took a quick downwards turn in the 15th c. as colder temperatures and overfishing became a prevalent issue in the Øresund, the industry struggled for another hundred years or so before completely drying up after A.D. 1520 (Hoffman 2014; Cairns 2015).

The Black Death

Through the combination of historical analysis and bioarchaeology data it has been ascertained that Denmark was hit by the Black Death in A.D. 1349 which peaked during the summer/autumn of A.D. 1350 (Benedictow 2004; Lenz & Hybel 2015; Hybel & Poulsen 2007). Primary historical sources detailing the plague in the Nordic countries is sparse with one of the only sources being the '*Rhyming Chronicles'* of Svealand which only briefly mentions that an epidemic is ravaging the kingdom in 1348. The entire epidemic swept across European Christendom in four or five years, as it ravaged a new region for a few months, burnt out, and moved on (Benedictow 2004; Lenz & Hybel 2015; Aberth 2005). The first wave is now known to be the biggest outbreak in the country, but smaller outbreaks occurred on a decadal basis (Lenz & Hybel 2015; Fagan 2000; Aberth 2005).

The plague was estimated to have had an 80-100% fatality rate and is thought to have killed up to 50% of Europe's remaining population (Hybel & Poulsen 2007; Lenz & Hybel 2015). This is just a general estimation though as plague mortality rates differed across Europe and exact numbers are largely unknown due to a lack of census records. This tremendous loss in population was felt throughout Europe for many generations as population numbers did not begin to rebound until the 15th c. (Hybel & Poulsen 2007; Aberth 2005; Brooke 2014; Gough 2013). Even then, Denmark did not reach pre-plague numbers until after the 1800s when the kingdom's population reached 1 million once again (Whited et al. 2005). The plague not only affected total population numbers but also disturbed the very sensitive balance between birth and mortality rates by favouring the latter (Vahtola 2003). This balance was not reversed until well into the 15th c. when birth rates once again rose in Europe, perhaps as a result of individuals trying to fill the voids left behind by deceased family members (Thomas 2003; Benedictow 2012; Hybel & Poulsen 2007). Essentially Europe's demographic environment was "disease-dominated" until the end of the second half of the 15th c. (Campbell 2016: 353). A population that was already weakened by plague may have also been more vulnerable to respiratory diseases as compromised immune systems could no longer fight off infections that were once easily managed (Weiskopf et al. 2009; Plackett et al. 2004; Castelo-Branco & Soveral 2014; Grubeck-Loebenstein & Wick 2002).

The plague had a trickle-down effect on Denmark and its remaining population. No new towns were created between A.D. 1350-1400 leading to economic stagnation (Andrén 1989). An increase in migration between rural and urban towns was also seen as rural populations resettled in the towns and replaced the missing population (Andrén 1989; Lewis 2002; Hybel & Poulsen 2007). This could have made urban settlements a very dangerous place to live as rising population densities would have brought with it a risk of increased respiratory disease as living conditions became evermore cramped and sanitation non-existent. A significant drop in population density also meant fewer hands and higher wages and also fewer mouths to feed. For a short time, the plague ameliorated conditions for peasant populations as they were given more freedom to choose the terms and conditions of their own employment, while also reducing rent and land prices, but this betterment did not last (Brooke 2014; Gamble 2014; Gough 2013; Aberth 2005; Orrman 2003). It was not long before all classes of Danish society were suffering from the after-effects of famine and plague. For the upper classes of society, the plague caused many to go into financial ruin. Many nobles and ecclesiastical institutions suffered greatly because they based much of their incomes on peasant rents (Orrman 2003). Although some landowners managed to keep their land, they had to make serious amendments in order to do so. This meant less stability and a loss of income for the landowners. This instability may have also impacted all other aspects of their lives including their individual health which could have suffered due to these prolonged periods of stress (Goodman et al. 1988). External stressors like drastic loss of income, losing one's home, and concurrent pathological processes (like the plague) could have also caused a deterioration in immune response, especially in the elderly, and may have resulted in an increase in morbidity simultaneously with a decrease in the immune system's ability to fight off concurrent respiratory diseases (Goodman et al. 1988).

Sweden

Introduction

The second of the three main Nordic countries, Sweden, is located on the Scandinavian Peninsula and shares a border with Norway to the west and another with Finland to the northeast. During the medieval period Sweden was also closely linked to Denmark through the Öresund, a narrow waterway that forms the border between Denmark and Sweden (Helle 2003). Due to this proximity, Sweden was one of Denmark's fiercest rivals during the medieval period (Gustafsson 2017). The longstanding enmity between these two kingdoms was not only caused by the desire for Scandinavian supremacy but also for control of superior land and resources, like stock fish. Clashes between them were unavoidable and occurred quite frequently (Gustafsson 2017). The power dynamic between medieval Denmark and Sweden was much like a seesaw as the power was often shifted as each country experienced significant hardships. This political instability between the two kingdoms forms the basis for many of the sociocultural changes seen throughout the medieval period and is thus important to quickly note within the contexts of this thesis. For example, roaming armies and political upheavals could have put further strain on already impoverished communities, while also putting agricultural supply and livestock at risk. This lack of consistency, in both sociocultural and environmental context, is what could have put many at-risk individuals, like the elderly, in danger of further deteriorating health.

Much like its neighbour, medieval Swedish history lacks primary information, in the form of written sources like sagas or chronicles before the 12th c. (Line 2007). Primary sources are even rare for the rest of the medieval period as there are still only a few known chronicles that pertain to this period. The earliest known chronicle for Sweden is the *Erikskrönikan*, or the Eric Chronicle, written sometime in the early 14th c. by an unknown author. It details the life of Duke Eric of Södermanland, the brother of King Birger of Sweden. The chronicle is one of the many that make up a larger volume called the '*Rhyming Chronicles'* which speaks to the political history of Medieval Sweden and is the source for much of the primary information on the sociocultural and political structure of medieval Sweden (i.e. lack of feudalism and general urbanization) (Nordquist 2015).

Population Demographics

During the medieval period, Sweden was very sparsely populated with the entire kingdom, including Finland only reaching a maximum of "650,000-750,000 by A.D. 1300" (Korpiola 2014: 97). Moreover, approximately 95% of Sweden's population at the time lived in small rural hamlets spread across the kingdom (Lagerås 2016). In theory this isolation could have better protected medieval Swedish populations from plague outbreaks that were ravaging Danish towns due, in large part, to an increase in population density and concurrent deterioration of sanitary standards (Hybel & Poulsen 2007). Evidence contradicts this statement though and states that despite the isolation, Sweden was still ravaged by the plague (Larsson 2019). The population would have diminished greatly during the Black Death which, like many other regions, annihilated anywhere between 40-60% of the population (Lagerås 2016). This would have left Sweden with around 250,000-300,000 people directly after the plague, but the population would continue to decline as additional waves of the plague continued to attack the kingdom in decadal intervals. The population took another hit in the mid-17th to late 18th c. when the kingdom experienced increased mortality rates due to food shortages, war, and changes in climate (Larsson 2019).

Urbanization and State Formation

The circumstances that would lead to much sociocultural change and the emergence of urbanization within the medieval kingdom of Sweden, was the unification of the country around the 12th c. Prior to this time the kingdom's provinces were largely self sufficient, unstable, and prone to population stress as they functioned as independent rural republics (Sawyer & Sawyer 1993). Sweden was originally separated into two main regions; Götaland which represented the southern half of Sweden and Svealand which made up the north (Ersgård 2018). Each region was itself then subdivided into smaller provinces, which largely governed themselves while still under the supremacy of the king (Ersgård 2018). It was only later in the medieval period that Sweden expanded and officially divided into four principal regions (Götaland, Svealand, Norrland, and Österland/Finland). Each region had important administrative centers, but the most significant region in medieval Sweden was Uppsala, Svealand (Line 2007). Due to its central location, it was the perfect location for the king to rule from and could allow easy access to his entire kingdom from this position (Line 2007).

The beginning of urbanization in Sweden commenced during the early medieval period around A.D. 1000 (Ersgård 2018). During this period small, scattered farms that were established in the Viking Age were slowly amalgamated into proto towns, like Sigtuna in Eastern Sweden. Along with this change came a centralization of government and royal power, which were very different from the sporadic chiefdoms that were the basis of Viking Age Sweden (Line 2007). These changes were certainly not linear though as towns would dissolve into smaller fragments and merge once again in later periods. Overall, urbanization in Scandinavia during the medieval period was a phenomenon almost exclusive to southern Denmark. In comparison to its southern counterpart, Sweden lacked the necessary infrastructure to support urbanization and was far behind Denmark in the process. By the 13th c. Denmark had over 20 well-established towns spread throughout its kingdom while Sweden barely boasted half that number (Line 2007). Having said this, Sweden experienced steady urban growth between A.D. 1250-1320 as urban centers began slowly appearing in the west. Despite this increase, the west never achieved the same kind of success, growth, and stability their eastern counterparts did (Line 2007). The east and west remained culturally very different from one another, which was signified in their lack of unification until after the 12th c. (Line 2007).

Most medieval towns in Sweden were located in the central and southern regions of the kingdom where agriculture could flourish (Ersgård 2018). During the early medieval period it was the Mälaren Valley, located in the most eastern region of Svealand that was the most densely populated area in the Swedish kingdom (Kjellström 2016). The east continued to flourish throughout the period as Stockholm soon became the most densely populated town in the country during the 15th c. with approximately 6,000-8,000 individuals inhabiting the town (Korpiola 2014). Much like the urban towns of Denmark, Stockholm, and other small urban towns dotting the Mälaren Valley would have faced the same detrimental circumstances that are believed to be contributing factors to a decline in respiratory health. This can be seen through Sundman & Kjellström's work (2013a/b) which shows that there was a significant increase of sinusitis in the urban town of Sigtuna in comparison to rural villages in the surrounding area (Sundman & Kjellström 2013a/b). The authors state that, concerning the specific history of Sweden, little is known about the differing health statuses of individuals in urban towns and rural villages. Though it can be extrapolated from other studies (Lewis et al., 1995; Roberts, 2000, 2007; Roberts et al., 1998) that factors specific to urban towns, such as poor sanitation, air/water pollution, high rates of immigration, and craft specialization and industrialization might have led to respiratory health problems due to increased levels of toxic fumes and other irritants that may exacerbate respiratory problems like asthma and later cause sinusitis (Sundman & Kjellström 2013a/b).

Northern Sweden continued to be quite isolated and lacked any urban centers. Culturally, the north was very different than the rest of Sweden, although still under royal power, northern freeholders were much more independent (Lagerås 2016). Towns, landowning nobility, and tenants did not exist in this region until the early modern period when urbanization was expanded into previously uninhabitable areas of the kingdom (Ersgård 2018). The isolated nature of the north could have therefore protected these more remote populations from the most serious outbreaks of respiratory diseases that relied upon densely populated areas to facilitate infection. This is reflected through the evidence collected from plague research done in the country which shows that although the plague ravaged most of medieval Sweden researchers are unsure whether the disease ever impacted northern populations (Lagerås 2016). This uncertainty could be due to a true lack of disease prevalence in the north and therefore a healthier population or could be due to a lack of research or a lack of available skeletal material as collections from northern Scandinavia are largely lacking (FASE 2021). It is therefore difficult to draw comparisons osteologically as more research needs to be done using skeletal collections from these remote northern regions of medieval Sweden.

Most of the successful and well-established towns in Sweden began as religious centers like Linköping and Turku. Oftentimes religious groups, such as the Dominicans or Franciscans, would settle in towns with a well-established agricultural system and bring with them money, business, education, and an administrative system that would then attract more individuals to settle in the same area; thus, quickly creating an influx in the town population (Line 2007). Towns were also quick to settle in agriculturally rich areas like Northern Östergötland and Södermanland as well as along trade routes where there would have been a constant flow of business and trade (Line 2007).

The period between A.D. 1150-1300 was a time of great transition for Sweden's social structure. It was during this time that the nobility emerged as a separate class that lived in manors instead of being a part of the rural village. The kingdom continued to gain power and influence as it was during the 15th c. that Sweden really hit its stride and was at the top of European prominence as the Swedish nobility became more organized (Otte 1910).

Rural Life

Throughout the medieval period, Sweden for the large part, remained rural with only roughly 5% of the population choosing to live in urban settings (Lagerås 2016). This meant that most of Sweden's population was involved in the kingdom's various subsistence systems. Since Sweden at the time was not a feudal kingdom, serfdom, a system that Denmark heavily relied upon, did not exist in Sweden. This became a defining characteristic of medieval Sweden, making its social structure very unique amongst its European peers. The lack of feudalism in Sweden meant that the country lacked the necessary infrastructure to support large-scale urbanization, the implications of which, and how they potentially relate to a population's respiratory health, will be explored further on in the chapter.

Each region had their own unique subsistence strategy, most often influenced by their geographical location and the type of soil available to them. In the north the terrain was characteristically mountainous with quaternary deposits dotting the landscape due to previous glacial activity. Due to this extreme topography, most of Norrland and the Southern Swedish Uplands had poor agricultural soils that were naturally very stony and sandy (Lagerås 2016; Fredh et al. 2018). This led to significantly poorer agricultural yields and less populated areas (Fredh et al. 2018). Agriculture in Norrland was therefore quickly replaced by other subsistence methods which included animal husbandry as well as iron and timber production, which farmers could then trade for food (Lagerås 2016; Fredh et al. 2018). In other regions like Northern Sweden and Finland, naturally occurring hay meadows were so crucial to the success of animal husbandry that it may have been a determining factor for settlement locations up until A.D. 1500 (Wallin 1996). Vital hay areas were typically found adjacent to bodies of water, which included coastal areas, lake shores and riverbanks. Areas without this natural source of hay could only be settled with sedentary farming much later when the proper technology allowed it (Wallin 1996). Most of the kingdom's agriculturally rich areas presided in the Central Swedish Lowlands which ran from east to west and included provinces such as Södermanland and Northern Östergötland (Line 2007). The soils in this region were fertile and accommodated most of Sweden's medieval agriculture.

Osteologically, the isolated nature of Sweden's rural villages translates into relatively lower rates of sinusitis which will be discussed at further length in later chapters (Table 2). In one instance the rural settlements in the Mälaren Valley (70 %) and the proto-urban town of Birka (82%) had lower frequencies of sinusitis in comparison to the urban town of Sigtuna (95%) (Sundman & Kjellström 2013a/b). The authors explain that despite the difference in prevalence, both urban towns and rural villages had generally the same risk factors for respiratory problems but in different levels. For instance, in urban towns humans and animals came into closer contact due to the crowdedness of towns but due to the larger number of animals in rural villages, inhabitants would have also been exposed to irritants related to animal dander and the general unhygienic nature of living in close quarters with large animals (Sundman & Kjellström 2013a/b). Although the kingdom's urban centers would have all the previously mentioned risk factors, many of its rural villages were prone to food shortages due to inhospitable living conditions and unsuitable agricultural soils which would have increased their susceptibility to respiratory infections brought on by continued stress, malnutrition, and a decline in immune health (Sundman & Kjellström 2013a/b; Eriksson 2019). This theory of urban and rural settings both sharing common risk factors is further mirrored in Eriksson's (2019) research which concludes through the analysis of both rural (35.5%) and urban (36.4%) skeletal remains, that there was no significant difference in sinusitis prevalence between urban and rural locations. The author attributes these results to a multifactorial aetiology for sinusitis with environmental, social, and biological/genetic factors all playing a part (Eriksson 2019). Medieval Sweden lacked the increased urbanization experienced by Denmark which led to its urban towns and rural villages resembling each other greatly. This would explain why researchers such as Eriksson (2019) and Sundman & Kjellström (2013a/b) are finding similar rates of sinusitis throughout all of Sweden, except for the most densely populated urban towns, like Sigtuna, as both rural and urban populations suffered risk factors that would contribute to a decline in respiratory health, be that poor sanitation, increased air pollution, food insecurity, proximity to livestock, or industrialized craft activities.

The Black Death

The plague came to Sweden through Halland and Norway in A.D. 1349, and by A.D. 1350 the whole country was ravaged, with the sickness moving in an easterly direction (Lagerås 2016). The Swedish Upplands were decimated in comparison to the lowlands while researchers still debate whether the plague affected the Northern regions at all. In general, the east was more well established than the west and thusly fared better after the plague (Lagerås 2016). This may have been due to their different levels of development. For example, after the plague farmsteads in the east chose to collaborate and replace the old manorial systems by expanding urban spaces. On the other hand, western settlements chose to stay independent with no collaboration taking place between towns and countryside (Lagerås 2016). This led to decline and de-urbanization in the west while towns in the east were able to recuperate their losses much faster (Lagerås 2016).

Reoccurring bouts of plague occurred in Sweden on a decadal basis much like the rest of Western Europe (Lagerås 2016). One major outcome of the plague in Sweden, which spoke to the extensive prevalence of the plague, was farm abandonment. Fertile areas in the provinces of Uppland, Ostergötland, and Scania were most extensively hit by this phenomenon (Lagerås 2016: 15). Overall, only 15% of Swedish farms were abandoned due to the plague in comparison to the 40% in Norway. Newly deserted farms were often taken over by surviving family members who turned them into pastures and meadows to accommodate the increased popularity of animal husbandry in the kingdom (Lagerås 2016).

Norway

Introduction

During the medieval period Norway was divided into five major regions or provinces: Nord-Norge (Northern), Sørlandet (Southern), Trøndelag (Central), Vestlandet (Western), and lastly Østlandet (Eastern) with each of these regions experiencing unique sociocultural and disease patterns, as will be explored later in the chapter. Norway is the northern most kingdom located on the Scandinavian Peninsula. During the medieval period it was also the largest of the three Nordic countries. At one point in time Norway could have also been considered the most powerful of the three countries as its very successful foreign expansion policies continued to win the country more land, resources, and tax revenue (Helle 2003). This can be seen in its conquering of Greenland, Iceland, Northern Scotland, and the Northern Isles which were comprised of Orkney and Shetland (Helle 2003). Norway's luck began to run out during the late medieval period when it succumbed to civil war and the Kalmar Union. It was during this period that Norway gave away much of its independence to Denmark, and it did not fully recuperate until the 19th c (Helle 2003; Andrén 1989; Gustafsson 2017; Bagge 2013).

Population Demographics

Norway, although several times larger than Denmark, in square footage, had only about half the population, which perhaps explains the dearth of primary sources available for this country and results in an overall lack of detailed information pertaining to the particular sociocultural conditions medieval Norwegian populations would have experienced and which may have exacerbated their respiratory health (Lauring 1976). Norway's total population during the medieval and early modern period is uncertain but estimates hover around 400,000 with the urban population totalling no more than 20,000 (Helle 2003). In comparison to Denmark, information concerning the medieval and early modern periods in Norway is severely lacking with virtually no written records dating to before A.D. 1150 (Holt 2007). Moreover, much of

Norway's medieval demographics were dictated by its harsh terrain and rough topography as it greatly limited what could be achieved agriculturally throughout the country.

Urbanization and State Formation

Unlike other medieval kingdoms, like England or even Denmark, Norway's feudal system was very weak, which caused the kingdom's urban centers to be fragile and ineffective (Holt 2007). This lack of urbanism in medieval Norway may have effectively protected much of the kingdom's population from many respiratory disease outbreaks as the conditions necessary to proliferate such outbreaks (population density, poor sanitation, cramped housing which allowed for easier spread of droplet infections) may have been missing altogether throughout the country, except for in its few well-developed urban centres like Oslo. Norway's initial period of urban expansion began between A.D. 1000-1100 with all of its medieval towns being established by A.D. 1200. The successful declaration of a Norwegian national monarchy, independent of the Danish yoke was also achieved during the early medieval period (Holt 2007). A few examples of early Norwegian towns included such settlements as Trondheim and Bergen on the west coast, while Oslo, Tønsberg, Borg, and Konghelle were settled along the eastern border (Holt 2007). Many of these early towns were used as seaports as they were located close to the open sea or the mouth of a major fjord. Oslo, with a population of approximately 3000, quickly became an important royal centre and the political capital of Norway, during the 14th c. (Holt, 2007).

Although Norway exported many valuable goods, they also heavily relied on foreign imports, which included manufactured goods and corn (Holt 2007).This need to import manufactured goods was due to Norway's restricted urban development during this period. Although Norway did have towns, they never transitioned to become centers of production, and they never produced commodities for their rural counterparts (Holt 2007). Any kind of production was only on a household or town level, there was never enough produced for rural markets. This may in part be due to a lack of commercialization of Norway's internal economy. There were rarely any specialized craftsmen, no guilds, and no market centers, which were all pivotal elements to the Danish economy.

Rural Life

Rural settlement patterns in medieval Norway did not boast the same homogeneity and stability as its southern counterparts. This can partially be attributed to the kingdom's mountainous geography and the sparseness of its population which did not allow for the land to be farmed the same way across the country. Traditional longhouses which were popular during the Viking Age were replaced by single-aisled buildings. These new settlements were typically made of wood and built above ground by utilizing cross-timber and stave techniques which could have noticeable changed the amount of smoke present inside the home and ameliorate respiratory conditions inside as the smoke could have been more easily risen above ground level and away from the living spaces (Sauvage & Mokkelbost 2016; Zimmermann 1998). Rural homes were no longer the multifunctional longhouses they had been in previous eras, these new smaller buildings were built to have only one function. Farms would thusly be composed of several smaller buildings, each dedicated to a specific function instead of one very large central building in which all activities would take place in. This could be due to the trend towards downsizing farms to single family units. This trend was not universal though as both more dispersed large hamlets and even village-like clustered settlements co-existed (Øye 2000). In general, however, although larger farms and hamlets did exist in Norway, typically farms were smaller, more irregular and with limited arable land in comparison to the villages and hamlets in southern Scandinavia (Øye 2000).

Although a rough approximation, medieval farms in Norway have been estimated to have totalled 36,500 but with holdings ranging between 60,000-70,000 (Øye 2000). This large discrepancy in numbers is due to the fact that some of the biggest farms in the kingdom were actually subdivided into three or four holdings each run by a single household (Vahtola 2003). These clustered holdings, typically located in the western and northern regions of the country, were subdivided into strips of equal size, and were based on common ownership. The smallest in size and largest in number of such holdings were to be found along the coast and fjord districts, where the farms were extensively divided due to a lack of available arable land (Holmsen 1956). The cramped nature of these holdings may have made it easier for certain respiratory diseases to proliferate as many families worked and lived in close proximity. In other regions of Norway, in areas that could only support smaller one-household farms, especially in the mountainous and wooded areas, the old method of farming commanded the landscape. This type of farming involved moving cattle to summer pastures a long distance from the farm, and the gathering of winter fodder in the mountain and forest pastures. This type of agriculture is commonly known as transhumance farming and is a highly labour-intensive system where individuals are often away moving their herds between their summer and winter farmsteads (Brothen 1996). These solitary family farms were forced to develop a high degree of economic self-sufficiency due to their remoteness, and lack of regular communication with other parishes and towns (Holmsen 1956).

Medieval diets in Norway were similar to those in the rest of Scandinavia. They were composed mostly of cereal grains like rye, barley, oats, and wheat for most of the population with barley being predominantly grown in Norway. Most crops were grown near the coast as the soil was more conducive to large-scale agriculture there (Cairns 2015). Much like the rest of Scandinavia, Norway also had a thriving fishing industry, but it was not sufficient to make the country rich like it had in Denmark (Lauring 1976). During the early modern period, a few large silver and copper mines as well as a number of smaller iron works were established in Norway (Holmsen 1956).

Another feature of the early modern period in Norway was the king's decision to sell a large part of his landed property between A.D. 1650 and 1740. The land in question was previously owned by the Church but was confiscated by the king during the Reformation. Norway lacked any rich nobility that could have bought this former public property, so much of the land was bought by town officials or traders who then resold the land. Tenant farmers were also able to purchase their farms directly from the king, particularly in the east (Holmsen 1956, 21). It was not unusual for farmers to own their land in Norway, especially in the poor mountain regions in the south and central regions; but it was now also possible for peasants to own their farms even in the richer parts of the country. Most of the peasant class were now becoming freeholders (Holmsen 1956, 21).

Overall, Norway's rural settlement system was quite unique in Scandinavia, mainly due to its weak and ineffectual feudal aristocracy. This meant that "no manorial system developed; no large-scale farming on great complexes of aristocratic property; no forced labour in the form of serfdom; and no laws that gave the landowners legal rights over their tenants" (Holmsen 1956 19). Moreover, a weak aristocracy meant an inability to impose high land rents and taxes. Therefore rent, in comparison to European standards of the time were very low; usually being only one-sixth of a farmer's production, and only ever going as high as one-fifth. However, this increase in rent only occurred in the 14th c. after the plague ran its course through Norway (Holmsen 1956). It furthermore meant that the free peasantry owned one-third of the land in the early 14th c., with the Church owning roughly 40 %, the king 7 %, and the aristocracy owning the last 20% (Holmsen 1956).

It is impossible to ascertain how Norway's specific lack of feudalism and formal urban centers specifically impacted respiratory health as no studies using Norwegian skeletal collections from the medieval period could be located. It can be inferred that due to their similar lack of urbanization and varied topography the general trend of respiratory health in medieval Norway may have closely resembled Sweden's experience, but this cannot currently be tested. It can be hypothesized that respiratory diseases were higher in large urban centers and were relatively low in proto-urban and rural villages elsewhere in the country. It may also be possible that due to a lack of true urbanization both rural villages and urban towns experienced the same levels of respiratory disease due to their shared characterisics.

<u>The Black Death</u>

The plague has been extensively studied throughout Norway (Cairns 2015; Brothen 1996; Oeding 1990; Lunden 2008; Larsen 1948; Derry 1960). Research has largely focused on primary sources in the form of Icelandic annals which describe how the plague entered the kingdom and how it subsequently spread throughout (Brothen 1996; Derry 1960; Oeding 1990; Lunden 2008). Other researchers focused on how the plague caused the general population to decline and the subsequent political and economic downturn of the kingdom (Brothen 1996; Larsen 1948). Due to this spotlight, it was determined that the plague was introduced into Norway through Bergen and Oslo, and then travelled both north and south, following along the coast, and over the mountains between A.D. 1349 and A.D. 1351. Similarly, to the rest of Western Europe, Norway experienced subsequent decadal plague pandemics that continued to wreak havoc on its population (Brothen 1996; Derry 1960). The quick spread of the plague through the kingdom has been greatly attributed to Norway's social structure, as individuals often lived in close proximity to one another in small log buildings especially in Western Norway which greatly facilitated transmission. Norway's sparse population also necessitated long distance travel which may have encouraged quicker transmission.

Norway lost a considerable amount of political and economic status within Northern Europe after A.D. 1350 due in large part to the plague (Brothen 1996; Derry 1960, 70; Cairns 2015). The successive plague outbreaks caused a massive population decline in the country. The kingdom's population maximum which was reached between A.D. 1280 and A.D. 1320 dropped by about two thirds due to the plague. The maximum which was estimated to be between 300,000 and 400,000 dropped to about 125,000 by A.D. 1550. This very rapid decrease caused an equally as jarring movement towards nationwide farm abandonment, that had not yet recovered by the 16th c. (Derry 1960). From there, crop production fell to 35% of its original production numbers while wages were only a quarter of what they used to be (Derry 1960).

Greenland

Greenland, one of the many territories acquired by Norway in the medieval period, was almost entirely settled by Norsemen in A.D. 985 and fully conquered by Norway by A.D. 1261 (Hartman et al. 2017). The population in the 12th c. reached approximately three thousand settlers, which was very small in comparison to Iceland. This diminutive number of settlers may partially be due to the island's polar climate, seasonal sea ice and a short growing season (Hartman et al. 2017). Greenland's severe medieval landscape was further characterized by harsh climatic cycles and inland regions that were covered in ice. Temperate boreal forests with European flora dotted coastal regions that boasted populations of grazing caribou and colonies of seals. This led to many settlements hunting seals for subsistence which quickly replaced the need for fish (Hartman et al. 2017).

Much like the rest of Scandinavia, Greenland also experienced the detrimental effects of the Little Ice Age. It is hypothesized that it was the extreme climate variability of the LIA that caused the Norse settlements to eventually fail between A.D. 1450 and A.D. 1500 (Dugmore et al. 2012; Hartman et al. 2017; Ogilvie 1991). The island became semi-permanently covered in ice while the coastlines were under water which had a serious impact on the viability of agriculture on the island (Kuijpers et al. 1999; Cairns 2015). Although the initial climate shock in the 13th c. was overcome by settlers intensifying communal activities like the seal-hunt, subsequent years of bad weather beginning in A.D. 1425 made them increasingly more vulnerable to outside forces (Hartman et al. 2017). Other contributing factors leading to Greenland's demise included the island's marginalization after Norway shifted focus on the East and South, declining importance of walrus ivory, and the tiny size of the settlements, which meant that even small raids posed a serious threat to colonists (Kelly & Ó Gráda 2014a).

Greenland's medieval economy largely relied on the old traditional model of high value and low quantity resources. Their main commodity was walrus ivory which led to economic hardship for the settlers when ivory became increasingly harder to harvest, mainly due to the increased distances hunters needed to travel in order to hunt walrus (Hartman et al. 2017). A shift towards expanding trade networks related to elephant ivory markets also greatly affected the demand for walrus ivory (Williamson 1982; Star et al. 2018; Williamson 2014). Greenland's reliance on the old economic model therefore gradually weakened their connection to mainland European markets which had already adapted to the new model that Iceland had also previously adopted (Hartman et al. 2017).

Iceland

Iceland, another important conquest that fell to Norway's foreign expansion policies, was settled by Norsemen nearly a hundred years before Greenland in A.D. 871 and conquered by Norway in A.D. 1262 (Hartman et al. 2017). For five centuries these islands represented the westernmost outposts of Christendom and while Iceland survived to become a fully developed 21st c. Nordic society, the Greenland colony ceased to exist by the end of the 15th c. (Hartman et al. 2017). Unlike Greenland, which never boasted a very large population, Iceland was quite successful and had a thriving population of roughly fifty to sixty thousand by the 12th c. Although formally part of Norway, Iceland was under the control of Denmark after the dissolution of the Kalmar Union in the 15th c. Iceland's great success as a colony was largely due to their variability in settlement styles. For example, farmsteads including large manors housing dozens of kin and servants, and tiny cottages housing single families dotted the island. The pooling of community labour and resources also aided in their survival as subsistence was turned into a communal event, especially during cultivation of their barley and flax crops (Hartman et al. 2017).

Iceland's climate, in comparison to Greenland, boasted a relatively mild climate due to the Irminger current, as only 10% of the island was covered in glaciers during the medieval period (Blöndal & Gunnarsson 1999). When settlers arrived on the island, they brought with them grazing animals like sheep, cattle, horses, and pigs to aid their settlements in thriving. However, this led to extensive vegetation changes and soil erosion between A.D. 1200 and A.D. 1500, as the farm animals and extensive agricultural practices caused the degradation of over

90% of woodland areas (Hartman et al. 2017; Gísladóttir et al. 2011). The seasonal limit of the Arctic drift ice was also very influential to Iceland's climatic cycles. Due to the ice's proximity to the island, it became an important feature of its climate as it negatively affected the ability for vegetation to grow by lowering the local air temperatures throughout the 12th and 13th c. (Hartman et al. 2017; Ogilvie 1991, Bergporsson 1967). The LIA also caused agriculture to stop completely in Iceland by the 15th c. with crop cultivation only picking up again in the 20th c. (Grove 2004; Cairns 2015).

Perhaps one of the most important factors that affected Icelandic weather patterns were the approximate two to three hundred volcanic eruptions that occurred on the island since the Norse settled there. These eruptions, which lasted anywhere between a few months up to several years, passively released emissions even when dormant (Walser III et al. 2018). The Örae Fajökull eruption in A.D. 1362 devastated nearby farming communities (Hartman et al. 2017) while the Eldjá eruption affected the south of the island in the 3rd decade of the 10th c. (Walser III et al. 2018). Another large volcano, known as Hekla, erupted several times, first in the 12th c. and then again at the beginning of 14th c. These eruptions may have resulted in extremely high levels of mercury exposure for the inhabitants and livestock of the island (Walser III et al. 2018).

Much like Greenland, Icelandic settlements exported walrus ivory, but when the trade gradually dried up, inhabitants switched to exporting dried fish and woolen cloth (Hartman et al. 2017). This switch in exports is indicative of Iceland's necessary adjustment to low value/ high-volume exports. This was an important characteristic to Iceland's successful economy and one that allowed the island to thrive in the evolving European markets. Seasonal trade centers were also established along the coast as the number of fishing sites increased after A.D. 1250. These settlements mostly harvested cod to dry and trade internally which allowed for trade to flourish with kingdoms like Germany, the Netherlands, and Denmark in the 15th c. (Walser III et al. 2018).

Monastic and trade networks that were put into place early within the island settlement allowed for the Icelandic populations to stay connected to the European mainland (Hartman et al. 2017). The only time that Iceland seemed to be truly isolated was when the island was hit by the plague (Streeter et al. 2012). Although Iceland did not succumb to the plague until much later than the rest of Scandinavia (A.D. 1402) they, like the rest of Europe, experienced many subsequent pandemics which resulted in the breakdown of shipping routes. This left the island isolated and closed off from the outside world which ultimately protected Iceland from further outbreaks (Lagerås 2016).

England

Introduction

In order to contextualize Scandinavia's medieval and early modern history it was determined that England would be used as a comparison to see how these two kingdoms differentially experienced factors like urban growth, environmental anomalies, and other sociocultural circumstances and how these unique experiences may have affected respiratory health in either population. Specifically, England was chosen as an appropriate comparison due to the kingdom's long and intertwining history with Scandinavia. Many Scandinavian men and women travelled to England first to raid but then to settle and farm the rich agricultural lands found in there. Sociocultural transplantation also occurred in Scandinavia as the English church sent numerous clergy and missionaries to Scandinavia in their efforts to Christianize the northern pagans.

The medieval period in England is generally known to have begun around the year A.D. 1000 when several Nordic countries adopted Christianity, and the Norman's began their rule in England (A.D. 1066 to be precise with the Battle of Hastings). It was around A.D. 900 that the Viking raids began to peter out in Britain which left the kingdom in a period of relative peace and political stability for a short while before the Normans invaded England in the 11th c. The peace was relatively short lived though; between the 9th and 12th c. England was invaded and conquered more than any other Western European kingdom at this time (O'Brien 2011). This may partially be due to England's reputation as a kingdom rich in agriculture and monetary wealth which would have attracted all kinds of foreign raiders, like those from Scandinavia. Its vulnerable position surrounded by water also made it relatively easy to access. England is bounded by the North Sea to the east, the English Channel to the south and the North Atlantic to the west. Further facilitating raider's attempts to penetrate inland were the many estuaries that flowed into river systems throughout the country (Rippon 2011). England then began the canalization of several rivers starting in 11th c. which meant that they could be more easily navigated by larger boats, which facilitated local trade but also made it much easier for invaders to travel deeper into the country unrestricted (Rippon 2011).

Population Demographics

During the Norman Conquest (11th c.), England's population is estimated to have ranged between 1.5 and 2.5 million people (Huscroft 2005; Langdon & Masschaele 2006) which continued to increase until three centuries later when the population totalled approximately 3 million (Rigby 2010; Platt 1978; O'Brien 2011). The high pressure put on natural and human resources preceding the outbreak of plague was believed to have pushed the kingdom into war, famine, and pestilence (Platt 1978). Despite high population numbers, an examination of England's population distribution suggests that only about 6% of England's population lived in towns in the 10th c. while over 90% of the population still lived in rural settlements (Rigby 2010). The number of urban dwellers increased to around 10% in A.D. 1086 then shot up quickly to 15-20% by the 14th c. (Rigby 2010; Everitt 1966).

Between the 14th and 16th c. England's population experienced a slight decline and stagnation as it is estimated that the population dropped from nearly 2.8 million in A.D. 1377 to about 2.3 million by A.D. 1524 (Rigby 2010). This downward trend may have been a result of successive plague outbreaks that hit the country throughout the 14th c. and 15th c. (Langdon & Masschaele 2006). Naturally, England was not prepared to face all these disasters simultaneously and the drop in population demonstrates that (Platt 1978). This theory is highly debated as some scholars argue that it was a slow but steady accumulation of other infectious diseases that allowed the plague to take such a strong hold on an already "disease-ridden society" (Benedictow 2012: 17). The population was eventually able to recover as England began to recuperate in the 16th c. (Platt 1978). Although it may be tempting to take these population figures as fact, it should be kept in mind that they are general estimations. These estimations in particular were sourced from English tax records for the 14th-16th c. and may not represent the true nature of medieval England's population (Rigby 2010). Certain tax records may be falsified in order to avoid high tax collection or may simply be missing as medieval tax collection was not heavily regulated or consistently collected throughout the period.

Urbanization and State Formation

In the early 11th c. English society experienced a complete feudal revolution that replaced the old governmental system with a new seigneurial system that allowed, among many other things, for the development of more nucleated villages and towns (Baxter 2011). Many of these early towns began as riverside trading centers called 'wics' (meaning compact settlement); for example, Lundenwic (London) and Eoforwic (York) (Griffiths 2011). Several of these early town examples lost significance; but a few, like London, persisted and continued to flourish into densely populated urban centers. High population density was not only confined to London though, as many other towns in Medieval England boasted large populations. For example, Winchester inhabited about 81 people per acre which exceeds the density of many modern English cities (Kowaleski 2014).

By A.D. 1066 England had over one hundred towns, mostly concentrated in the southern and eastern regions of the country (Langdon & Masschaele 2006). Some of the most important towns in this period were Winchester, Norwich, Lincoln, York, and London (Langdon & Masschaele 2006, Griffiths 2011). These towns were for the most part centers of manufacturing, food production and distribution which flourished so by the late medieval period, England had around 600 towns. London consistently held the title of England's largest and most influential town as its population reached 50,000 by A.D. 1500 (Rigby 2010). London was also the wealthiest town in England, as it was five times as wealthy as Bristol, the next city in line by the 13^{th} c. (Platt 1978).

Most urban houses in the late medieval and early modern England were made of stone with tiled or slated roofs, as a sign of wealth and prestige but also for fire prevention (Platt 1978; Dyer 2013,2008; Griffiths 2011). Despite their prestigious nature these stone houses trapped smoke more readily inside the house which could have worsened the air quality in the home and irritated respiratory conditions like asthma which could lead to sinusitis. Urban residences, garden walls, or outbuildings were also sometimes made of mud or clay, regardless of the societal rank of the family. Prosperous and destitute peasants alike all used mud walls to build some part of their residences as these building materials were often cheaper and more readily available than stone or tile (Dyer 2008).

Due to the increase in population, space was also a hot commodity in many towns, so houses were often built up instead of outwards. Therefore, many houses were at least two storeys tall and also included a cellar for food storage (Kowaleski 2014; Dyer 2013,2003). Families that could afford more land would also have backyards that were used for a myriad of different purposes, including housing subsidiary buildings, wells, cesspits, animal pens and middens (Griffiths 2011; Dyer 2013). These setups were not very hygienic as waste and trash piles were often put next to wells, which may have contributed to the higher rates of pestilence, respiratory diseases, and mortality in urban towns.

England also experienced a period of ‘Great Rebuilding’ that took place in towns across the country in the 16th c. which greatly improved housing standards. Houses were renovated with staircases, closets, indoor bathrooms, glazed windows, plasterwork, floored-over halls, and/or wainscoting (Platt 1978; Dyer 2013). Complete rebuilds were not an option that many families could afford though so these renovations were often done over a long period of time. Moreover, architecture changed once again during the Tudor period as more experimental building materials were used to build and adorn houses; these included terra cotta, plaster, and painted Dutch tiles (Platt 1978). These renovations were not universal either as many manor houses retained their old hall and chamber structure until well into the 17th c. This means that discerning which housing style was the most harmful to respiratory health is difficult for modern researchers as medieval houses were often a patchwork of many different heterogenous styles and functions which would have made each home unique.

Furthermore, urban housing was far from homogenous as it often depended on the family’s socioeconomic status (Dyer 2008). ‘Wealden’ style houses were inhabited by the middle classes. They were characterized by large open central halls with good ventilation, symmetrical service and chamber wings, and specialized wood working throughout the house (Platt 1978; Dyer 2008; Dyer 2013). While the ‘cruck-built hall-house’ which were mainly for peasants, were often two storied end block buildings. Lastly, the ‘longhouse’ was reserved for the poor and destitute and would have had the most detrimental impact on respiratory health due to squat nature of these homes and the subsequent lack of ventilation save for a single hole overtop the hearth (Dyer 2008; Dyer 2013).

Commercialization was the key to the medieval English economy (Rigby 2010). During the early medieval period England’s economy was restricted by demand, subsistence crises, and rising mortality rates (Langdon & Masschaele 2006). Circumstances quickly changed along with the 12th/13th c. population increase, as markets selling food and manufactured goods became high in demand in order to satisfy the influx of new arrivals to the city. This constant stream of emigrants to urban centers, that were already beginning to feel the pressures of a high population density, could have brought with them new pathologies, and aided in the spread of disease throughout the regions in which they travelled. Although only 60 markets were mentioned in the

Domesday book in A.D. 1086, by the 12th c. 150 markets were known to exist, and a whopping 350 markets were active by the 13th c. (Langdon & Masschaele 2006). It was during this time that markets experienced several structural changes; this included their detachment from the church, standardization, spread and growth, and new legal status (Britnell 2011). This new status came from royal charters that were awarded to certain towns that exempted them from tolls (Langdon & Masschaele 2006).

However, these towns quickly became oversaturated with markets and by the 14th c. they began their slow decline. This decline was seen across England as there was an overarching failure of urban centers after A.D. 1425. Town populations suffered as they also fell between A.D. 1377-1524, but some urban sectors continued to prosper despite the drop in population, mainly because of the growth in the wool and cloth industries (Rigby 2010; Dobson 1977).

With subsequent years of excellent weather, the country often produced more grain on a yearly basis than it needed to feed its own population (Hamerow et al. 2019; Hamerow et al. 2020). Despite this fact, many of its poorer populations were never in a position to take advantage of this bounty. These populations were therefore accustomed to seasonal shortages as before the 17th c. they were extremely common. For example, there were 500 food shortages and disease outbreaks between A.D. 900-1200 which would cause English populations to undergo long periods of stress which could have led to a decline in general health especially if these populations were already weakened by disease or general malnutrition (Rawcliffe 2011).

Rural Life

Similar to many other medieval kingdoms, England was mostly inhabited by rural populations that lived in a variety of different settlements, including built up nucleated villages, hamlets, and dispersed or isolated settlements (Dyer 2000). These settlements were also composed of several different types of peasants including villeins (an unfree labourer or serf), cottagers, freemen, and slaves. The livelihoods of the peasantry in medieval England were unstable as they were often the first to suffer from any climatic, economic, or social disturbances. Cottagers and freemen constituted approximately 40% of the English peasantry and they typically held a yardland, which constituted 30 acres of land (Platt 1978). These peasants were usually able to produce enough food for their families and also a small surplus to sell at the market (Platt 1978). On the other hand, villeins constituted roughly 30% of the peasantry class and held only between 3-5 acres which was not enough land to be self-sufficient (Bekar & Reed 2013; Dyer 1989; Olson 2009). Moreover, they often had to work as tenants on larger estates to make enough money to survive. A large portion of peasants made barely enough to survive. Therefore, in times of instability, like in the 12th/13th c. when overpopulation led to an increase in inequality and poverty, peasants were the first to feel the negative ramifications of disease outbreaks (Bekar & Reed 2013).

There were many different types of accommodations that rural populations lived in, many of which were based on hierarchy and regional trends. For example, in the east, estates were the primary settlement style. Characteristically peasants would live peripherally to the estate and work the lord's lands everyday (Platt 1978). The northern villages experienced a major resettlement after William's Harrying of the North in A.D. 1069-1070 (Griffiths 2011; Liddiard 2018). While in the midlands, the central part of England which generally encompassed the kingdom of Mercia, nucleated villages were the most popular settlement type and continued to thrive throughout the 13th c. Their success was largely based on available money and population growth, as these factors dictated which churches and fields were rebuilt or expanded (Liddiard 2018). These villages could be rather large as some are recorded to have housed up to five dozen peasant families that each owned between 15-30 acres of land and participated in communal ploughing of those fields (Fleming 2011; Olson 2009).

On the other hand, manors were the most popular type of settlement style in the southern regions of medieval England. These settlements were comprised of a large main house, or manor, for the lord, a church, and number of houses grouped together for the peasants. This type of configuration often began as villages with the whole settlement being surrounded by fields (Platt 1978). The peasants themselves typically lived in single or double aisled structures that sometimes evolved into baronial aisled halls made of stone if the peasants themselves were wealthy enough. They often began as very simple, one-storey mud and wattle structures with infield yards and backyards facing onto common greens (Griffiths 2011; Dyer 2013). Wealthier rural families often lived in larger two storey farmsteads, or communally in big complexes with other wealthy families to accumulate more land (Platt 1978).

All these settlement types changed in the 13th/14th c. as overpopulation and crowding caused peasant land hunger and economic instability. This meant that large tracts of land owned by lords or wealthy peasants were broken up into even smaller plots that continued to push out arable farmland into ever less fruitful soils (Hamerow et al. 2019; Hamerow et al. 2020; Platt 1978). For example, due to the 12th c. population increase more coastal marshes were embanked, drained, and settled. This was done with a high cost, high risk, high return mindset which did not always end advantageously (Rippon 2011). In A.D. 1086 there was 8.5 million acres of arable land available to farm but by A.D. 1300 upwards of 11.5 million acres of arable land was recorded (Baxter 2011). This new trend caused agricultural yields to continually decrease as unsuitable soil continued to degrade with use (Platt 1978). Several peasant families were forced to share one holding which compounded the problem of inequality amongst the peasantry as more and more families were unable to produce enough food to feed their families and many fell into unfavourable circumstances (Everitt 1966). Moreover, shortages of good pastural land drove up its price considerably, making the acquisition of meadowland nearly impossible for the impoverished peasantry. This led to peasants being unable to keep any animals, as they had no land for them to roam and graze on. This meant no meat for consumption, and no manure for their agricultural fields which ultimately led to increased soil exhaustion and ever decreasing agricultural yields (Platt 1978).

This all came to a head in the 14th c. when worsening climatic conditions forced many landowners to abandon their efforts of cultivating their land. This resulted in the land market becoming oversaturated as the peasantry along with smaller manors were forced to sell their land (Dyer 2000; Bekar & Reed 2013). Larger manors, on the other hand were not affected for another 100 years, rather, they mostly benefitted from this chain of events as they were ultimately able to snatch up the land that their less fortunate peers were forced to sell (Dyer 2000).

In general, the wealthiest, and most prosperous regions of England were the well-established counties of Kent, Essex, Suffolk, Norfolk, Devon, Cornwall, and Somerset (Hopcroft 1994). All of these regions were located within a small central band across lowland England, which spanned from Somerset, in the southwest, to Lincolnshire, in the east (Platt 1978). These counties had the best agricultural yields; with twenty bushels of wheat cultivated per acre and a 7:1 yield per seed recorded in the southwest (Hopcroft 1994; Platt 1978; Hamerow et al. 2020). These regions were also rich in textile industries, brewing, salt making, fishing, shipping, tanning, baking, and carpentry, making these regions some of the richest in the kingdom (Campbell 1984).

Osteologically, the evidence for high prevalence rates of respiratory diseases like sinusitis can be seen across both rural and urban populations in England and is summarized later on in Table 2. This largely supports the historical data that shows medieval England's early adoption of urbanization, commercialization, and relatively high population density across both rural villages and urban towns negatively impacted the population's respiratory health. While some rural villages like Wharram Percy demonstrated a moderate 39.5% prevalence rate of sinusitis (Lewis et al. 1995), others like Raunds Furnells (50%) (Roberts et al. 1998) in Northamptonshire, Bishopsmill School in County Durham (80%) and Fishergate House (48%) in Yorkshire showed higher rates of infection (Roberts 2007). Urban cemetery collections were also quite varied with examples from St Helen-on-the-Walls (55%) (Lewis et al. 1995), Christ Church Spitalfields in London (17%) (Roberts 2007), and Chichester Hospital in Sussex (54.9%) demonstrating varied rates of infection (Boocock et al. 1995). Despite the fluctuations in prevalence, it seems that in general urban centres in medieval England showed slightly elevated rates of respiratory disease with rates typically over 50%, except for Christ Church Spitalfields which had a very low rate of 17%. However, this cemetery represented a middle-class population which may have been afforded some luxuries not available to lower status individuals living in poorer neighborhoods, like improved sanitation and access healthcare. This could indicate that social class played a large role in determining respiratory health as poorer parishes like St Helen-on-the-Wall and Fishergate House both had significantly higher rates of infection than Spitalfields despite representing both urban and rural populations. As for the rural cemeteries they were truly varied with rates ranging between 39-80%.

Such high prevalence rates found in both rural and urban populations may be due to medieval England's early embracing of urbanization and high population density across the kingdom. England was so densely populated that by the late medieval period there were over 600 nucleated and densely populated towns that dotted the country. It was also not uncommon for some towns like London to have populations in the tens of thousands (Griffiths 2011). Although rural, manors and estates dotting England's medieval landscape may have also been as densely populated as some urban centers which means they could have shared some of the same risk factors which could have led to higher rates of respiratory disease. Widespread commercialization also occurred in the 12th to 13th centuries and was largely enabled by these earlier increases in population which would have driven demand simultaneously (Rigby 2010;

Langdon & Masschaele 2006). It is therefore likely that both urban and rural populations were at risk of respiratory diseases due to the myriad of factors prevalent in both towns and villages. The similarities in prevalence between the two populations may also mean that the traditionally recognized urban aetiological factors of higher air pollution due to industrialized craft specialization, denser populations, and poorer hygiene may not be the sole contributing factors detrimental to respiratory health or perhaps that they were also prevalent in rural populations as well. It is also possible that the rural risk factors in English peasant farms were equally as harmful to respiratory health (Roberts 2009). Increases in agricultural activity seen during the agrarian revolution may have caused more dust and pollen in the air which would have caused irritation to the nose and lungs and could have subsequently led to increased rates of respiratory disease (Davies-Barrett 2018; Davies-Barrett et al. 2021). Perhaps fluctuating environmental conditions also played a large role which could explain why sinusitis was prevalent in many English skeletal collections, regardless of settlement type (Bernofsky 2010; Lewis et al. 1995; Boocock et al. 1995; Roberts 2007). Environmental anomalies would have affected both urban and rural populations in much the same way as both were still largely at the mercy of the environment during the medieval period (White 2014; Yoder 2006; Pfister et al. 1996). The potential role local and regional climatic conditions played in affected respiratory health will be discussed in more detail in later sections.

The Black Death

The Black Death hit England for the first time in June of A.D. 1348 and ravaged the country until late A.D. 1349 (Theilmann & Cate 2007; Lenz & Hybel 2015; Bos et al. 2011 Dewitte 2015; Benedictow 2004; Yoder 2006; Wood & DeWitte 2003). Due to modern molecular testing, it has now been confirmed that the medieval plague that swept through Europe in the mid-14th c. was caused by *Yersinia pestis* carried by rats and fleas (Bos et al. 2011; Haensch et al. 2010; Schuenemann et al. 2011). The plague spread through the south of England and reached London by November before moving north (Theilmann & Cate 2007; Lenz & Hybel 2015). It is estimated to have killed about 35% of England's total population and is suspected to have presented itself as two variants known as bubonic and pneumonic with the former producing boils and black pustules on the body of its victims and the latter's involvement still not certain (Platt 1978; Bos et al. 2011; Yoder 2006; Benedictow 2004). While some researchers firmly believe it was solely the work of the bubonic strain (Benedictow 2004), others believe that the plague's rapid spread through Europe, its high mortality rate, and its similarity to modern pneumonic outbreaks demonstrate that the pneumonic version of the plague may have played a larger role than originally believed (Poos 1981; Callow & Evans 2016; Yoder 2006). Most cities were so overwhelmed by the sudden number of deaths that many established emergency cemeteries. This is exemplified in London which tried to plan ahead and had two emergency cemeteries set up on the outskirts of the city, in the West and East Smithfield areas before the worst of the plague hit the city (Kowaleski 2014; Bos et al. 2011). England's increased exposure may have been facilitated by the many seaports that allowed the disease to spread like wildfire throughout the town (Theilmann & Cate 2007; Lenz & Hybel 2015). Many of the town's characteristics that enable the plague to ravage its inhabitants so thoroughly would have also permitted non-specific respiratory diseases to do the same, especially on populations already weakened by malnutrition and the successive plague years.

Although subsequent plague outbreaks did not hit England as hard as the original outbreak did in A.D. 1348, it continued to ravage the country well into the 17^{th} c., meaning that its influence on medieval English demographics was much more diffuse than originally thought (Poos 1981; Yoder 2006; Benedictow 2004). The repercussions of the plague were felt throughout the country, and for many the plague altered many aspects of their daily lives. Firstly, migration into towns during the post plague era increased drastically in response to the high demand for labour, which caused rising wages and falling rents especially in the A.D. 1370s/80s and 1420s (Kowaleski 2014; Platt 1978). An influx in migration would have also led to an increase in further disease outbreaks as individuals from across the country gathered in one town and brought with them their previously acquired respiratory diseases. This migration influx was spurred on by the decrease in agricultural profits which caused a shift to pastoral farming and a general loss of employment. This ultimately pushed more people into towns looking for employment and may have also pushed them directly in the path of subsequent epidemics (Kowaleski 2014). Due to the increase in urban migration, many small villages experienced gradual attrition as their populations either died or migrated until finally, many of them disappeared (Platt 1978).

Chapter 5-Environmental Histories

Introduction

The medieval period in Scandinavia (A.D. 1050-1536) is characterized by many well-known environmental events, for instance the Medieval Warm Period, the Great Transition, and the Little Ice Age, which all have traditionally been thought to have drastically impacted past European populations. Abrupt changes in climate, and its indirect link to shifts in sociocultural, agricultural, and economic circumstances, are also thought to have led to a general deterioration in respiratory health (Roberts & Lewis 2002; Wells 1977; Bernofsky 2010; Davies-Barrett 2018; Davies-Barrett et al. 2021; Sundman & Kjellström 2011; Cairns 2015; Ayres et al. 2009). As this section will argue, the circumstances associated with these climactic events may not be as straightforward as once believed, and the link to deteriorating respiratory health difficult to demonstrate. The relationship between climatic stability and instability is much more complex and intertwined and their potential effects on past European population's respiratory health will be further examined within this chapter.

There is very little mentioned within Scandinavian primary sources about abnormal weather patterns or epidemics throughout the medieval period (Hybel & Poulsen 2007; Yoder 2006; Alexandre 1987; Herlihy 1980), but there are a few scattered sources such as *Ælnoth of Canterbury's biography of St. Canute* (Ælnoth 1908-1912), and the *Chronica Sialandie* (Gertz 1917), and *Annales Essenbecenses* (Waitz 1892) that briefly mention certain periods of climactic instability. Unfortunately, they are quite selective in the events they report and often do not give any exact details. The Danish texts that do exist are typically urban chronicles or monastic annals (Alexandre 1987). They report mostly on winter temperatures and conditions, as they were often those that affected daily life with the most severity (Glaser 1997). More comprehensive information can be gathered from proxy data taken from ice cores, glaciology (Broecker 2001), dendrochronology (Büntgen et al. 2005), biological proxies like Chironomids (lake flies) (Axford et al. 2009), and foreign primary sources from Germany and England. Therefore, if a climactic anomaly is mentioned in sources from neighbouring countries, like Germany, it is a fair assumption that these same events occurred in Denmark. Having said this, it is unlikely, but has occasionally happened, that a climatic event or epidemic that hit most of northern Europe skipped over Denmark (Hybel & Poulsen 2007).

Medieval Climate Anomaly (MCA) / Medieval Warm Period (MWP)

The medieval period and the early modern times in Scandinavia were marked by two distinct climactic events. The Medieval Climate Anomaly (MCA) (more traditionally known as the Medieval Warm Period (MWP) which occurred roughly from the 10th-13th c., and the Little Ice Age (LIA) that followed afterwards, beginning in the late 14th, and lasting until the 19th c. (Hybel & Poulsen 2007). Although there was only an estimated 1-2 °C difference between the two periods, these small fluctuations in temperature along with constantly changing weather conditions, in the form of droughts or excessive rainfall caused immense agricultural and economic damage across Scandinavia (Hybel & Poulsen 2007). These variations in weather greatly impacted regional agricultural practices and caused famines that stretched for several years at a time which would have put populations under prolonged periods of stress and made them more susceptible to various diseases, including respiratory ones (Hybel & Poulsen 2007). Fluctuations in humidity, precipitation and aridity could have also affected the general respiratory health of medieval populations, especially the oldest old whose immune systems would not have been as strong as their younger counterparts (Weiskopf et al. 2009; Plackett et al. 2004; Castelo-Branco & Soveral 2014; Grubeck-Loebenstein & Wick 2002). Which means, that acute respiratory infections or bouts of asthma could have become chronic and led to sinusitis or reoccurring ear infections (Bernofsky 2010; Davies-Barrett 2018; Davies-Barrett et al. 2021).

Before the 14th c., Medieval Denmark thrived during the "climatic golden age" or "Medieval Warm Period" where temperatures gradually increased and stabilized (Scott & Hoppa 2018; Hybel & Poulsen 2007; Scott 2015). Contrary to popular belief the MWP was not always continuously warm and stable though as there were periods of fluctuation and climate reversals that punctuated the milder periods (Glaser 1997). For these reasons, this period will henceforth be referenced in this thesis as the Medieval Climate Anomaly (MCA) instead of its more traditional name since the former alludes more to these variations. For example, the period spanning A.D. 750-1300 include several fluctuations that included colder than average winters that were just as cold as those experienced in the LIA (Campbell 2016). This is especially true of the Oort minimum (A.D. 1010-1050) which caused a decline in global temperatures and regional food shortages (Campbell 2016; Fagan 2000).

Specifically focusing on the Danish climate during the early medieval period, the English monk, Ælnoth, who traveled to and settled in Denmark describes several bad winters and long-lasting famines throughout the 11th c. in his legends of St. Canute (Hybel & Poulsen 2007). Ælnoth of Canterbury describes a famine that lasted for 9 years being caused by disease and "great storms" during King Oluf's reign from A.D. 1086-1095 (Gertz 1912). He describes "fields becoming barren, meadows poor in grass, water and streams yielding few fish, disease destroying cattle and men weakened and killed by illness" (Hybel & Poulsen 2007: 71). These sources clearly depict this period as tumultuous, with unpredictable weather patterns negatively impacting Danish populations in the form of reoccurring famines and increased frequencies of disease. As Hybel & Poulsen (2007: 75) state, "Denmark, like the rest of northern Europe, was probably ravaged by these catastrophes nine times in 320 years… approximately once every thirty-five years." If this statement is true then it stands to reason that sporadic climatic conditions, such as fluctuations in humidity, aridity, heat, and precipitation, could have played an important role in a possible degeneration of respiratory health in the general population but particularly in older adults due to their often-compromised immune systems and heightened susceptibilities to respiratory infections; although this remains to be demonstrated osteologically in medieval Scandinavia (Flohr & Schultz 2009; Tovi et al. 1992; Bernofsky 2010; Davies-Barrett 2018; Davies-Barrett et al. 2021; Sundman & Kjellström 2011; Cairns 2015; Brachman 1990; Ayres et al. 2009).

Nevertheless, The MCA was shaped fundamentally by several essential climatic occurrences, the first being a lower rate of volcanic activity between A.D. 960-1150, which resulted in a solar maximum that ran from the 11th-13th centuries (Brooke 2014). The second is the temperature change associated with this period. Although there are variations in the reporting of the temperature change, with some sources stating a 2 °C difference while others state there was no significant change; most sources agree that temperatures were 0.7-1.0 degree higher than the average temperatures today (Gamble 2014; Gough 2013; Yoder 2006; Fagan 2000; Lamb 1965). Denmark has traditionally had a mild insular climate with variations in summer and winter temperatures being mild. Rainfall is more or less evenly distributed throughout the year with concentrations in the summer and fall (Hybel & Poulsen 2007). In the medieval period the climate was little different but its influence on daily life was greater than what it is today. This may have been due to weather being felt more directly because individuals worked outside for most of the year which could have put them at greater risk of upper and lower respiratory tract infections (Fagan 2000). People's livelihoods also greatly depended on their agricultural production and ability to trade wares, which are two activities that are greatly influenced by the weather. Moreover, these activities were not at the level yet at which they could sustain substantial climate swings without serious consequences (Hybel & Poulsen 2007; Gough 2013). The environment is therefore the source of both resources necessary for survival and the stressors that adversely affect adaption (Goodman et al. 1988). The Medieval Optimum itself ended sometime between A.D. 1270-1350 just as El Niño events were ramping up throughout the Pacific Ocean and, adversely, the climate in the North Atlantic gradually turned colder and more erratic (Brooke 2014).

The Great Transition

The Great Transition, as mentioned by Campbell (2016), occurred between MCA and the LIA, roughly between the 13th and 15th centuries, with variations depending on geographic location. The term 'Great Transition' had previously been coined by Keneth E. Boulding in his monograph, *The Meaning of the 20th Century- The Great Transition* (1964) which explored the shift between pre-modern and post-modern societies and seems to have been repurposed by Campbell to also signify the transitional period between the MCA and the Little Ice Age. This period experienced erratic climatic changes, in the form of a see-saw pattern, and is generally broken up into three distinct phases. The first runs from A.D. 1260s/70s-1340 and is characterized by a ramping up of erratic climate and reoccurring famines interspersed with shorter but stable climate periods (Hybel & Poulsen 2007). The second phase, A.D. 1340-1370, is perhaps the most extreme, in which the weather caused irreparable changes to the environment and human culture (Campbell 2016). This is exemplified in such anonymously written sources as the *Chronica Sialandie 1028-1363* (Gertz 1917) which describes several instances of drought and crop failure in the early years of the 14th c. The unknown ecclesiastical author of the *Annales Essenbecenses 1020-1323* (written sometime between 1323 and 1367) (Waitz 1892) also describes consecutive instances of bad weather and associated famine in the 13th and 14th c Danish countryside. The last phase, which ran from A.D 1370-1470, is characterized by the regaining of climatic stability, as well as economic and demographic renewal (Campbell 2016).

The Great Transition has been described as perhaps just as erratic as the Little Age Ice would come to be as shifts in climate occurred often (Campbell 2016). Fluctuations were relentless, which did not allow individuals the time to adapt to their new circumstances before they changed again. These extreme climatic fluctuations coupled with large-scale disease outbreaks (plague) and an economic slump brought on by the Great Famine, may have significantly increased the level of stress experienced by populations across Europe (Scott & Hoppa 2018). These heightened levels of stress may have then led to a sharp decline in population health as individuals succumbed to higher rates of secondary pathological processes, such as non-specific respiratory diseases brought on by a decline in immune system function that could not properly adjust to the prolonged periods of stress (Lee 2012; Weiskopf et al. 2009). A 'tipping point' was reached in the mid-14th c., when temperatures once again deteriorated and the short period of stability that had been achieved in the last phase of the Great Transition gave way to the LIA (Campbell 2016).

Much like the MCA being formed by factors such as a lack of volcanic activity, solar maximums, and a reduction in sea ice, the Great Transition was reversely shaped by a definitive increase in such activity. The 13th c. recorded a massive surge in eruptions; with around ten recorded eruptions occurring between A.D. 1225, and A.D. 1285. (Gamble 2014; Langway et al. 1995; Budner & Cole-Dai 2003; Campbell 2016). The total volcanic activity for this century is the largest in the last millennium (Budner & Cole-Dai 2003, 174; Campbell 2016). A colossal volcanic eruption of Mount Samalas (Indonesia) in A.D. 1257 left the largest sulphur signature of any eruption in the Holocene with a magnitude of 7 (Lavigne et al. 2013). There was also a match between the geochemical composition of the ash expelled by Mount Samalas with glass shards found at the appropriate time level in the ice cores from Greenland (Lavigne et al. 2013). This heightened level of volcanic activity coincides with the transition to the LIA and may have been the final push for its commencement (Budner & Cole-Dai 2003; Campbell 2016). Another event that coincides with the Samalas eruption is the Wolf minimum (A.D. 1270-1370) which ultimately caused an increase in El Niño events along with an increase in polar temperatures hitting northern Europe (Campbell 2016).

The Great Famine

Early periods of famine and disease were seldom written about as only a few examples could be found in the *Chronicon Roskildense*, which covers a small swatch of Danish history as it relates to health and demographics between the years 800-1150 AD (1917). An exception to this was the Great Famine, a moniker first used by Henry S. Lucas when he described "The

Great European Famine of 1315, 1316, and 1317" (1930) which hit medieval Scandinavia and England during the first phase of the Great Transition. Although famines were common throughout this period, this particular famine gained notoriety for its unrelenting duration and intensity. The Great Famine lasted for 7 years, A.D. 1315-1322 (Jordan 1996; Hybel & Poulsen 2007; Whited et al. 2005), with A.D. 1316 being the worst year for grain (Hybel & Poulsen 2007; Yoder 2006). The rains prevented "thousands of hectares of cereals from ripening fully, as well as the complete failure of fall plantings of wheat and rye and hay could not be cured properly" (Fagan 2000: 32). People reverted to eating foliage, and there was also an increase in piracy, assault, and theft (Fagan 2000). These catastrophic events were felt across Northern Europe, from Ireland to Germany and North into Scandinavia. The only perceived exception being Sweden which experienced the same environmental conditions that caused the Great Famine in Denmark but avoided the worst of its effects due to the "sparseness of agricultural societies [which] made them less vulnerable" (Lagerås 2016: 9). As was previously described, Sweden is an extensive kingdom that was sparsely populated at the time. Communities could have therefore been more well equipped to withstand the hardships inflicted upon them by such an event as competition for the dwindling resources was much lower.

The Little Ice Age

It is nearly impossible to determine exactly how the LIA affected daily life, as regions with diversified agriculture and good access to international trade networks could have coped comparatively well with severe weather conditions. Unfortunately, remote settlements that concentrated on a single crop, like those that doted the Northern Swedish and Norwegian regions could have fared much worse (Whited et al. 2005). The extreme climatic fluctuations experienced during the LIA will be explored in depth throughout the section in the hopes of establishing the environmental context of late medieval Denmark which will later be used to inform the analysis of the osteological data. Prolonged levels of stress coupled with compromised immune systems, worsening living conditions, and a decline in nutritional health could have allowed secondary pathological processes, such as non-specific respiratory diseases to run rampant throughout European populations but this has yet to be established osteologically in Scandinavia (Lee 2012; Weiskopf et al. 2009; Scott & Hoppa 2018).

The LIA across Scandinavia seems to have begun in the 14th c. with marked glacial advancement (Cairns 2015) which continued to worsen until its peak in A.D. 1625 (Mikalsen et al. 2001). The Little Ice Age lasted for upwards of 500 years, and most notably, was anything but stable. The LIA had its origins in the interaction of solar variability and volcanic eruptions along with oceanic and atmospheric circulations that caused extreme weather conditions to become more common (Brooke 2014; Fagan 2000; Campbell 2016). This period was further characterized by increases in sea ice which blocked shipping routes, with the maximum levels of ice hitting Greenland and Iceland between A.D. 1470-1490 (Campbell 2016) along with a rapid decrease in population density from marginal lands due to heightened levels of farm desertion (Lamb 1965; Gamble 2014). Most of the LIA is characterized by great variability as "The LIA was never a monolithic deep freeze, rather a climatic seesaw that swung in volatile and disastrous shifts, arctic winters, blazing summers, serious droughts, torrential rain" (Fagan 2000: 48). Classic, sub-zero winter conditions were only prevalent between A.D. 1550-1850 (Matthews & Briffa 2005). Mean temperatures from A.D. 1590-1850 were only 0.3-1.0 degrees lower than present levels but in the winter, the mean temperatures were more than a degree lower (Le Roy Ladurie 1972; Whited et al. 2005). Snow and frosts were earlier, and thaws occurred later, and by the late 16th c. harsh winters and cool summers in Central Europe brought average temperatures of 2 degrees lower than the 1900-1960 mean temperature (Whited et al. 2005).

One of the main factors behind the turnaround of optimal climate is the reversal of the North Atlantic Oscillation (NAO) system. NAO is a result of changes in sea surface temperature and atmospheric pressure in the North Atlantic. It is a major contributor to the erratic weather that descended on Europe after A.D. 1300 and accounts for nearly half of the variability in winter temperatures (Fagan 2000). Around the mid-14th c., the NAO turned from a positive (warm north) to a negative (cold north) which changed the pattern of drought and precipitation (Brooke 2014; Whited et al. 2005). For example, if a high prevails around the Azores (a high NAO index) and a low around Iceland, warm Atlantic winds create mild winters and stronger westerly storms in Northwestern Europe (Whited et al. 2005; Pfister et al. 1996; Fagan 2000; Briffa 2000; Campbell 2016). If the high is around Iceland/Greenland (a low NAO index), cold arctic winds can easily penetrate the continent and British Isles from the North Pole and Serbia, which is what happened in the 14th c. (Campbell 2016). This phenomenon caused a great deal of coastal erosion, especially in kingdoms bordering the North Sea such as Denmark and the Netherlands

(Van Dam 2001). As a result of the A.D. 1240 and A.D. 1362 floods, it was reported that 60 parishes accounting for over half of the agricultural incomes of the Danish diocese of Slesvig were inundated (Lamb 1995).

The tumultuous nature of the LIA means that there were many significant cold spells that occurred throughout the period in Northern Europe. There was no shortage of these periods in the 14th c. as they took place in: "A.D. 1312-1314, A.D. 1323-1327, A.D. 1336-1338, A.D. 1349-1353, A.D. 1378-1382, A.D. 1389-1390, and finally A.D. 1392-1394" (Campbell 2016: 279). These colder periods were then interspersed with short periods of warmer and dryer conditions that verged on droughts in the later 1320s, the 1330s, and the 1380s (Hybel & Poulsen 2007), while the 1360s were predominantly wet (Lamb 1995). Minimum tree growth in Asia, North America and Europe shows a global correlation in deteriorating climate conditions in the 1340s and 1350s. These correlations occurred across many different species and regions. The 14th c. is hence a perfect example of the variability experienced in the LIA.

The following centuries saw no amelioration either as cold fronts continued to hit Northern Europe. Extreme cold continued to dominate the winter months throughout the 1400s and did not ameliorate until A.D. 1550 (Le Roy Ladurie 1972). The mid 16th c. was once again characterized by a progressively negative trend for summer temperatures, as they continued to deteriorate from that point onwards along with their winter counterparts (Glaser 1997; Brooke 2014; Le Roy Ladurie 1972). These conditions continued to persist in the 1600s, especially between 1651-1660, when winter temperatures plummeted once again (Glaser 1997).

Many of the climate anomalies that took place before A.D. 1850 can be explained through the fluctuations and intertwining of such events as solar radiation, volcanic activity, and human impact in the form of mass deforestation (Haldon et al. 2014). The veils of sulphur that volcanic eruptions emitted often obscured the sun for several consecutive years and caused many harvest disruptions (Brooke 2014; Whited et al. 2005; Lamb 1995; Budner & Cole-Dai 2003). The dust from these eruptions is also 30x more effective in shielding the earth from solar radiation than it is in preventing the earth's heat from escaping (Fagan 2000, 57; Lamb 1995). Meaning the earth, or the parts shielded by the dust, are not capable of intaking any solar heat. Moreover, it may take up to 3 years for the dust itself to settle and temperatures to come back to normal levels (Fagan 2000; Budner & Cole-Dai 2003). This increased concentration of dust particles in the air could have also irritated previously acquired (or genetic) respiratory problems and caused individuals to suffer from respiratory infections for long periods of time (Bernofsky 2010; Davies-Barrett 2018; Davies-Barrett et al. 2021). It is also possible for large eruptions that take place within 20 degrees north or south of the equator to affect the whole planet (Lamb 1995; Budner & Cole-Dai 2003). For example, between February and March of A.D. 1600 a spectacular eruption engulfed Peru. The Huanyaputina volcano erupted for 24 hours, resulting in 20 cm of ash falling and 19.2 cubic km of fine sediment being discharged into the upper atmosphere. This sediment was found as far away as Greenland and was detectable in ice cores as sulfuric acid peaks (Langway et al. 1995; Briffa 2000; Dybdahl 2012; Budner & Cole-Dai 2003). The eruption wreaked havoc on the global climate, but also resulted in the summer of A.D.1601 being the coldest since A.D. 1400 in the northern hemisphere and amongst the coldest of the past 1,600 years in Scandinavia (Fagan 2000). Although largely unknown there were eight more large eruptions followed by cold summers recorded in the 17th c. (Whited et al. 2005).

The LIA also had its fair share of solar minimums that are associated with this increase in volcanic activity. This includes the Spörer minimum (A.D. 1400-1550) that coincides with the eruption of Kuwae in A.D. 1453, a submerged volcano off the east coast of Australia (Budner & Cole-Dai 2003; Campbell 2016). There is also a second minimum that occurred later in the period, called the Maunder minimum (A.D. 1640-1725) (Whited et al. 2005; Pfister et al. 1996). This minimum is also associated with volcanic activity, specifically the A.D. 1641 eruption of Mt. Parker (Briffa 2000; Budner & Cole-Dai 2003).

The increased number of volcanic eruptions during the LIA also could have wreaked havoc on the respiratory health of medieval populations. The increased level of toxic volcanic gases and ash being expelled into the atmosphere would have irritated not only the skin and eyes of Scandinavian populations but also the upper and lower respiratory tracts (Guðmundsson & Larsen 2016). Although the long-term health affects caused by volcanic eruptions are not well understood and have not been studied osteologically, modern studies have demonstrated that individuals with prior respiratory conditions, especially older individuals, typically suffer the most long-term damage due to a re-emergence of symptoms during the periods after volcanic eruptions (Guðmundsson & Larsen 2016).

Nordic glaciers experienced their advances and hit their maximum a little later than their Alpine counterparts. These glaciers started advancing between the 14th-16th c. and hit their maxima at the end of the 17th – beginning of the 18th centuries (Nesje et al. 2008). Virtually all

Scandinavian glaciers are found in Norway, and included the Abbrekke, Nigardsbreen, Jostedalsbreen (being the biggest mainland icecap in Europe), Bøyabreen, Lodalsbreen, and Østerdalsisen glaciers (Grove 2003). They are mostly all found within "180 km from the West coast" (Grove 2003: 101) and are remote and far away from human settlements. This makes it difficult to find records on their positions, activities, and effects on Medieval populations, but it is believed that such glacial thrusts could have destroyed homes and entire villages, caused floods, and destroyed agricultural land, through landslides, rockfalls, and avalanches (Grove 2003; Cairns 2015).

One of the many remarkable tools utilized to analyze climatic shifts during the medieval period are the Greenland ice cores, GISP 1 & 2 (Le Roy Ladurie 1972). These cores have an accuracy of +/- 1 year and use changes in oxygen isotopic signals to show variations in temperatures, like the low signals observed in the 14th century (Fagan 2000; Cairns 2015; Mayewski et al. 1993). These ice cores were able to demonstrate that A.D.1343-1362 was the most frigid period in the 14th century, with the period being an average 10 degrees below normal (Hoffman 2014). The ice cores were also able to identify general periods of low temperatures occurring in A.D. 1200, A.D. 1500, and A.D. 1800, with higher temperatures occurring in A.D. 1400 and A.D. 1700 (Grove 2001).

When comparing the experiences of all Scandinavian countries with the climatic patterns of the medieval period, many of these kingdoms experienced much of the same conditions. For example, much of Norway's experiences with the MWP and the LIA paralleled Denmark's own exposure. Having said this, the LIA may have hit Norway even harder due to its more northern location, higher altitude settlements, and the remoteness of its populations. This can be seen in the level of glacial expansion Norway experienced north of Jostedalsbreen in the early 14th c., activity that Denmark did not experience (Thorsen & Dale 1997).

Land abandonment was characteristic especially in Northern Norway in areas such as Håsvag, Håsvik, and Sørvaer during the LIA (Sjögren 2009; Cairns 2015). Farm abandonment was variable as areas like Sor-Trondelag experienced 40% land abandonment while northern regions had 75% decline and the east only about 30%. The north may have experienced the most abandonment because farms there were located closer to the expanding glaciers, and the inner fjords. Farm abandonment occurred more predominantly in Denmark from the end of the 14th c. to the mid 15th c. (Hybel & Poulsen 2007). Regional differences throughout Denmark and

Southern Jutland were very common as Southern Jutland experienced close to 50% land abandonment while in towns such as Århus, (in Northern Jutland), only 10-20% of farms were deserted (Vahtola 2003). These variable levels of abandonment were not only due to climatic events and the subsequent sociocultural decline but also village restructuring (Hybel & Poulsen 2007). Throughout the late medieval period, several smaller hamlets and villages 'disappeared' when they were amalgamated into one larger village, or its inhabitants left their secluded settlements to live in a more urban setting (Hybel & Poulsen 2007). Settlements were best preserved near coastal areas with rich agrarian land and where fishing and trading gained an important place in the Danish economy (Vahtola 2003). Sweden also experienced the phenomenon with 15-40% of farms being abandoned during the agrarian crisis and later in the 14th c. (Antonson 2009).

Extended periods of colder weather in Scandinavia occurred throughout the LIA as the period was characterized by many climatic variations. Despite the historical data, the link between colder or fluctuating temperatures and a decrease in respiratory health in the oldest old has yet to be recognized osteologically. Having said this, some modern research shows that colder temperatures do indeed cause a general increase of morbidity and mortality, especially in older individuals (Mourtzoukou & Falagas 2007). Through research undertaken on modern British populations, respiratory tract infections have been shown to follow prolonged exposure to cold temperatures as the inhalation of cold air cools the temperature of the body which exposes the individual to cold stress and causes "vasoconstriction in the respiratory tract mucosa and suppression of immune response" (Mourtzoukou & Falagas 2007: 938). Modern research in the UK has also shown a 30% increase in mortality in elderly populations during the colder winter months due mainly to exposure, which would have been an even bigger issue for medieval populations who spent much more time outdoors or in poorly insulated homes (Dyer 2013). Especially harmful to respiratory health are sharp fluctuations in humidity and temperature which are often characteristic of mild winter climates (Mourtzoukou & Falagas 2007).

England's experience with the LIA closely resembled that of Scandinavia's as the country was hit with climatic instability, droughts, floods, increasingly stormy weather, and mild to severe winters (Platt 1978). A climatic minimum also hit England at the end of 13th c., followed by a short recovery period until A.D. 1350, and then another downwards trend that continued relentlessly until the 16th c. (Platt 1978). Primary records like the '*Inquisitions of the*

Ninth' which date to A.D. 1341-1342 demonstrate on a parish level the extreme weather conditions experienced by medieval England (Platt 1978). On average, LIA temperatures were 0.45-0.50 °C colder than mid-20th temperatures with the 1590s and 1690s begin recorded as especially cold decades (Crowley & Lowery 2000; Kelly & Ó Gráda 2014b). Overall, England fared better economically and demographically throughout the LIA than its Scandinavian counterparts (White 2014). This may, in part, be due to England's already milder climate, diversified rural economy, and access to maritime imports.

Chapter 6 -Previous Research on Respiratory Diseases in Scandinavia and England

Introduction

There has been a great deal of research done in both Scandinavia and England in relation to respiratory conditions like leprosy and tuberculosis during the medieval period (Kelmelis & Pederson 2019; Kelmelis et al. 2020; Pedersen et al. 2019; Boldsen 2001, 2005, 2009; Boldsen & Freund 2006; Møller-Christensen 1951, 1952, 1953, 1958, 1965, 1978). Unfortunately, the same cannot be said about non-specific conditions like maxillary sinusitis, otitis media, and mastoiditis. To be able to identify the gaps within the present research, emphasis must first be placed on the broader bioarchaeological context. Much of this greater context has been previously established by researchers such as Gamble (2014) and Bernofsky (2010) who have compiled detailed literature reviews about the paleopathological and paleodemographic work that has been done in relation to health in medieval Denmark (Gamble 2014) and respiratory research undertaken in England (Bernofsky 2010). The goal of this chapter is to review the current available data pertaining to non-specific respiratory research in medieval/ early modern Scandinavia and England in both rural and urban circumstances and across all sociocultural classes of society.

Tuberculosis and Leprosy in Denmark

The bulk of previous paleopathological work done in Denmark has been related to leprosy and tuberculosis and includes such topics as the effects of urbanization (Kelmelis & Pederson 2019; Kelmelis et al. 2020), prevalence rates (Pedersen et al. 2019; Boldsen 2001, 2005, 2009), and lesion characteristics (Boldsen & Freund 2006; Møller-Christensen 1951, 1952, 1953, 1958, 1965, 1978).

Møller-Christensen's mid-20th century work with leprosy in Denmark was among the first to focus on identification techniques and the various osteological manifestations of the disease on different portions of the human skeleton. His research was fundamental in laying the groundwork for future research of leprosy in Denmark such as the work later undertaken by Boldsen (Boldsen 2001, 2005, 2009). He used several collections for his research including those from the St. Jørgen's leprosy hospital, or leprosarium, (Sankt Jørgens Spital) near Næstved (AD c. 1250-1550) (Møller-Christensen 1951, 1953) and the Æbelholt monastery cemetery, associated with one of the largest Augustinian Abbeys found in Scandinavia (AD 1175-1536) (Møller-Christensen 1958). Møller-Christensen's work not only propelled the study of leprosy in Scandinavia, but it also made invaluable contributions to the historic and modern understandings of the disease while also driving research in Scandinavia for the next seventy years (Møller-Christensen 1951, 1952, 1953, 1958, 1965, 1978). The skeletal remains from Næstved are still being studied today and have given the opportunity to many current researchers, like those mentioned in this thesis, to undertake their own unique research and further our current knowledge about the intricacies of leprosy by studying one of the few completely excavated cemeteries in the region.

The skeletal collections originally excavated by Møller-Christensen have inspired the work of many modern-day researchers like Boldsen who used sensitivity, specificity, and sample frequency to estimate the prevalence of leprosy in several skeletal samples from medieval Denmark (Boldsen 2001). This included the parish cemetery of Tirup (AD 1150-1350) (Boldsen 2005), four non leprosarium cemeteries in the urban city of Odense (The Gray Friars Monastery (AD 1279-1536), St. Albani Parish Church (11th-16th c.), St. Knuds Cathedral (11th-19th c.), and the Black Friars Monastery (13th-17th c.)) (Boldsen & Mollerup 2006), five cemeteries within the border town of Schleswig (Rathus Markt AD 1060-1205), St. Nicolai Kirche (11th c.), St. Clemens Kirche (~AD 1196-?), Dominikaner Kloster (AD 1239-?) St. Johannis Kloster (AD 1170-15th c.)) (Boldsen et al. 2013), and the Westerhus cemetery in Jämtland, Sweden (AD 1073-1356) (Boldsen 2009). The remains were scored based on the presence of seven specific osteological manifestations of leprosy and through this research it was concluded that leprosy had significantly different prevalence rates across medieval Denmark (Boldsen 2001). For example, a rate of 26% was found in Tirup (Boldsen 2005), and a similar rate was also found in Westerhus although a sex difference in prevalence was observed, with females exhibiting a rate five times higher than the males (Boldsen 2009). This seems to suggest that many people across medieval Denmark were afflicted with leprosy and were not always confined to leprosy hospitals as the remains of leprosy sufferers were also found in non leprosarium cemeteries (Boldsen & Mollerup 2006). Despite the widespread nature of the disease across medieval Denmark it seems like a stigmatization of the disease was still prevalent as those with facial lesions associated with leprosy were more often institutionalized compared to those who did not have such “visible manifestations of leprosy” (Boldsen & Mollerup 2006, 350). Through his use of transition analysis when aging the skeletal remains, Boldsen was also able to examine leprosy probability scores in relation to survivorship curves, thus providing insight on the age dynamics of particular populations affected by leprosy.

In their research on tuberculosis, Kelmelis and Pedersen (2019) used four different skeletal samples from medieval Denmark, two rural and two urban, and analyzed the collection using a probabilistic approach based on lesion sensitivity and specificity to estimate disease prevalence. This type of statistical work for tuberculosis analysis was first developed by Pedersen (2016) in her PhD work which she based on a documented 20th century American skeletal collection before applying it to the archaeological context in Ribe (Pedersen et al. 2016). Moreover, this kind of statistical approach in itself builds on the previous work done by Boldsen (2001, 2005, 2008, 2013). They found that tuberculosis frequency varied between 39-69% and the rural cemetery of Sejet had the highest disease frequency. Pedersen et al. (2019) once again used the probabilistic approaches that she had previously developed to examine prevalence rates of tuberculosis in over 700 skeletons from the Ribe cemetery. The authors determined that TB increased from 17% to 40% throughout the medieval to early modern periods and that lower class individuals (29%) were afflicted with TB more often than their higher-class counterparts (10%) (Pedersen et al. 2019). In their later research, Kelmelis et al. (2020) further investigated thirteen more cemetery samples and used the same probabilistic approach to determine that tuberculosis prevalence was uniformly much higher than leprosy across all sites while rural and proto-urban sites had significantly higher disease prevalence in comparison to well-established urban centers.

Overall, the research conducted by Kelmelis & Pedersen (2019) determined that disease prevalence does not simply rely on urbanization but rather, there are several biological and behavioural factors that contribute to prevalence rates of tuberculosis in a given population. This statement could also be true for a variety of other pathologies, including respiratory diseases which were oftentimes prevalent in high rates in both rural and urban populations (Lewis et al. 1995; Boocock et al. 1995; Roberts et al. 1998; Roberts 2007).

Tuberculosis and Leprosy in Norway & Sweden

When comparing respiratory research done throughout the Scandinavian kingdoms, it was made abundantly clear that research involving Danish collections outnumbered those done with any other from Scandinavia. Denmark has historically been the most populated and 'Europeanized' Nordic kingdom due to its location as the southernmost of the Scandinavian countries, which has made research much easier and accessible in this region. Norway and Sweden were never as densely populated as Denmark making research itself just as sparse. For example, there are only a few accessible pieces of respiratory research in Norway that could be found.

The first was a recent dissertation of the kingdom's history of health in conjunction with socio-economic and environmental factors in the medieval and early modern period, and its connection to tuberculosis, leprosy, and several other skeletal lesions (Cairns 2015). By comparing the Norwegian collections to others from Europe, Cairns was also able to determine that the health of Norwegian populations was comparatively good with exceptions to high levels of NSIs (Cairns 2015). The second source is a report for an archaeological excavation that took place in Trondheim, in which Hughes (1998) details possible cases of leprosy in the remains of 60 individuals from the Nidaros Cathedral, Norway (18^{th}-19^{th} c.). Specifically, Hughes (1998) studied the remains for signs of caries, linear enamel hypoplasia, non-specific infections, and alveolar defects with a pathologic origin. Through her research Hughes determined that the individuals interred at the cemetery were likely lower-class individuals from Trondheim who suffered from improper diets, like many others during this time. She also found that several infectious diseases ran rampant throughout this population, but despite these shortcomings, life expectancy in this population was relatively high, which Hughes took to mean they were relatively well adapted to the harsh conditions of lower class living in Trondheim (Hughes 1998). As corroborated by both authors, there has been virtually no research done in Norway about tuberculosis (Cairns 2015; Hughes 1998). Associated with Norway are its many conquered kingdoms, which include Greenland and Iceland. Only one project briefly mentions medieval Greenland's experience with tuberculosis (Wood 1991). Although the research is primarily about tuberculosis and leprosy in 19th c. Norway, it briefly mentions a 13th century burial that displays the skeletal manifestations of tuberculosis (Wood 1991; Cairns 2015).

Historically, paleopathological work in Sweden focused largely on well-known Swedish historical figures, such as King Erik XIV or St. Bridget of Sweden, whose tombs were excavated, and their remains analyzed by early Swedish archaeologists like Nils-Gustaf Gevjvall and Carl Fürst (Ahlström & Arcini 2012). This focus on famous Swedish figureheads was largely influenced by the researcher's efforts to entice community interest in their archaeological work. This can perhaps explain the lack of research into more obscure, non-specific diseases such as otitis media and mastoiditis, as research into these pathologies may not have garnered the same level of interest from the broader community (Ahlström & Arcini 2012).

Although the interest is high for general human osteological studies in Sweden, as of 2012, only one researcher, Caroline Arcini, has been granted funding for paleopathological research in the country (Ahlström & Arcini 2012). This may be due to the Heritage Conservation Act in Sweden which regulates and protects the country's heritage which includes historic human remains and archaeological finds (Ahlström & Arcini 2012). This may limit the amount of destructive analysis that is permitted on skeletal remains. Working within these barriers Arcini has studied a broad range of pathological processes including metabolic diseases (Arcini 2003), the general health status of certain medieval Swedish populations (Arcini 1999; Arcini 2007; Arcini 2008), and leprosy (Arcini & Artelius 1993). For her dissertation Arcini examined over 3,000 individuals from the town of Lund for signs of poor oral health, joint diseases, infections, and trauma and found that oral health deteriorated through time while leprosy was the most common infection in the early medieval period (1999). Her later work focused on the cemetery associated with the Cathedral of Linköping, Sweden and by combining historical research with bioarchaeological analysis Arcini was able to determine that tuberculosis was another common infection in this specific population, but a lack of access to her articles did not allow for further analysis of her data (Arcini 2008).

<u>Leprosy and Tuberculosis in England</u>

Studies regarding tuberculosis and leprosy in medieval and early modern England are plentiful, and much more so than research on any other respiratory disease. The focus on leprosy and tuberculosis in the paleopathological research undertaken in England is a prime example of the long-lasting impact of the historical legacies of these diseases and how they shape the future of research in regions like Scandinavia and England. As has been demonstrated in these last few sections, this has often been at the detriment of other non-specific diseases like sinusitis, otitis media, and mastoiditis who have received little to no attention.

The goal of this thesis is not to illuminate every source that has been published on the topic, it is instead to demonstrate how much more attention has been paid by researchers to tuberculosis and leprosy in comparison to other non-specific respiratory diseases perhaps due to the historical legacies of these particular diseases across Europe. Therefore, the following list of topics does not fully comprise the vast array of research done on the matter; it is rather a snapshot of what has been done. Such topics include how these diseases affected juvenile populations (Lewis 2011; Lewis 2008; Dawson 2021; Dawson & Robson Brown 2012), their association with environmental changes and rural vs. urban pollution (Roberts & Lewis 2002; Mays et al. 2001; Rawcliffe 2006), the past and present cultural perceptions of these diseases (Roberts 2011; Rawcliffe 2006; Roffey & Tucker 2012; Miller & Smith-Savage 2006), and their DNA and molecular analyses (Taylor et al. 2013; Mays et al. 2001; Mays et al. 2002; Donoghue et al. 2017; Witas et al. 2015; Mendum et al. 2014).

A general look into the history of leprosy in England can be found through Carole Rawcliffe's 2006 monograph entitled *Leprosy in Medieval England* which uses unpublished manuscripts and other primary sources to speak on the disease's medical, religious, and social history. Through her research, Rawcliffe overturns many common misconceptions about leprosy in the medieval period including the sociocultural and medical treatment of people who suffered from the disease, as well as the rise and decline of the leprosy in medieval England (Rawcliffe 2006). For a broad work concerning tuberculosis in England, Roberts and Lewis (2002) offer a general look into the history of tuberculosis and other respiratory diseases in prehistoric and historic skeletal collections throughout England. Their research is another useful resource that can be used to understand the wide-ranging impacts of tuberculosis and the many ecological factors that may increase its prevalence across different societal groups. Through their research the authors find a general increase in respiratory diseases through time and suggest this may be due to increased levels of urbanism, housing changes, increases in population density, and industrialisation which are all factors known to contribute to increased environmental pollution and lead to a propagation of non-specific respiratory diseases like sinusitis, otitis media, and mastoiditis (Roberts & Lewis 2002).

DNA analyses are the main focus of many modern respiratory research projects throughout England and have been used to determine prevalence rates of leprosy and tuberculosis on many medieval English collections. This recent focus on DNA research is perhaps due to the recent advancements seen in leprosy and tuberculosis research, in large part due to the incorporation of DNA analyses in bioarchaeology research. These developments include the positive identification of the bacterium that cause leprosy and tuberculosis in a variety of demographic categories which have not been able to be tested before (Taylor et al. 2013; Mays et al. 2001; Dawson-Hobbis et al. 2021). This research and their impact on the paleopathological field in England will be further discussed throughout this section.

Researchers use strain typing techniques to identify the specific strain of *Mycobacterium leprae* in nine skeletons from the Magdalen Hill Research Project in Winchester (Taylor et al. 2013). The authors also used stable isotope analysis along with osteological, geochemical, and biomolecular techniques to determine that three of the nine individuals were local to the Winchester area (Taylor et al. 2013). DNA analysis was also undertaken by Mays et al. (2001) during their examination of nine skeletons from the rural agrarian village of Wharram Percy. Mays et al. (2001) used polymerase chain reactions to detect whether these individuals were infected with *M. tuberculosis* or *M. bovis.* Through their work the authors were able to determine that all nine individuals were infected with *M. tuberculosis* (Mays et al. 2001), which represents one of the few instances where this distinction had positively been made at the time of publication.

A year later Mays et al. (2002) used the same DNA analysis to examine another seven skeletons, from the same collection, that demonstrated proliferative rib lesions. The goal of this research was to put into question the common association between rib lesions and *M. tuberculosis.* The researchers were able to disprove the association as no tuberculosis DNA was recovered (Mays et al. 2002). This conclusion is misleading though, as the absence of evidence is not evidence of absence. Simply because tuberculosis DNA was not able to be found should not be interpreted as a complete lack of infection, it may just mean that tuberculosis had not yet reached a stage in which it would cause DNA changes, or it had not reached the specific ribs analyzed. These results emphasize the importance of examining the entire skeleton rather than basing a diagnosis on a single skeletal element as well as conducting a thorough DNA analysis.

Further DNA analysis was undertaken by Donoghue et al. in their research on ancient DNA (aDNA) and lipid biomarkers (2017) of leprosy and tuberculosis. The authors utilized several collections including those from Winchester and Great Chesterford to conclude that by combining the two methodologies researchers are able to analyze older incomplete samples that were previously deemed unfit for analysis (Donoghue et al. 2017). This type of duel research on leprosy and TB was also performed by Witas et al. (2015) in their efforts to investigate the origins and evolution of the two diseases in England in order to understand and mitigate new disease outbreaks (Witas et al. 2015). Lastly, Mendum et al. argue, through their DNA research, that leprosy declined throughout the late medieval period because communities developed a resistance to the disease, a type of herd immunity, after the weakest of the group died from the disease (2014).

In their research, Dawson (2008) examined two possible cases of tuberculosis, while in 2012 the remains of one young child, between the ages of 3 and 5, were analysed (Dawson & Brown 2012). These finds are quite unique as the identification of tuberculosis in juvenile remains is quite rare. The unique skull and vertebral lesions found on the remains also allows for future comparative work (Dawson & Brown 2012). Dawson further investigated these remains in 2021 and was able to determine through DNA research that the remains belonged to a 3–5-year-old male who indeed suffered from tuberculosis (Dawson-Hobbis et al. 2021). This was the first UK sample of a juvenile to be molecularly tested for TB and thus provides an important reference for future studies (Dawson-Hobbis et al. 2021).

Maxillary Sinusitis

The work that has been undertaken across Scandinavia and England concerning non-specific respiratory diseases such as maxillary sinusitis, mastoiditis, and otitis media is greatly limited. This was made evident when all the available data was summarized into data tables (Tables 2-4). These tables include all the relevant data concerning disease prevalence across Scandinavia and England as it pertains to the general collections observed as well as the limited number of 'oldest old' who were identified throughout these research projects. These tables allow, for the first time, the comparison of non-specific respiratory disease data across vast regions of Northern Europe in the hopes of identifying prevalence patterns across different demographic and regional groups. None of the references included within these tables focused primarily on the oldest echelons of society, rather the old were included as an afterthought and therefore the extrapolated data does not accurately represent the true level of respiratory disease prevalence in the oldest old. Many of whom were most likely misidentified and included in other age categories or ignored all together and labeled as anomalous. Even though incomplete, the data relating to the oldest old was included in these tables to generally represent their experience with these diseases, as well as in the hopes of inspiring future research to focus more clearly on the oldest old in order to bring to light their true experiences with non-specific respiratory diseases.

The proceeding sinusitis research from both Scandinavia and England is summarized in Table 2. There is only one study that focused on maxillary sinusitis in a medieval Danish context (Bennike et al. 2005). The main focus of that work is child morbidity and how it correlates to a variety of factors including demographic profiles, long bone lengths, and non-specific stress and disease (Bennike et al. 2005). As maxillary sinusitis was not the main focus, only the prevalence rate of the disease, amongst the two populations studied, was recorded, along with a possible link between maxillary sinusitis and leprosy (Bennike et al. 2005). The prevalence rate of maxillary sinusitis at Æbelholt was 8.5% (7) while at Næstved the prevalence rate was much higher at 24% (13) (Bennike et al. 2005). These results, along with the prevalence rates of other stress indicators, were interpreted as the children from the Næstved leprosarium being more socially disadvantaged and less healthy than their counterparts at Æbelholt (Bennike et al. 2005). However, the authors also noted that the children with maxillary sinusitis were on average living 2.4 years longer than the kids without signs of sinusitis (Bennike et al. 2005).

In Sweden, significant research was published discussing the connection between sinusitis and increased levels of urban environmental pollution (Sundman & Kjellström 2013a/b; Eriksson 2019), as well as prevalence rates between different age categories (Eriksson 2019). In Sweden, no significant differences in prevalence rates of sinusitis were found between certain rural (70 %) and proto urban (82%) populations, meaning that living in a proto-urban environment had no apparent added negative impacts on sinus health (Sundman & Kjellström 2013b). When an urban town like Sigtuna is compared though, a significant increase in prevalence rate (95%) was observed (Sundman & Kjellström 2013a/b). It was also determined that in the urban sample of Sigtuna, older individuals showed more severe bony changes with males being more commonly affected than females but only in the urban setting; in the proto-urban town of Birka the results were actually opposite (100% females, 68% males) (Sundman & Kjellström 2013a/b). Other rural and urban Swedish collections were later examined by Eriksson who found that there was no significant difference between the two populations in terms of prevalence rates of sinusitis, but a higher prevalence rate was found in the older segments of the collection (Eriksson 2019).

In Iceland, Cecilia Collins (2011, 2019, 2020) has published several valuable pieces of work on the island's medieval experience with non-specific respiratory diseases, while also detailing the occurrence of tuberculosis in three medieval Icelandic collections (Collins 2020). The age categories used by Collins are the same she used in a previously published work (Collins 2019) which include non-adults, who ranged from 0-17 and adults who were considered any individual older than 17. The earlier publication specifies the non-adult category as broken down into six smaller age ranges (0-1, 1-3.9, 4-6.9, 7-10.9, 11-13.9, and 14-16.9) while the adult category was only subdivided into five smaller ranges (17-25, 26-34, 35-44, and 45+) (Collins 2020). Even though the adult age range is significantly larger (17-45+) than the subadult (0-17) category, Collins chose to subdivide adult ages into fewer, larger age ranges that span longer periods of time with an open-ended age group of 45+ which is an often-used categorization system that has led to a gross underrepresentation of the oldest old in many osteological collections.

Furthermore, Collins (2019) summarizes her findings from across all four cemetery collections observed and is able to extrapolate that roughly 71% of adults in general suffered from sinusitis, while 39 % exhibited signs of mastoiditis (Table 3). Otitis media was the hardest of the three to accurately ascertain due to the low levels of preservation, but with the ossicles that were preserved Collins noted that almost 33% of all adults exhibited signs of otitis media (Collins 2019) (Table 4). The discrepancies seen between these figures and the data included within Table 2 is due to the inclusion of all age categories (from infants to older adults) in the data from the table while final percentages reported by Collins (2019) only pertains to the adult segments of her collections.

By using a new scoring system applicable to both the sinuses and temporal bones Collins was also able to determine that sinusitis and otitis media were significantly correlated, with 42% of the skeletons observed showing signs of both pathologies (2019). It was also postulated that a population already suffering from TB should be examined for tuberculous versions of sinusitis and otitis media (Collins 2019).

Another popular research topic in Iceland is the reporting of medieval volcanic eruptions and the possible effects they had on contemporary populations. One similar theme they all share is the eruption's detrimental effects on respiratory health (Guðmundsson & Larsen 2016; Walser III et al. 2018). Many of theses authors report a probable increase in 'respiratory diseases' as an outcome of these volcanic eruptions but make no allusions as to which specific diseases could be the culprit (Guðmundsson & Larsen 2016; Walser III et al. 2018). However, it can be inferred that they mean upper respiratory tract infections, which could ultimately lead to maxillary sinusitis and the like.

In comparison to the work done in Denmark, there seems to be an abundance of research written on maxillary sinusitis regarding English collections (Boocock et al. 1995; Bernofsky 2010; Lewis 2002; Roberts & Lewis 2002; Lewis et al. 1995; Roberts 2007; Mays 2012; Shapland et al. 2016; Papapelekanos 2003; Lilley et al. 1994) (Table 2). One of the seminal works regarding sinusitis was carried out by Boocock et al. (1995) who have produced perhaps one of the most well-known studies on maxillary sinusitis in England. The researchers used a collection from medieval Chichester to test the hypothesized link between leprosy and sinusitis. Through their work the authors revealed that out of the 133 individuals tested, approximately 55% showed signs of sinusitis with no comparable difference found between those with or without leprosy. The authors also addressed the then current issues with diagnosing such a disease and hypothesized on the aetiological factors behind the unusually high prevalence rates found at Chichester (Boocock et al. 1995).

Aetiological factors are also the focus of Roberts and Lewis' (2002) research in which they examined skeletal collections throughout several time periods in England. The authors concluded that respiratory infections, like sinusitis, increased over time and theorized that this was linked to the increase in urbanism seen throughout the country (Roberts & Lewis 2002). The same results were also found when Lewis et al. examined 663 medieval skeletons from Wharram Percy (rural) and St. Helen-on-the-Walls (urban York) in which they found that only 39% of rural skeletons showed signs of sinusitis compared to the 55% of urban population (Lewis et al. 1995). Lewis (2002) further analyzed the effects of urbanism and industrialization on the respiratory health of medieval and post-medieval skeletons and found that although there were small differences in morbidity and mortality rates between urban and rural sites, it was industrialization that actually had the most detrimental impact on children's respiratory health. Other cemetery collections were analyzed for indicators of respiratory health and found varying rates of sinusitis. These included the Jewbury cemetery in York in which 31% of skeletons examined had sinusitis (Lilley et al. 1994) while at Fishergate House, of the 109 individuals examined 48.6%, with at least one sinus, showed signs of sinusitis (Papapelekanos 2003).

A thorough meta-analysis performed by Bernofsky (2010) included an analysis of 1,203 individuals from 12 collections across Southern England which date from the Iron Age to the post medieval period (Bernofsky 2010), eight of which are included in Table 2 along with more detailed renditions of their results (Brothwell et al. 2000; Duhig 1998; Anderson 1990; Allen 1990; Coheeny 2007; Bekvalav & Kausmally N/A; Cowal 2007; White 1988). Through her research Bernofsky discovered that 49.5% of individuals with at least one sinus, had sinusitis in one or both sinuses. She also noted that prevalence rates for maxillary sinusitis ranged from 30.6% in the post medieval period to 75.4% in the Iron Age (Bernofsky 2010). Bernofsky's detailed meta-analysis also did not correlate with previous beliefs that poorer air quality, cramped and unsanitary housing conditions, and greater population numbers brought on by urbanisation directly equated to higher prevalence rates of maxillary sinusitis, as the urban samples she examined did not consistently show higher rates of the disease, nor did samples from lower class individuals (Bernofsky 2010). Bernofsky suggests caution when examining collections with sinusitis and not to assume that the main causal factor is poor air quality, as she states the relationship is much more complex (Bernofsky 2010).

Despite Bernofsky's findings, both environmental and historical research suggest that urban conditions, at least in big town centers like London, were detrimental to many people's general health, which was evidenced through earlier research (Roberts & Lewis 2002; Lewis et al. 1995). The rapid increase in population density that occurred in a short amount of time in London was specifically dangerous as waste disposal could not keep up and led to increased pollution of the streets and water contamination which was common throughout the city (Walter & DeWitte 2017). Historical documents in the form of "court records, complaints, and ordinances or decrees to abate pollution" (Walter & DeWitte 2017, 1) all write about the horrid conditions the lower classes, especially women of lower socioeconomic standing, had to endure. Environmental data also supports this by looking at the correlation between increased air pollution, population growth, and decreasing health (Schofield 2011). Poor sanitation was an ongoing problem for London officials as consecutive directives trying to ameliorate the issue were set in place throughout the 12th-14th centuries (Sharpe 1905). This continual enforcement of legislature concerning public sanitation points to the problem being an ongoing one that remained to be solved.

More recently published works are wider in scope and focus on co-morbidities, for example, the relationship between maxillary sinusitis, septal deviation (Mays 2012), and sex (Shapland et al. 2016). There is also research that references 'respiratory diseases' associated with dental pathologies, which could be interpreted as maxillary sinusitis, as a connection has been previously established between such a disease and bad oral hygiene (DeWitte & Bekvalac 2010, DeWitte & Bekvalac 2011). Lastly, research exploring the possible connections between concha bullosa (air-filled cavity in the nasal concha), and maxillary sinusitis was recently published (Mays et al. 2014).

Regional differences were compared by Roberts (2007) when her research studied maxillary sinusitis as a proxy for poor air quality. She did so by comparing skeletal collections from North America, Africa, and England which would represent populations who are subject to a wide range of environments and subsequently depend on different subsistence economies. She found that a comparatively low prevalence rate of 18% was found in Spitalfields, England compared to Hardin Village in Kentucky which had 51.5% and 21.8% in Kulubnarti, Sudan (Roberts 2007). This study demonstrates that although regional climate and local weather patterns can influence local respiratory health other factors like sex, urban vs. rural settings, and social status must also be taken into consideration in order to achieve well rounded conclusions on the living conditions of past populations. Climatic conditions differed greatly depending on locality, as is seen by the work done by Roberts (2007). Ultimately, a region's climate is largely dependent on local factors such as elevation and proximity to geographic features such as mountains, glaciers, and large bodies of water which would affect the region's aridity, humidity, level of precipitation, and heat index (Davies-Barrett 2018; Davies-Barrett et al. 2021; Brachman 1990; Ayres et al. 2009). Researchers must therefore keep in mind both regional and local climate conditions when examining collections as they both have the potential to determine the general respiratory health of a population.

Female respiratory health was the focus of Shapland et al.'s research which examined over 300 female skeletons from several English sites and found that within their sample, women (25.2%) had higher rates of sinusitis in comparison to men (9.5%) and also found that their most urban samples from London (20.2%) had the lowest prevalence rates in comparison to other sites like St Helen-on-the-Walls and St Andrew's cemetery at Fishergate House in York (both 46.6%) (Shapland et al. 2016). St Helen-on-the-Walls was a poor parish settlement in the urban town of York while Fishergate House represented a monastic cemetery where both religious and secular elites were interred (Shapland et al. 2016). To help explain this discrepancy the authors theorized that indoor air quality may play a bigger role in sinusitis prevalence rates than outdoor air quality (Shapland et al. 2016). They also assumed that females would thusly be more susceptible to respiratory infections due to their increased amount of time indoors where they would be exposed to higher levels of wood smoke and cramped conditions (Shapland et al. 2016). Through her work Roberts (2007) has also concluded that in most instances female rates were significantly higher than their male counterparts and urban sites had a mean prevalence rate of 48.5% while rural sites had a sinusitis prevalence of 45%. These assumptions will be explored further on, as it is now largely put into question whether medieval women would have truly spent more time indoors or if this is simply a biased look into gendered roles in the past.

Much of this research, regarding English collections at least, demonstrate the commonly widespread nature of respiratory infections like sinusitis in both rural and urban populations in the medieval period, which can be seen in the varied prevalence rates seen in Table 2. Although it has been shown, in certain studies, that sinusitis was more prevalent in some urban towns in England (Roberts & Lewis 2002; Lewis et al. 1995), this should not be taken as a proxy for urban centers in Denmark as the country experienced urbanisation at a much slower and less intensive rate. As it will be explored further on, it was not until the late medieval period in Denmark that urban towns truly began flourishing and taking on a more distinct form from their rural counterparts. It is therefore much more difficult to make the distinction between rural and urban settings in Scandinavia which consequently makes it more difficult ascertaining which, if any, sociocultural factors had any impact on respiratory health in Nordic Europe.

Site Name	Location	Dates	Description	N	%	N OA	%	Old Age Range	Reference
St. Jørgen's Hospital, Næstved	Denmark	AD 1250-1550 (late medieval)	Leprosaria, urban disadvantaged	54	24% (13)	N/A	N/A	N/A	Bennike et al. 2005
Æbelholt		AD 1175-1550 (late medieval)	Augustinian Monastery, privileged	82	8.5 % (7)	N/A	N/A	N/A	
Mälaren Valley	Sweden	AD 750-1200 (Viking Age/early medieval)	32 Rural sites	20	70% (14)	10	70% (7)	40+	Sundman & Kjellström 2013b
Birka		AD 750-960 (Viking Age)	Proto town	34	82% (28)	8	62.5% (5)	40+	
Sigtuna		AD 970-1100 (early medieval)	Urban	41	95% (39)	12	92% (11)	40+	
St. Jørgen, Malmo		AD 1461-1549 (late medieval)	Urban	107	36.4% (39)	7	28.5% (2)	40+	Eriksson 2019
Löddeköpinge		11th-12 c. (early medieval) *	Rural	107	35.5% (38)	29	65.5% (19)	40+	
Norra Åsum		N/A	Rural					40+	
Chichester, Sussex	England	AD 1100-1500	Leprosaria, urban	133	55% (73)	40	65% (26)	45+	Boocock et al. 1995
Raunds Furnells, Northamptonshire		AD 700-900	Rural, Agricultural	109	50% (55)	N/A	N/A	N/A	Roberts et al. 1998
Wharram Percy, Yorkshire		AD 900-1800	Rural, Agricultural	268	39.55% (106)	80	52.5% (42)	45+	Lewis et al. 1995
St Helen-on-the-Walls, Yorkshire		AD 1100-1500	Urban, disadvantaged	246	54.7% (134)	40	60% (24)	45+	
Fishergate House, Yorkshire		AD 1100-1500	Rural, disadvantaged	109	48% (53)	N/A	N/A	N/A	Roberts 2007
Christ Church, Spitalfields, London		AD 1700-1800	Urban, middle class	417	18% (71)	N/A	N/A	N/A	
Cannington, Somerset		AD 200-700 (early medieval)	Rural	131	48% (63)	7	86% (6)	N/A	Brothwell et al. 2000
Edix Hill		AD 500-600 (early medieval)	Rural	39	54% (21)	N/A	N/A	N/A	Duhig 1998
Staunch Meadow		AD 700-1000 (early medieval)	Rural	16	31% (5)	N/A	N/A	N/A	Anderson 1990
Abingdon Vineyard		AD 1100-1540 (late medieval)	Rural, low status	142	67% (95)	11	45% (5)	N/A	Allen 1990
Merton Priory		AD 1117-1538 (late medieval)	Rural, high status	103	56% (58)	18	67% (12)	46+	Coheeny 2007

St. Mary Graces, London		AD 1350-1540 (late medieval)	Urban, high status	78	59% (46)	7	86% (6)	46+	Bekvalac & Kausmally (N/A)
Guildhall Yard East, London		11th-13th centuries (late medieval)	Urban, low status	20	40% (8)	2	100% (2)	46+	Cowal 2007
St. Nicholas Shambles, London		AD 1187-1551 (late medieval)	Urban, low status	20	60% (12)			46+	White 1988
Hofstaðir	Iceland	AD 872-1300	Farm/Parish Church	111	45% (50)	25	76% (19)	45+	Collins 2019
Keldudalur		AD 900-1250	Farm/Parish Church	38	42% (16)	7	57% (4)		
Skeljastaðir		AD 890-1220	Farm/Parish Church	44	70.5% (31)	25	72% (18)		
Skriðuklaustur		AD 1496-1552	Monastery	64	66% (42)	18	39% (7)		

Table 2: Summary of previous research concerning sinusitis across Scandinavia and England.

N= the number of individuals with at least one sinus floor preserved
N OA= the number of old adults with at least one sinus floor preserved
*debate regarding date, theorized that the cemetery was used for longer period of time, 12th-14th c. (Jonsson 2009)

Otitis Media & Mastoiditis

Otitis media is the focus of only a few papers written in Scandinavia and England (Qvist & Grøntved 2000/2001; Bruinjes 1990; Dalby 1994; Collins 2019). The detailed results of these studies and how they relate to the oldest old can be found in Table 3. The first of these studies focuses on the recovery of the auditory ossicles (malleus, incus, and stapes) from thousands of crania from two early medieval rural cemeteries in Denmark (Qvist & Grøntved 2000). This is with the express purpose of analyzing the prevalence of otitis media and otosclerosis (1-7%) and to use the morphometric data to inform any future research (Qvist & Grøntved 2001). The second of the two projects focuses on the same collection and also looks at the temporal bones for potential abscesses and fistulae that could have caused middle ear infections. The authors also found that prevalence rates of otitis media increased with time which may indicate a decline in living conditions as time went on (Qvist & Grøntved 2001).

Mastoiditis was also sparsely studied across medieval/early modern Scandinavian and English contexts (Primeau et al. 2018; Collins; Dalby) (Table 4). Primeau et al.'s (2018) research focuses on a juvenile collection and records the co-occurrence of three skeletal markers that are associated with childhood stress; Harris Lines (HL), linear enamel hypoplasia (LEH), and mastoiditis in relation to chronic infectious middle ear disease (Primeau et al. 2018). The project found a statistically significant relationship between mastoiditis and HL, and an upwards trend for all three diseases and increased urbanity in Denmark (Primeau et al. 2018). In Iceland, Collins (2011) and Collins & Jónsson (2010) give an in-depth look at the many examples of bilateral mastoiditis and otitis media found across several different sites in east Iceland (Collins 2011; Collins & Jónsson 2010).

In England, research on otitis media (Bruintjes 1990) and mastoiditis (Dalby 1994) is sparse as there is only one source that could be found that analyzes these pathologies in medieval/early modern contexts. Bruintjes' (1990) research details how the auditory ossicles are detrimentally affected by chronic middle ear infections and leprosy, with a possible link being identified between the two. Bruintjes also reported that 51% of the ossicles examined had erosive lesions likely due to chronic middle ear infection with the incus showing the most marked changes (1990). The same osseous collection is also investigated later by Dalby (1994) in which different methodological and identification techniques are explored and different results reached. Temporal and geographical trends and prevalence rates for these diseases are also explored as the dissertation covers the entirety of Britain and spans several centuries (Dalby 1994).

Site Name	Location	Dates	Description	NI	NT	NAO	%	n	Adult Ossicles	Old Age Range	Reference
Nordby	Denmark	AD 1050-1200	Rural Parish	167	210	147	0.7% (1)	2 (1.2%)	N/A	Postpubertal Adults	Qvist & Grøntved 2001
Tirup	Denmark	AD 1150-1350	Rural Parish	319	450	1162	1.1% (13)	22 (7%)	N/A	Postpubertal Adults	
St James & St Mary Magdalene Hospital, Chichester	England	12th - mid 17th centuries	Leprosaria	257 (177 adults)	471	113	51% (58)	N/A	40/85 ossicles (47%)	Adults 20+	Bruintjes 1990
St James & St Mary Magdalene Hospital, Chichester		12th - mid 17th centuries	Leprosaria	270	495	134	10.5% (14)	N/A	7/87 ossicles (8%)	46+	Dalby 1994
St. Giles, Brompton-on-Swales		12th - 15th centuries	Rural Hospital	32	60	61	13% (8)				
Raunds, Northamptonshire		AD 900-1200	Saxon cemetery	233	427	79	11% (9)				
Hofstaðir	Iceland	AD 872-1300	Farm/Parish Church	137	266	358	19.5% (70)	92 (67%)	21/26 (81%)	45+	Collins 2019

Keldudalur		AD 900-1250	Farm/Parish Church	41	80	70	40% (28)	32 (78%)	7/9 (78%)		
Skeljastaðir		AD 890-1220	Farm/Parish Church	48	93	23	35% (8)	35 (73%)	20/27 (74%)		
Skriðuklaustur		AD 1496-1552	Monastery	77	146	267	47.5% (127)	51 (66%)	10/18 (55.5%)		

Table 3: Summary of previous research concerning otitis media across Scandinavia and England

NI=Number of individuals analyzed
NT= Number of temporals observed
N AO = Number of auditory ossicles retrieved
%= percentage of ossicles with erosive changes with # of affected ossicles in brackets
n= number of individuals affected with % in brackets

Site Name	Location	Dates	Description	N	%	N OA	%	Old Age Range	Reference
Tjærby	Denmark	AD 1050-1536	Rural parish	91	26(29%)	28	N/A	45+	Primeau et al. 2018
Randers	Denmark	AD 1150-1550	Urban Benedictine nunnery	59	24 (41%)	5	N/A	45+	
Skeljastaðir	Iceland	AD 890-1220	Farm/Parish Church	40	35% (14)	22	41% (9)	45+	Collins 2019
Skriðuklaustur		AD 1496-1552	Monastery	33	51.5% (17)	12	50% (6)	45+	
St James & St Mary Magdalene Hospital, Chichester	England	12th - mid 17th centuries	Leprosaria	270	0.7% (2)	N/A	1	46+	Dalby 1994
St. Giles, Brompton-on-Swale		12th - 15th centuries	rural hospital	32	0	0	0		
Raunds, Northamptonshire		AD 900-1200	Saxon cemetery	233	0	0	0		

Table 4: Summary of previous research concerning mastoiditis across Scandinavia and England.

N=the number of individuals with at least one mastoid preserved
N OA= the number of adults with at least one mastoid preserved

Chapter 7-Analysis and Discussion

Introduction

The main goal of this research was to ascertain whether the oldest old of society would have been differentially affected by non-specific respiratory diseases in Scandinavia and England. Current medical research shows that older individuals are disproportionally affected by respiratory diseases, in comparison to all other demographic segments of society. This is largely due to their age-related decrease in immune response and nutritional status, as well as their age-related increased pathological load (Weiskopf et al. 2009; Plackett et al. 2004; Castelo-Branco & Soveral 2014; Grubeck-Loebenstein & Wick 2002; Ortner 2003; Mays 1998; Bernofsky 2010, Thane 2005). Unfortunately, no bioarchaeological work has yet been able to test this theory for medieval and early modern Scandinavia or England, although many researchers have suggested such a link, due to a fundamental problem in age estimation techniques, prior to transition analysis, and lack of focus on non-specific respiratory infections.

It was discovered that although researchers often speculated or made a passing remark towards the belief that older individuals would have experienced higher prevalence rates of respiratory diseases (Boldsen 2008), they could not substantiate this hypothesis as they did not focus their examinations on the older individuals from their collections. Research could not be found that focused solely on the elderly, rather a few suspected elderly individuals from a collection were examined along with the majority, and overarching theories would be based off these few individuals. This is despite the research calling for an increased focus on 'Archaeology of Old Age' as stated by Appleby (2010) who demonstrated that increased risk of morbidity intertwined with sociocultural and environmental circumstances would have heavily contributed to the elderly's deteriorated biological status. This is further exemplified in Bernofsky's (2010) study on chronic maxillary sinusitis in medieval England. She states that within the modern clinical literature, "age has been found to be a significant factor in the development of sinusitis" (Bernofsky 2010: 24). This lends more credence to the notion that with increased age also comes increased prevalence of disease, including respiratory diseases. Having said this, no evidence could be found in the bioarchaeological literature for medieval/early modern Scandinavia as there seems to be a complete dearth of focus on the oldest echelons of medieval society and the pathologies that may have plagued them.

Summary of Findings- Climate

In terms of climatic events, Scandinavia like much of Western and Northern Europe, experienced many extreme fluctuations, the first being the Medieval Climate Anomaly that took place before the 14th c. across Europe. The warmest period in England was in the 13th c. while in Scandinavia the 11th/12th centuries were the warmest (Crowley & Lowery 2000; Platt 1978).

Temperatures were regularly 0.7-1.0 C° higher than the average temperatures today (Yoder 2006; Fagan 2000; Lamb 1965; Hughes & Diaz 1994; Crowley & Lowery 2000; Campbell 2016). This is not to say that these periods were completely stable though as the country was plagued by intermittent cold snaps throughout the early medieval period (Glaser 1997; Campbell 2016).

Weather became increasingly erratic throughout the late 13th and 14th centuries during the transitional period between the MCA and the LIA, which continued to gain strength in the Northern Hemisphere while warmer and more stable periods became increasingly shorter and altogether rare (Campbell 2016; Le Roy Ladurie 1972). Unlike popular belief, "The LIA was never a monolithic deep freeze, rather a climatic seesaw that swung in volatile and disastrous shifts, arctic winters, blazing summers, serious droughts, torrential rain" (Fagan 2000: 48). Most of the LIA is characterized by this variability and in actuality, 'classic' sub-zero winter LIA climate was only prevalent in Europe between A.D. 1550-1850 (Matthews & Briffa 2005). Moreover, mean temperatures from A.D. 1590 to A.D. 1850 were only 0.3-1.0 degrees C° lower than present levels but in the winter, the mean temperatures were more than a degree lower (Le Roy Ladurie 1972; Whited et al. 2005).

Although the Little Ice Age was prevalent throughout the Northern Hemisphere it may have hit Norway and Sweden even harder due to their more northern location, higher altitude settlements, and the remoteness of their populations. This can be seen in the level of glacial expansion Norway experienced north of Jostedalsbreen in the early 14th c.; activity that Denmark did not experience (Thorsen & Dale 1997).

Summary of Findings- Socio-Cultural Context

Re-occurring bouts of sickness, famine, erratic climatic conditions, along with high birth rates resulted in a lower mean life expectancy for much of the Scandinavian population during the medieval period. Mean life expectancy estimates ranged between "15-18 years on average at the age of twenty and 18-23 years at birth" (Vahtola 2003, 561). These estimates included even the wealthier noble classes of Scandinavian society as everyone was susceptible to long-lasting famine and disease brought on by changing weather patterns. This low life expectancy at birth does not truly reflect low survivorship to older ages though as these estimates are heavily influenced by the very high mortality rates seen among infants, with over half of all children dying before they reached the age of seven during the medieval period (Vahtola 2003). This high infant mortality rate significantly skews life expectancy estimates and makes it appear as though individuals did not survive past their early 20s. Although it is indeed true that, at birth, life expectancy was not very high (18-23), if an individual did make it through infancy their chances of reaching old age would have dramatically increased (Vahtola 2003). Therefore, although a large segment of the medieval population did perish at a young age, it was not completely uncommon nor impossible for an individual to survive to be ‘old’ (Shahar 2005).

Northern European society was overwhelmingly rural, almost 90% (Whited et al. 2005; Thomas 2003). A fact that would not change for several hundred years, except for the urban populations in England which increased to about 15-20% in the 14th c. (Rigby 2010; Everitt 1966). Rural villages and early urban towns were not that dissimilar in this period as houses and occupations resembled each other closely (Jordan 1996; Roesdahl 1999). While urban housing throughout Scandinavia resembled their rural counterparts, they were replaced in the early modern period by houses made of stone or brick, with tiled or slated roofs, that helped in the prevention of fires (Kristensen 1999) but may have also trapped smoke inside and increased respiratory problems (Roberts & Lewis 2002; Whited et al. 2005; Kristensen 1999). Nevertheless, timbered homes with wattle and daub walls and thatched roofs were still popular and more cost efficient which led them to be continuously built within urban centers even into the early modern period. In comparison, most urban houses in the late medieval and early modern periods in England were made of stone and were at least 2 storeys while also including a cellar for food storage (Kowaleski 2014). England’s rural populous lived in a variety of different settlements, including estates in the east, sparse settlements in the north, villages in the midlands, and manors in the south (Platt 1978).

Virtually all towns in Scandinavia were established in the southern regions of the kingdom, with exceptions being made to a few northern mining towns and remote farming settlements (Andrén 1989). Lending credence to this statement is the fact that Denmark was the most urbanized country in Scandinavia (Dahlbäck 2003). Both Norway and Sweden lacked much of the necessary infrastructure to support urbanization and was far behind Denmark in the process. Although Norway and Sweden did have towns, they never transitioned to become centers of production, as they never produced commodities for their rural counterparts (Holt 2007). Moreover, their rural settlement patterns also did not boast the same homogeneity as its southern equivalents. This can partially be attributed to the region's mountainous geography and the sparseness of its population which did not allow for the land to be farmed the same way across the country. This resulted in smaller farms that had limited arable land compared to the larger farms and hamlets that rarely popped up in the southern regions of the kingdom (Øye 2000).

Moreover, densely populated urban environments were not plentiful in Scandinavia and only became popular in Denmark in the late medieval period (Hybel & Poulsen 2007). This is in comparison to England which in the early 11th c. had over one hundred towns, and by the late medieval period, that number grew to around 600, mostly concentrated in the southern and eastern regions of the country (Langdon & Masschaele 2006). Denmark, the most 'urbanized' of the Scandinavian countries boasted less than 100 towns by the end of the medieval period, and at this time towns still closely resembled their rural counterparts, with only a slight increase in population density and focus on speciality trades. It wasn't until the early modern period that urban towns began taking on a more distinct entity separate from their rural contemporaries (Bernofsky 2010; Lewis 2002; Roberts et al. 1998; Andrén 1989; Dahlbäck 2003). This distinction, which occurred in the early modern period, is associated with a higher population density and thus more exposure to risk factors such as droplet infection, cramped housing, and polluted air. Burning solid fuels (i.e., charcoal) on indoor open fires, for cooking, heating, and light, would have also led to dangerous levels of exposure to toxic pollutants, including carbon monoxide. Also, the burning of coal for market activities would have made outdoor air pollution in towns a dire affair, as they were common practices both in medieval and early modern periods across Europe (Sundman & Kjellström 2013b).

It is impossible to know archaeologically how much pollution may have been present in a home or how much time a family spent exposed to it, even if historians know what materials medieval homes were made from. Moreover, although speculated, it is unclear which members of a family would have spent more time indoors, which may have varied greatly depending on the family or society. It is surmised, based largely on modern biases, that gendered work and social hierarchy would have kept women, children, and the elderly indoors which meant they would have been exposed to higher levels of indoor pollution (Shapland et al. 2016). Although this may be true in some circumstances, women and children would have also spent an equal amount of time outdoors accomplishing a plethora of different tasks like, tending to the garden, looking after the farm animals, doing work around the yard, or working domestically in the village (Shapland et al. 2016; Kowaleski 2014). All of these tasks would have taken them out of the house and reduced their level of exposure to indoor pollution.

Social Bioarchaeology and the Interpretation of Old Age

In order to create a complete picture of an individual's age, it is necessary to consider all categories of ageing including chronological, social, and biological. Moreover, to properly understand the ageing process and correlate it to physical appearance and physiological function the social circumstances of an individual must be taken into consideration. Although past individuals would have recognized the significance of their chronological and biological ages, it was perhaps their social age that would have held the most weight in past societies (Sofaer 2011; Appleby 2017; Appleby 2011). Due to the highly social nature of ageing, social identity and how an individual's age would have been socially perceived or determined by their peers must be acknowledged when examining an individual's skeletal remains. As social bioarchaeology dictates, identity is not a static characteristic but is rather very fluid as old age is a social idea and is constantly being renegotiated by the individuals themselves and their peers (Appleby 2011). An individual's social age may also be gleaned from their remains as bones are highly malleable and are the by-product of all the cumulative events an individual undergoes throughout their lifetime (Agarwal & Beauchesne 2011).

Social age is also dependent on the experiences, rites of passage, and sociocultural rituals an individual undergoes throughout their lifetimes (Sofaer 2011). For example, pregnancy, teeth grinding/filing, foot binding and the use of neck rings are all social rituals used to denote the coming of age or other significant markers in someone's life and they all significantly modify the appearance and physiological structure of their skeletal systems. Therefore, social growth is just as much defined by biological development as it is the cultural experiences an individual partakes in (Sofaer 2011). For example, some cultures base social age on body modification rituals (dental remodelling, body piercings, or tattoos) while others determine age through major life events like menstruation or marriage (Sofaer 2011). Perhaps social bioarchaeology best explains the idea that age and the process of aging cannot be determine through rigid guidelines, rather it is an ever-evolving process, one that spans much longer than biological or chronological age. Social bioarchaeologists also understand that the skeleton itself cannot be analyzed through a singular lens, it is a living organ that is shaped by a lifetime of sociocultural experiences (Agarwal & Beauchesne 2011). It is a status an individual achieves through the biological and social experiences they undergo and is unique to every individual (Welinder 2001; Sofaer 2011). As such, they all play a significant role in determining individual identity and should therefore be studied together (Appleby 2017).

Social age would have also been used to determine an individual's worth to their own community (Thane 2005). If an individual can no longer perform certain social tasks (i.e., weaving, hunting, agricultural work) their social standing within the community would have been revaluated (Appleby 2017). This does not mean that they were any less socially relevant, it simply suggests that the social parameters in which they once lived in, would have changed to suit their present biological circumstances.

The interpretation of social age would have also been heavily intertwined or influenced by physical/biological ability (Appleby 2017). A change in physical abilities is often one of the most visible signs that an individual is ageing. For example, posture and ease of movement, as well as range of motion, loss of vision, or a degeneration of fine motor skills and dexterity would have all been changes in biological factors that would have altered an individual's standing in their social circle (Appleby 2017). Archaeologists can thus learn valuable information through the way past societies depicted older individuals in their writings or paintings/drawings and can decipher that society's attitude towards certain age-related physical changes through which characteristics they chose to highlight in their material recordings (Appleby 2017). The aging process and the degenerative changes an individual experiences are unique which creates skeletal heterogeneity amongst the oldest adults. This ultimately leads to individuals reaching certain chronological ages and social standings at different stages throughout their lives. It is therefore critical that bioarchaeologists consider the unique social circumstances an individual would have experienced to be able to properly interpret any skeletal manifestations that may be present on the remains.

Transition Analysis (A Biostatistical Method Used to Identify the Oldest Old)

Up to date aging methods, specifically the transition analysis program, have allowed researchers to attribute accurate age intervals to the oldest of adult remains, by using a combination of anatomical features to attribute age to skeletal remains and creating more compatible statistical frameworks (Milner & Boldsen 2012a, b, c; Boldsen et al. 2002). Thus, for the first time, it is possible to analyze the potential impact of respiratory infections on the oldest tiers of Danish society, now that they can be accurately identified. All methods developed from analysis of either archaeological material or modern samples have fundamental conceptual errors and biases. These include having skewed age distributions, socio-economic or genetic biases, small sample sizes, or a disproportionate representation of sexes and ancestry (Cox 2000). It is with these issues in mind that the transition analysis program was first developed in 1996 and is increasingly being used and modified, according to new insights, a decade later (Milner & Boldsen 2012c).

The transition analysis program models the timing of transitions between physical changes seen in certain skeletal elements, so that it is the age-specific probability of having completed the transition between one state and the following state that forms the basis of the likelihood of being a certain age (Boldsen et al. 2002; Chamberlain 2006). Instead of simply producing a single age range estimate like traditional methods do, the transition analysis generates both point estimates and age intervals that vary from one skeleton to the next (Boldsen et al. 2002). Transition analysis focuses on "interindividual variation and the difference in rates of change" (Milner & Boldsen 2012a, 274) found in the human skeleton. It considers that the more traditionally recognized morphological traits used to estimate age have a great deal of variation not only between populations but also between individuals of the same population (Usher 2002). It forgoes the assumption that one can use the same preestablished age categories to determine age of highly unique and variable morphological traits. It therefore uses age intervals unique to that individual to establish the most accurate age estimation.

The original transition analysis program produced point estimates, otherwise known as maximum likelihood estimates, or ranges with an 95% confidence rate when based on uniform (uninformative) priors such as the Terry and Coimbra collections, or informative priors such as the 17th c. deaths collected from Danish rural parish records in which the second version also relied upon (Milner & Boldsen 2012c; Tangmose et al. 2015; Konigsberg & Frankenberg 1992). The newest version of the program also produces maximum likelihood estimates, but these include an upper 95% precision bound, a lower 95% precision bound, and a standard error (Milner et al. 2020). These age ranges lessen the margin of error that single point estimates produce and thusly have a greater chance of encompassing the individual's true age while also maintaining accuracy and precision. For a more detailed look at the statistical equation behind this age-estimation methodology and for a more in-depth explanation of the components that comprise it please refer to Milner & Boldsen 2012a, b, c; Boldsen et al. 2002; Ousley et al. 2019; Getz 2019; or Getz 2020.

The most recent version of the transition analysis program (Transition Analysis 3 or TA3) was developed in 2019 and used data collected from over 1,600 skeletons from several regions around the globe to ensure variation was accounted for. These regions included the United States, Portugal, South Africa, and Thailand, as well as remains from the University of Tennessee and Museum of London collections (Ousley et al. 2019).

The original version of the transition analysis method used nineteen morphological traits from the pubic symphysis, the auricular surface, and the crania. These traits are the same ones used in traditional age estimation methods but are scored and examined independently (Milner & Boldsen 2012c). For example, the pubic symphysis and cranial sutures are broken down into 5 different components/segments each while the sacroiliac joint is broken into 9 parts and then combined to generate an overall age estimate (Boldsen et al. 2002). The newest version of the transition analysis method uses 121 morphological traits from across the skeleton, which means that age-estimations are no longer solely reliant on the pelvis or crania (Getz 2020), other skeletal elements like the vertebral column are also used (Milner et al. 2019; McInnis 2022).

There are many advantages to using the transition analysis method to determine age-at-death, the first is the simple fact that this methodology does not need morphological features to be whole to produce age estimates, because this method breaks down each feature into several components, it works very well with fragmentary remains (Milner & Boldsen 2012b). Thusly, this method will work efficiently with any number of components or any combination of multiple traits (Milner & Boldsen 2012c). This characteristic makes it very appealing to use on the oldest old of any archaeological collection as the reality is that many of these collections are comprised of very fragile, fragmented remains and it is rare to have an entire collection that contains perfectly preserved skeletons. Another advantage, and one of the main factors for the development of such a methodology, is that the program is not influenced by the age distribution of the reference sample (Milner & Boldsen 2012c; Chamberlain 2000). This is achieved by estimating the age-at-death of an individual only after the age-at-death distribution of the entire archaeological population (Boldsen et al. 2002; Hoppa & Vaupel 2002; Litton & Buck 1994).

This is known as the prior distribution of ages-at-death and is widely used to regulate biases, like those brought in by reference samples, through Bayesian analysis. By estimating the age distribution of the entire population before that of the individual it also allows the researcher to ascertain the quality of the reference sample (Aykroyd et al. 1999).

Transition analysis, along with Bayesian analysis, have many advantages but also some crucial drawbacks, the first is that the target population has to be large enough to provide accurate estimates (Aykroyd et al. 1999). This becomes a real problem with small collections as they are not large enough to produce accurate approximations and trends within the population being examined. It is also an issue if the population the individual derives from is biased itself, with predispositions to certain ages or sexes. The methodology therefore depends on the population to be unbiased, as it is supposed to be a natural representation of a living population, this becomes a real setback and could produce inaccurate age estimations (Konigsberg & Frankenberg 1992). The transition analysis program deals with these issues by offering users two informative prior distributions which helps determine the collection's age-at-death structure before (Milner & Boldsen 2012c). Moreover, it is widely accepted that every skeletal collection is not a true representation of its original living population, at best, it merely represents the frailest segment of the population and will have some inherent biases within it.

The reality is that no osseous collection will ever be a truly perfect representation of the once living population but using the original skeletal population as a reference may be the best representation that can be achieved using our current knowledge (Usher 2002). This means choosing a collection that is not only from the same relative geographic location as the skeletons that are being investigated but also choosing one which reflects their chronological age, ancestry, sex, and general socioeconomic circumstances (Milner & Boldsen 2012b; Usher 2002). Ensuring the compatibility of all these various factors will systematically aid in the elimination of reference biases on the target sample.

For middle aged individuals, the transition analysis program also tends to create wider age intervals (Milner & Boldsen 2012c). This may be caused by the increase in skeletal variation that follows increases in age, which is a biological phenomenon rather than the program's fault in particular. It has also been noted that not all researchers agree with the optimism surrounding the transition analysis program due to the complex nature of statistical programing (Clark et al. 2019). The newest version of transition analysis has addressed many of these issues as it is now available as a downloadable software with a built-in statistical package which allows researchers who are not well versed in statistical work to use the program with ease (Mcinnis 2022).

The use of alternative osseous features that are related to old age is perhaps one of the strongest advantages of the newest version of the transition analysis program, and what makes it especially useful in ageing the oldest old of any collection. Traits that were once disregarded for their ability to only distinguish between young and old are now combined and used in connection with other morphological traits to produce accurate age estimations (Milner & Boldsen 2012b). These features include the "rough areas where tendons and muscle attach, the lipping of joint margins, and the characteristics of vertebral body borders that range from rounded to angular and lipped" (Milner & Boldsen 2012b, 226). This shift away from the traditionally used skeletal characteristics and onto a wider array of age indicators allows for more adaptability in the program and produces estimates that are tailored to the specific skeleton being analyzed. Moreover, the use of so many different traits also means that not every one of them is necessary to produce an age estimate, allowing for more freedom in choice and a wider applicability to degraded or fragmentary remains (Ousley et al. 2019).

<u>What Do We Understand About These Diseases in This Specific Time Period?</u>

Based on the limited published literature, diseases such as otitis media, mastoiditis, and maxillary sinusitis seem to have been present across Scandinavia and England and affected both rural and urban populations (Roberts 2009; Boocock et al. 1995; Bernofsky 2010; Qvist & Grøntved 2000/2001; Roberts 2007; Primeau et al. 2018; Sundman & Kjellström 2013a/b; Bruintjes 1990). It seems that a deterioration of both living and environmental conditions experienced between the 11^{th} and 14^{th} c. contributed heavily to the increasing levels of chronic otitis media and middle ear infections in medieval, as well as early modern Denmark especially in rural parishes like Tirup and Nordby (Qvist & Grøntved 2001). Such deterioration was likely caused by several environmental events that simultaneously occurred in Denmark at this time, including a transition into the LIA (increasingly unstable and erratic weather patterns), the presence of the plague, and the Great Famine.

A tenuous link between leprosy and sinusitis was also established when it was discovered that rates of sinusitis were potentially higher in leprosaria collections than collections without the disease present (Boocock et al. 1995). This is perhaps a result of co-morbidity and the fact that leprosy targets the sinuses which may introduce more bacteria and infection in the area and ultimately lead to sinusitis (Bennike et al. 2005; Lewis et al. 1995). The association between leprosy and maxillary sinusitis has further been strengthened through the determination that leprosy causes a concentration of bacilli in the anterior parts of the maxilla, palate, and nasal region (Boocock et al. 1995; Kjellström 2012; Lewis et al. 1995). Therefore, the higher prevalence of sinusitis in leprosy communities in medieval Denmark is considered a result of secondary infections associated with leprosy, rather than a new exposure to non-specific stress factors (Bennike et al. 2005).

There was also a positive association between those with maxillary sinusitis and increased longevity, as some individuals suffering from the disease were living typically 2.4 years longer than those without such stress indicators (Bennike et al. 2005). This can be explained using Wood et al.'s (1992) theory of the 'osteological paradox' which theorizes that skeletons with healed osseous lesions were perhaps healthier, or had lower frailty, than individuals with active lesions at time of death, as they lived long enough for their bodies to heal and survive the period of stress. This is in comparison to those without healed lesions who may have been too weak to fight off disease and died before lesions had the chance to affect their skeletal systems and begin to heal (heterogeneous frailty). Wood et al. (1992) admit that in reality the situation is much more complex than these statements suggest, as there are many additional factors that determine the relative health of past populations. For example, how certain pathologies interact (comorbidity) and how they differentially impact the host must be considered (Wood et al. 1992).

The theory of unobserved heterogeneous frailty explains that all populations are heterogenous, even at the individual level, due to hidden, or unobserved, factors that contribute to their frailty. These factors include biological frailty or robusticity, lifestyle choices/circumstances, regional/local environmental conditions, and acquired weakness (Zarulli 2016). This is an important concept as it affects an individual's risk of mortality while also simultaneously influencing mortality at the population level (Vaupel et al 1979). For example, a population is composed of individuals with varying levels of frailty and robustness. The frailer individuals will likely die first leaving an aging population that seems to be more robust. However, this observation does not reflect the individual lived experiences and must be taken into consideration when analyzing population health and frailty (Zarulli 2016). The varied nature of differing lesions must also be taken into consideration, as certain lesions may represent certain pathologic processes that have a greater impact on future survivability and quality of life than others, (i.e., TB vs. LEH). Furthermore, shifts in the mean age at death of certain populations do not necessarily correlate to a deterioration of health and an increase in mortality, it can also mean changes in fertility patterns of that community (Wood et al. 1992).

The osteological paradox can also help explain patterns seen in rural vs. urban pathological prevalence. For example, chronic infectious middle ear disease, or IMED, which leads to pathologies like otitis media and mastoiditis, were found commonly in juvenile collections across rural and urban Denmark with higher prevalence rates found in urban collections (Primeau et al. 2018). This may indicate better living standards in the rural populations with better nutrition and an environment with fewer infectious diseases, resulting in fewer juvenile deaths. The urban sample may be indicating a higher pathogen load due to overcrowded living conditions resulting in frailer sub-adults (Primeau et al. 2018). However, the opposite might be also true as part of "The Osteological Paradox" which interprets the data as the urban sample being healthier and more robust as they lived long enough to develop osteological signs of the pathology (Wood et al.1992). As previously stated, the relationship is much more complex than this though as health and survivorship are impacted by a multitude of other factors like sociocultural circumstances of the individual, the overall frailty/health of the individual prior to the pathological process, and the specific pathology itself and its unique biological characteristics (Wood et al. 1992). Moreover, a higher juvenile mortality rate was recorded in the rural population of Tjaerby (43%) (Primeau 2014) compared to the juvenile mortality rate for the urban sample from Randers (28%) (Frøhlich et al.1993). This is much lower than what would be expected for an urban population in the medieval period and is most likely caused by the incomplete nature of the excavation of the urban cemetery of Randers. The comparison of these urban and rural cemeteries in Denmark is thusly problematic and biased.

Non-specific respiratory diseases were also prevalent in other kingdoms across Scandinavia, including Iceland whose population was not able to escape the affects of tuberculosis, mastoiditis, and otitis media despite its remote and isolated nature. Through the analysis of several east Icelandic cemeteries, it was concluded that male individuals, between the ages of 16 and 45, were more often afflicted with such respiratory diseases than their female counterparts. Several male skeletons were found with bilateral mastoiditis and changes to the auditory ossicles (Collins 2011). It was also established that tuberculosis was one of, if not the main, contributor to respiratory tract infections in Iceland during this period, as it was endemic throughout the kingdom from its settlement until the 20th c. (Collins 2019). Sinusitis was also detected in children as young as 4.5-5.5 years of age with co-occurrence of sinusitis and otitis media being prevalent in children of all ages (42.2%). It was therefore shown that respiratory infections did not discriminate between age groups, rather it was prevalent across all demographics. Lastly, a correlation between sinusitis/otitis media and diseases of the gastrointestinal tract was also tentatively established in Icelandic collections through the connection of the respiratory and gastrointestinal tracts by the mucosal immune system which covers both systems in its efforts of defending the body against external microscopic threats (Collins 2019).

In Sweden, no significant differences in prevalence rates of sinusitis were found between certain rural (70 %) and proto urban (82%) populations meaning that living in a proto-urban environment had no apparent added negative impacts on sinus health (Sundman & Kjellström 2013b; Eriksson 2019). Although proto towns in medieval Sweden did serve a commercial function, a seasonal drop in markets perhaps made the population less exposed to polluted air and other factors leading to bony changes. This would have made their sinus health more similar to rural populations (Sundman & Kjellström 2013b). On the other hand, urban towns, like Sigtuna, had significantly more cases of sinusitis in comparison to its rural/proto urban counterparts (95%). Older individuals living in such towns were especially hard hit as they typically showed more severe bone changes (Eriksson 2019). The high prevalence in Sigtuna suggests that the condition was not entirely disabling, at least not for most of the afflicted. Only roughly 8% of afflicted individuals in the Sigtuna sample displayed the most severe degree of bone changes (Sundman & Kjellström 2013b).

There was also a significant difference found in prevalence rates between males and females in certain Swedish urban sites, with women significantly more affected by maxillary sinusitis than their male counterparts (Sundman & Kjellström 2013b, Eriksson 2019). This may be because of gender-based differentiation in work tasks and related environmental exposures (Sundman & Kjellström 2013b, Eriksson 2019). Anatomical differences could also be a factor, as females generally have a smaller ostium than males, meaning it can be blocked more easily by inflammation and cause infection (Falagas et al. 2007). Altogether, this suggests that the men were perhaps more mobile than women, who were more closely bound to the settlement while the men traveled to other parts of the kingdom in order to trade (Sundman & Kjellström 2013b). The opposite is also true, as males were more regularly afflicted by sinusitis than women in the late medieval and early modern periods. This is perhaps reflecting a shift to more specialized craft production in towns as men became more sedentary and worked as specialized craftsmen instead of travelling for trade. This would have led them to work consistently with implements such as kilns and open coal fires to produce their wares, which exposed them repeatedly to toxic fumes (Sundman & Kjellström 2013a).

Data that relates to early modern rural settlements in England is scarce but the little research that exists points to higher frequencies of sinusitis among women than men, whereas the frequencies for men and women were roughly the same in urban populations (Roberts 2007; Bernofsky 2010). The prevalence rates of maxillary sinusitis itself, varied quite a bit from 17% to 51 % across different settlements (Roberts 2007). Moreover, when comparing high and low status populations, it became evident that high-status populations, like that of St. Bride's Crypt, had the lowest prevalence rate for chronic maxillary sinusitis, while lower status populations, like St. Bride's Lower, had the highest prevalence rate (Table 2) (Bernofsky 2010).

In other medieval assemblages, like that of York, it was the men that displayed higher prevalence rates of sinusitis. This could again be explained by the men being more exposed to pollution through working as local craftsmen (Lewis et al. 1995). Although there were high prevalence rates of sinusitis across medieval England, often ranging from approximately 40-55%, it was determined that it was not until industrialization occurred that the greatest impact on children occurred (Lewis et al. 1995; Merrett et al. 2000; Boocock et al. 1995; Roberts & Lewis 2002). Urban and rural settlements in the early medieval period may not have differed from each other as much as previously assumed as both environments boasted factors that would have predisposed their inhabitants to sinusitis (Roberts & Lewis 2002; Lewis et al. 1995).

Moreover, although studies examining collections from regions in North America (Merrett & Pfeiffer 2000) and the Netherlands (Panhuysen et al. 1997) suggest rates of sinusitis increase with age due to "the cumulative effects of poor dental health, increased length of time for caries to develop, and the increased amounts of tooth wear with age" (Merrett & Pfeiffer 2000: 315), this has not always been true in relation to Scandinavian or English skeletal collections. While some studies conducted in Sweden (Eriksson 2019; Sundman & Kjellström

2013a) and Denmark (Bennike et al. 2005) show a tentative correlation between advanced age and increased prevalence of sinusitis, others from Iceland (Collins 2019) and England (Boocock et al. 1995) do not. The studies that do show a correlation also recommend caution with the interpretation of their results as they recognize the hidden biases in their work, which includes small sample sizes and varied preservation, which may affect disease prevalence.

Aetiological factors that cause respiratory infections are numerous, they include increased population density, underventilation, overheating, and the variable European climate during the medieval period. The cold, drying winds, and erratic Ice Age winters typical of Northern Europe in that period may also have resulted in the drying out of the mucosa, thus reducing resistance to disease (Waddy 1952). A combination of these factors in the winter creates a favourable environment for an increase in upper respiratory tract infections, and the development of sinusitis (Howe 1972).

One factor that has perhaps lost credence in causing sinusitis, as a sole aetiology, is indoor air pollution. It is problematic to use this factor to explain differences in rural and urban housing as both rural and urban families would have been exposed to pollution in the home. Both settlement styles boasted houses that resembled each other quite closely in the medieval period, as many houses, whether rural or urban, had an open hall concept along with an open hearth without a chimney (Bernofsky, 2010; Roberts & Lewis 2002). Moreover, houses were built to intentionally allow for a desired level of smoke, which would help limit certain types of pests and bacteria in the home, dry herbs or meat, while also allowing the occupants to breathe without issue (Letts 2000). This was done by keeping activities close to the floor, as smoke tends to rise and settle in the peaks of structures and having openings in the roof for smoke to escape through (Letts 2000). This may have changed during the early modern period in England as urban housing became better insulated and made of stone with a tiled roof, meaning that smoke may have been more easily trapped inside these buildings (Roberts & Lewis 2002). This is a problematic statement in and of itself though, as previously stated, it is impossible to definitively say, through archaeological research, how much pollution would have been present inside any historic home.

Regional Variations In the Range of Studies

In Denmark, the limited research published on non-specific respiratory diseases seems to be focused on conducting research on juvenile skeletal collections (Primeau et al. 2018; Bennike et al. 2005). This is perhaps because past research on juvenile skeletons in medieval Europe was generally limited due to the equally limited amount of juvenile collections available to study (Bennike et al. 2005). Bennike's research specifically looked at childhood stress and how different events adversely affected longevity and general health (Bennike et al. 2005). There is also a much more in-depth focus on leprosy and tuberculosis research in Denmark in comparison to non-specific diseases. Perhaps because these diseases are much more common in the archaeological record, or because it is possible to study these diseases without performing destructive analysis, which may not always be possible when looking at non-specific respiratory diseases like sinusitis or mastoiditis.

Historical legacy has also played a large role in shaping the trajectory of past research efforts in Denmark, as leprosy, tuberculosis and syphilis dominated paleopathological research efforts. Much of the early paleopathological work undertaken in Denmark was done by Møller-Christensen (1951, 1952, 1953, 1958, 1965, 1978) who focused primarily on the St. George's leprosy hospital near Naestved. Over the span of nearly twenty years Møller-Christensen and his team excavated 750 individuals, many of which showed signs of leprosy. In the following years Møller-Christensen published several seminal pieces of work that not only established the presence of leprosy in Denmark but also contributed significantly to the, then, current knowledge of the disease (International Leprosy Association 2022). So popular was his work that it inspired the work of many other researchers who based their work on his original findings. This greatly impacted the future of paleopathological work in Scandinavia as the increased popularity brought with it a clear focus on research concerning leprosy.

Danish studies also typically examined several osseous lesions and skeletal elements contemporarily. For example, Primeau et al. (2018) studied Harris lines, linear enamel hypoplasia, and chronic middle ear disease all in one paper, while Bennike et al. (2005) examined their collections for long bone lengths, bone mineral content, cribra orbitalia, maxillary sinusitis, endocranial lesions, and periostitis. Qvist & Grøntved (2001) also studied both temporal bones and auditory ossicles for signs of chronic otitis media sequalae (COMS). The use of several lines of data often helps to strengthen an argument; thus, when studying stress in an individual it is much better to study several non-specific indicators of stress rather than relying solely on one.

Lastly, all Danish studies on non-specific respiratory diseases primarily used non-invasive techniques and methodologies to study the osseous material. X-rays, CT scans, and microscopy were favourably utilized instead of drilling or cutting into the crania (Primeau et al. 2018, Qvist & Grøntved 2001; Bennike et al. 2005). One exception was used in order to verify results from non-invasive techniques (Primeau et al. 2018). Which demonstrated that invasive techniques are not needed in future research to achieve dependable results. Overall, Denmark has rarely reported on these kinds of non-specific respiratory diseases.

In Iceland, several studies focused greatly on respiratory complications in connection to volcanic eruptions (Guðmundsson & Larsen 2016; Walser III et al. 2018). This connection is evident as there was between two to three hundred volcanic eruptions on the island since the Norse settled it in A.D. 871 (Hartman et al. 2017; Walser III et al. 2018). These eruptions would have resulted in very high levels of mercury exposure, and exposure to other airborne toxins like silica and ash. This would have caused individuals to develop chronic pulmonary infections, which may have reduced immune responses and rendered medieval Icelandic populations more vulnerable to other respiratory diseases like tuberculosis and sinusitis. These diseases were known to have affected a large portion of the Icelandic population (Collins 2020; Walker et al. 2004; Zoëga & Murphy 2016; Kristjánsdóttir 2010).

Another unique feature of respiratory research done in Iceland is their simultaneous focus on the sinuses, and the temporal bones (Collins 2019; Collins 2011). Most other research done in Scandinavian countries studied one element or the other, but never simultaneously. Since chronic ear infections are recognized as the most common result of sinus infections, it is evident that the middle ear and sinuses should be studied together (Collins 2019). It is possible that it has not been done so because of budgetary or time/collection constraints as these physiological systems are quite delicate and it can be rare to find enough samples in a collection to base a study on. The ear ossicles are also often lost during exaction while the sinuses and mastoid process often fall victim to taphonomic process.

Also commonly found was the incorporation of tuberculosis in these studies (Collins 2020). Tuberculosis is known to often lead to otitis media, as it often affects the middle ear more frequently than other specific infections that are known to affect the cranium (i.e., leprosy and treponemal infections) (Collins 2019; Zahraa et al. 1996; Dale et al. 2011, Nicolau et al. 2006). Lastly it was speculated that the environmental conditions of Iceland in the medieval period (colder than average) were conducive to the spread of respiratory illness as the protective functions of the upper respiratory tract are usually damaged as human physiological functions deteriorate in the cold (Collins 2019; Mourtzoukou & Falagas 2007).

Swedish studies focused solely on maxillary sinusitis, there was no research that could be found that focused on mastoiditis or otitis media during the prevalent study periods. Perhaps this was due to there being not enough relevant study material (auditory ossicles are very easily missed or dislodged and lost during excavation), or time and money constraints which limited researcher's ability to widen their scope of research to include temporal bones. As mastoiditis is best examined non-destructively through x-ray or CT-scans, these studies can quickly become very expensive. Since all Swedish studies were also non-destructive, perhaps this is what caused researchers to focus solely on sinusitis. Lastly, all studies undertaken were focused on southern or southeastern Swedish collections (Sundman & Kjellström 2013a/b).

This could be due to the demographic makeup of medieval Sweden. During this time period both Sweden and Norway were markedly less populated in their northern regions when compared to their southern halves. Throughout the medieval period and for centuries beforehand, the northern regions of Sweden and Norway were largely only populated by the Indigenous Sami people who were hunter gatherers that also practiced pastoral nomadism for subsistence (Bagge 2013). It was only after the devastation of the plague that these kingdoms turned their expansionist efforts inwards and looked to colonize their most northern regions in the 16th and 17th c. Despite these efforts, life in the north largely remained nomadic until the 20th c. (Bagge 2013). This disparity in population density, could explain why there is a lack of northern collections dating to the medieval period from Sweden and Norway. Lastly, all Swedish studies incorporated dental disease within their scope of research, as they attempted to provide proof for the connection between dental disease and respiratory infections (Sundman & Kjellström 2013a/b).

A lack of large towns and urban centers in these medieval kingdoms could also explain the dearth of research. Urban centers are more appealing for archaeologists as they can provide substantial cultural deposits, as well as structures and archives that would significantly contribute to the present knowledge of these towns (Dyer 2003). Small rural hamlets often lack many of these characteristics, which may render them less appealing to archaeologists and historians alike (Dyer 2003). Large scale excavations triggered by development are also more likely to occur in urban centers than isolated rural areas. The fact that Sweden and Norway were mostly composed of small rural towns or hamlets perhaps means that they may not have had the same pull for research as rich English or even Southern Danish urban centers would have had (Dyer 2003).

A clear disparity of research on non-specific respiratory diseases can be seen in Sweden and especially in Norway, which is perplexing since both countries have excellent osteological collections that include skeletal remains from the medieval and early modern periods. In Norway the Schreiner Collection at the University of Oslo houses over 900 crania in a collection that spans from the Stone Age up to the 19th c., it is closed to the public but access for relevant research purposes is possible. In Sweden, there are at least two skeletal collections, the first is located at the Swedish Museum of National Antiquities in Stockholm which focuses on 1,100 graves excavated in the 19th century on Björkön near Lake Mälaren in southeast Sweden, and the second is at the Lund University which boasts over 2000 crania in its collection (FASE 2021).

A general lack of funding could explain the dearth of research on these less commonly known pathologies. It is perhaps also the historical legacy of diseases such as tuberculosis and leprosy that are dominating research efforts within Scandinavia (Ghosh & Chaudhuri 2015; International Leprosy Association 2022). Tuberculosis and leprosy have played a significant role in shaping Scandinavian sociocultural history as these two diseases were prevalent in the kingdom throughout the medieval and early modern periods (Møller-Christensen 1951, 1952, 1953, 1958, 1965, 1978; Boldsen 2005/2009; Pedersen & Milner 2019). Although European prevalence rates of leprosy began to diminish in the 12th-13th c., it continued to run rampant in Scandinavia, with cases of leprosy being reported in Norway as late as the 20th c. (Kearns & Nash 2021). It is also the Norwegian scientist Gerhard-Henrik Armauer Hansen, in 1873, who discovered that *Mycobacterium leprae* was one of the two bacterium that causes leprosy (Ghosh & Chaudhuri 2015). Norway was also the home of two other prevalent leprosy researchers, Dr. Daniel Cornelius Danielssen and Dr. Carl Wilhelm Boeck who both significantly contributed to early leprosy research and were considered the foremost researchers of leprosy not only in Norway but in all of Europe at the time (Ghosh & Chaudhuri 2015). Scandinavia, especially Norwegian towns like Bergen were also so commonly afflicted by the disease in the mid to late 19th century that a leprosy research center, headed by Hansen, was built along with several leprosy hospitals in the area in the 19th century which cemented the historical legacy of leprosy in Scandinavia (Ghosh & Chaudhuri 2015).

Norway and Sweden also lacked many of the general aetiological factors that are presumed to have led to high prevalence rates of respiratory infections in England and Denmark. Due to their low population density, characteristically remote and isolated northern settlements, and lack of urbanization and industrialization until much later in the 19th and 20th centuries, populations were perhaps not as commonly affected by respiratory infections as other urbanized countries. This is reflected in Norway and Sweden's very weak feudal system. The lack of feudalism in these kingdoms meant that no manorial system developed nor did an aristocratic class (Holmsen 1956). It is also seen in the theory that Sweden was able to escape the worst of the Great Famine that ravaged Denmark and England in the 14th c. (Lagerås 2016). It was perhaps a great advantage to these countries to have boasted "sparse agricultural societies [as it] made them less vulnerable" (Lagerås 2016: 9).

Research in England also focused heavily on studies of maxillary sinusitis with very limited research being completed on diseases of the temporal bone. Many of the studies undertaken in Scandinavia reference earlier work undertaken in England as the British collections were analyzed for sinusitis decades ahead of any other country and were the first to produce methodological papers for properly diagnosing and recording maxillary sinusitis (Boocock et al. 1995; Lewis et al. 1995; Wells 1967; Wells 1977). English studies also seemed to focus on a select few sites only, such collections included those from Wharram Percy, St. Helen-on-the-Walls, Raunds Furnells, and Christ Church Spitafields (Molleson et al. 1993; Lewis 2002; Bernofsky 2010; Roberts & Lewis 2002; Lewis et al. 1995; Mays 2012; Shapland et al. 2016; Roberts 2007). These studies focused on aetiology and tried to link increased respiratory infection rates with increased pollution both indoors and outdoors (Lewis et al. 1995; Bernofsky 2010; Lewis 2002; Shapland et al. 2016; Roberts 2007). Many researchers also studied the juvenile portions of these collections in an attempt to gather more metadata and fill any vacant holes in the bioarchaeological record (Lewis et al. 1995; Lewis 2002; Roberts & Lewis 2002).

Another limiting component of many English studies were their inconsistency in recording methods. Prevalence rates for sinusitis were recorded as either 'crude or true', which makes comparison between studies problematic. True Prevalence Rate (TPR) is the number of individuals with sinusitis as a percentage of the total number of individuals with one or two sinuses (Bernofsky 2010, 136). Crude Prevalence Rate (CPR) is the number of elements or individuals affected by the lesion of the total number of individuals available for analysis. Although TPR is the more accurate of the two recording methods, as it only calculates the rate of prevalence based on those individuals that have the necessary osseous element, most researchers use CPRs to record sinusitis (Roberts & Lewis 2002; Roberts & Cox 2003; Shapland et al. 2016), perhaps because CPR was the more traditionally used methodological recording method. If any future research is needed on sinusitis prevalence in medieval/early modern England all previous CPRs were recalculated into TPRs by Bernofsky (2010).

Lastly there was a complete lack of studies dedicated to older individuals in England and Scandinavia. All published studies examined the skeletal remains of general ages or juveniles, but many did not acknowledge the presence of individuals aged over 45. This can perhaps be attributed to the past, and still ongoing, issues associated with accuracy when dating the oldest segments of society. Early ageing techniques were fundamentally biased towards under ageing skeletal remains and were plagued with problems of age mimicry which created a demographic hole in the archaeological record (Milner & Boldsen 2012b; Bocquet-Appel & Masset 1982; Konigsberg & Frankenberg 1992; Cave & Oxenham 2014; Boddington 1987; Chamberlain 2000). It was believed, throughout the 20th c., that individuals in the past simply did not survive past the age of 50, but with the use of updated aging methods, like the transition analysis program (Boldsen et al. 2002; Milner & Boldsen 2012a/b/c), researchers now have the ability to identify individuals well into their 60s, 70s, and beyond (Smith et al. 2017; Mays 1998; Shahar 2005). Surviving into advanced age would have most definitely been harder to achieve in the past. It would have also been extremely variable, as some periods would have had more or fewer elderly people due to factors like disease, war, and social stability. Having said this though, if perhaps not as often, individuals did indeed survive into their 70s and 80s in the medieval and early modern period as circumstances that increased survivorship continued to ameliorate with time (Gowland 2007).

Methodological Challenges in Comparative Analyses

To protect valuable osseous remains many institutions are wary of the rise in popularity of more sophisticated but destructive analyses on skeletal collections. The rise in DNA sampling, radiocarbon dating, and isotopic analyses has brought with them many ethical concerns due to a penchant for viewing skeletal remains as a limitless resource. This is made apparent when destructive analysis is readily used over more modest methodologies (Squires et al. 2020; Lynnerup 2013; Pálsdóttir et al. 2019). Having said this, it has limited the research that can be undertaken on discrete skeletal elements like the mastoid or the sinuses.

Several ethical guidelines have been proposed that aim to address these ethical issues associated with destructive analyses. They advise the use of collaboration between researchers in different fields in an effort to mitigate the amount of destruction (Pálsdóttir et al. 2019). Restraint is also proposed, in terms of reserving destructive methodologies as a last resort in the analytic process (Squires et al. 2020). Proper training is also essential for researchers to avoid mistakes and unnecessary damage (Squires et al. 2020). Lastly, but perhaps most importantly, it has been advised that ethics must be at the center of any analysis that focus on skeletal remains (Lynnerup 2013).

Boocock et al. (1995) were the first to describe a methodology for examining sinusitis by using a steel endoscope to examine the inner sinus cavity and when necessary, drilling a hole into the sinus to get access. Since then, this has been the preferred method to study sinusitis (Boocock et al. 1995; Panhuysen et al. 1997; Roberts 2007; Lewis et al. 1995). Unfortunately, permission is not often granted to drill holes into the crania of skeletal remains which greatly limits collection availability. Other exploratory methods can be considered, including x-rays, although Boocock et al. (1995, 485) clearly state that in their experience, that radiographs taken of the maxillary sinus region do not show any osseous changes even in confirmed cases of sinusitis. Research published since then adhere to Boocock et al.'s (1995) destructive methodology and reference their early work in their own studies (Bernofsky 2010; Roberts 2007; Mays 2012; Shapland et al. 2016; Collins 2019).

The auditory ossicles are perhaps one of the most overlooked elements of a skeletal assemblage. A multitude of factors can contribute to the scarcity of auditory ossicles in the archaeological record. These include a lack of care and knowledge during excavation, the natural fragility of the skeletal elements, and taphonomic processes such as scavenger activity, weathering, ritualistic post-mortem movement of the body, and natural deterioration. All of these factors contribute to the dearth of examples in archaeological collections and thus the lack of research on these skeletal elements (Qvist & Grøntved 2000).

Researchers of Danish collections also demonstrated through their work that it is possible to examine ear ossicles and temporal bones non-destructively as they can be examined accurately with a microscope. This still allowed for the fine pitting, smoothing, and erosive lesions to be seen in appropriate detail (Qvist & Grøntved 2001). A small mirror or angled endoscope can also be used to extend the field of view into the temporal bone if it was limited by the external auditory meatus or the tympanic annulus (thickened rim of the tympanic membrane). By doing so, it is possible to examine the intracranial side of the temporal bone (Qvist & Grøntved 2001). This does not give the researcher a view of the mastoid air cells within the temporal bones, but it does give them some idea if infection was present within the bone. It can then be inferred that if infection was present on the intracranial surface of the temporal bone it is likely that it is also present inside the bone. This method is much more feasible as it is relatively inexpensive, non-invasive, and non-destructive in comparison to other known methodologies which cannot boast the same list of advantages. Other such methods include cutting the temporal bone in half to view the air cells (Primeau et al. 2018; Flohr & Schultz 2009a/b) or using CT-scans to produce 3D images of the mastoid bones (Primeau et al. 2018). In comparison to x-rays, which have difficulty in differentiating the many nuances of these intricate systems, CT scans have the ability to produce more detailed images, but they are very expensive (Lewis et al. 1995; Flohr & Schultz 2009a/b).

Maxillary sinusitis is typically examined using the criteria presented by Boocock et al. (1995) and new scoring systems are constantly being devised based on the work of previous researchers like Roumelis (2007) and Boocock et al. (1995). These new systems utilize grading schemes which score the lesions from ‘not present’ to ‘severe’ and is sometimes applicable to both maxillary sinusitis and otitis media. The addition of another grading scheme to the recording of sinusitis is somewhat problematic as there already exists several such schemes that are popularly used by researchers (Sundman & Kjellstrom 2013; Eriksson 2019; Bennike et al. 2005). These grading systems are all slightly different with some allowing for five categories while others only including three or four. Moreover, severity is very subjective and is described differently by each researcher, what one individual considers severe, another might describe as moderate change. This makes compiling data from different studies impossible as the data cannot be compared. Therefore, either a universal scale should be established, or photos should be included within the research report for all researchers to use to describe the lesions.

Chapter 8-Conclusions

In conclusion, there is an overall lack of non-specific respiratory research that has been undertaken across Scandinavia with respect to the oldest segments of medieval and early modern society. Even though there are a few key studies that have been published on non-specific respiratory diseases in Northern Europe, none have specifically focused or even addressed how older adults were affected by such pathologies. This has created a distinct gap in the bioarchaeological record in both Scandinavia and England. This is a puzzling phenomenon however, as it has been argued by previous researchers that the 'oldest old' in any community would have been the most at-risk segment of society to suffer from respiratory infections (Ortner 2003; Mays 1998; Bernofsky 2010, Thane 2005). This can be caused by numerous factors such as their age-related decrease in immune response, compromised immune function and nutritional status, and their age-related increased pathological load (Weiskopf et al. 2009; Plackett et al. 2004; Castelo-Branco & Soveral 2014; Grubeck-Loebenstein & Wick 2002; Ortner 2003; Mays 1998; Bernofsky 2010, Thane 2005). Degeneration is a natural pathway that all humans undergo as they age, and it is therefore reasonable to assume that along with this natural decline in health is a decrease in the body's ability to respond to sustained pathological assaults.

It remains a question then, as to why the oldest segments of society are continuously overlooked in these types of bioarchaeological studies. Part of the answer to this question perhaps lies in the built-in bias that many traditional age-at-death estimation methods demonstrate. This fundamental problem with methods of age estimation is not a new one as it has been influencing paleodemographic methodologies for decades. It was not until recently that, with new methodologies like the transition analysis (Boldsen et al. 2002), that researchers have begun trying to recognize and eliminate the bias (Milner & Boldsen 2012; Tangmose et al. 2015; Boldsen et al. 2002). Instead of simply producing a single age estimate like most traditional methods do, the transition analysis generates both point estimates and age intervals that vary from one skeleton to the next (Boldsen et al. 2002; Chamberlain 2006).

In terms of the sociocultural and environmental conditions that may have promoted increased prevalence rates of respiratory disease in the elderly there are many factors to take into consideration. Firstly, there is no single climatic event that occurred during the medieval/early modern periods that is known to have caused an increase in respiratory disease prevalence, rather it is most likely an accumulation of factors or the fluctuation in conditions that caused the most damage. Although the onset of the LIA was traditionally thought to have been a large causal factor, the affects that cooler temperatures have on the increased stress load of medieval populations is now being questioned (Scott & Hoppa 2018). That is not to say that the LIA did not cause individuals heightened stress, which it most certainly did, but what is now in doubt is the level of stress it caused. Many medieval populations demonstrated their resiliency by adapting to more diversified diets and relying on church assistance to survive (Scott & Hoppa 2018). Therefore, it was perhaps not the 'sub-zero' winters of the LIA that caused a differentiation in prevalence rates but rather the erratic and variable nature of the general medieval/early modern climate that was the root cause.

Neither the MCA nor the LIA were characterized by stability, both periods experienced extreme climatic conditions including arctic winters, blazing summers, serious droughts, and torrential rains (Fagan 2000). This seesaw-like climate did not allow for populations to adapt and adjust to their surroundings, as conditions typically changed by the decade. It is the social, political, economical, and environmental context that an individual lives in which will dictate how effective their bodies are at maintaining a healthy immune system and good respiratory health (Goodman et al. 1988). If those surroundings are continuously changing, the body can also be more susceptible to chronic pathological infections like sinusitis or mastoiditis. Lastly, this maybe why no significant differences in prevalence rates for non-specific respiratory diseases have been identified between the MCA and the LIA as both periods displayed the erratic climate necessary to propagate disease (Fagan 2000; Campbell 2016; Glaser 1997). It may also be a question of temporal resolution as a mix of good and bad years would mean that no significant negative or positive trend in respiratory health could be identified.

The same can be said for sociocultural conditions, as there were no clear differences between rural and urban settlements and their effects on respiratory disease until the late medieval and post-medieval period. In Scandinavia specifically, rural and urban housing resembled each other closely up until the early modern period (Jordan 1996; Roesdahl 1999). Much like early urban housing, rural houses were often made of wattle and daub or timbered buildings with thatched roofs (Roberts 2009). It was not until the late 15th- early 16th c. that urban housing differentiated itself by adopting more modern construction materials like stone, tile, and slate. In England this transition, known as 'The Great Rebuilding,' was even more demarcated when urban houses were renovated in the 16th c. with 'modern' characteristics

(Platt1978, 219). Moreover, houses whether urban or rural, were intentionally built to allow for a desired level of smoke to stay inside to help limit certain types of pests and bacteria in the home while also allowing the occupants to breathe without issue (Letts 2000; Roberts 2009). Although this may have changed in the early modern period when renovated urban housing altered this careful balance, this has yet to be demonstrated. It can therefore not be leaned on as an aetiological factor for changes in respiratory disease prevalence across Scandinavia.

Chapter 9-Challenges and Future Directions

Throughout the research process for this thesis there were several unforeseen challenges that arose and greatly hindered the natural progression of this work. Firstly, the methodological differences that researchers used when examining and recording non-specific respiratory diseases made it difficult to compare and amalgamate data. Additionally, the lack of studies encompassing the 'oldest old' was another barrier as there was not much available data, and the research that had been done was inconsistent in its focus. Lastly, there were only a few authors in Scandinavia that made their data accessible to the public which meant that undertaking detailed analysis was difficult to accomplish. In order for future research to take place, current and future authors should readily include data within their thesis or research reports in order for a publicly accessible database to be established.

The most important factor that needs to be addressed for future research to flourish is the current lack of consistency within the present data on non-specific respiratory diseases in Scandinavia. To date there have been only a handful of reports published on non-specific diseases like maxillary sinusitis, otitis media, and mastoiditis in the Nordic kingdoms (Sundman & Kellström 2013a/b; Collins 2011/2019/2020; Primeau et al. 2018; Bennike et al. 2005; Qvist & Grøntved 2000/2001; Eriksson 2019). A general increase of age-related respiratory research in Scandinavia needs to occur, especially concerning the 'oldest old'. Although it has been demonstrated time and again that individuals could have survived into their elderly years, older individuals are seldom present within the demographics of archaeological populations, and if they are, they are spoken of as great anomalies. As it so often happens, the oldest segments of many archaeological collections are systematically erased or overlooked in academia and have ultimately been rendered invisible (Appleby 2010,2017; Welinder 2001; Cave & Oxenham 2014). It is therefore pertinent that researchers embrace new age-estimation techniques, like the transition analysis program (Getz 2019; Getz 2020; Mcinnis 2022; Milner et al. 2019; Ousley 2019), to identify those that have so often been forgotten. Transition analysis does this by focusing on the inter-skeletal variability of every collection (Buckberry 2015). Despite the many advances made with the latest version of the method, one avenue that still needs more attention is the proposed use of alternative osseous features that have traditionally only been used to distinguish between young and old; but if combined with transition analysis they may have the ability to produce accurate age estimations (Milner & Boldsen 2012b). Once the elderly can be effectively identified, it is only then that research on the 'oldest old' can become conventional and less anomalous. Once this occurs, non-specific respiratory diseases can be better understood, along with their impacts and influence on medieval society.

Another area of research that needs more attention is the relationship between molar roots and the maxillary sinus floor. Despite it being known that dental pathologies lead to abscesses and oroantral fistulas that pierce the maxillary sinus floor and cause infection within the sinus, the teeth have rarely been included in sinusitis research (Sundman & Kellström 2013; Lewis et al. 1995). Although dental pathologies are not the only source of infection in the sinuses, the connection has been demonstrated with enough certainty that the teeth should be studied whenever an analysis is undertaken on the maxillary sinuses (Panhuysen et al. 1997; Sundman & Kellström 2013).

Another connection that should be examined is the one between the sinuses and temporal bones. As it has been demonstrated earlier, the nasal cavity is indeed connected to the tympanic cavity and the middle ear system through the Eustachian tube (Krenz-Niedbala & Lukasik 2017a; Collins 2019). This means that any infection in either one of these systems is most likely to cause a secondary infection in the other. It is therefore logical for researchers to further explore that connection and study both systems simultaneously, which has rarely been done in any currently published academic material (Collins 2019; Krenz-Niedbala 2017a).

Moving forward, the connection between non-specific respiratory diseases and intrinsic and extrinsic factors should be more thoroughly analyzed. Intrinsic factors like age and dental health should be made a priority in future studies, in order to give these diseases more context and create links between specific and non-specific pathologies. Extrinsic factors like sociocultural and economic status, as well as diet, should also all be taken into consideration as they have the ability to affect the health and well-being of past populations.

An increase in research of non-specific respiratory diseases, like mastoiditis, maxillary sinusitis and otitis media should be strived for, as they could provide clues to the general health of the individual suffering these infections. It has been previously established that many different pathologies are linked and interconnected, much like sinusitis and dental health, and leprosy, mastoiditis, and otitis media (Collins 2019; Primeau et al. 2018; Boocock et al. 1995; Sundman & Kjellström 2013a; Lewis et al 1995). Therefore, it is imperative that current and future researchers give attention to non-specific diseases as they may give insight into other more serious pathologies.

As it stands, the research concerning these types of non-specific diseases are inconsistent across many Scandinavian countries. It has become apparent that for too long, respiratory research in Scandinavia has focused mainly on tuberculosis and leprosy perhaps due to the historical legacies of these diseases within these northern kingdoms (Møller-Christensen 1951, 1952, 1953, 1958, 1965, 1978). Currently available studies concerning the 'oldest old' are largely unreliable and do not properly represent the past populations of medieval Scandinavia, as many older individuals were systematically underaged or labelled as outliers. It is time to diversify respiratory research and give focus to non-specific diseases, that for many reasons, have been greatly neglected until now.

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